CEMENT CONCRETE
& AGGREGATES AUSTRALIA

Guidelines for Delivery of Bulk Cementitious Products to Premixed Concrete Plants

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IMPORTANT NOTICE – PLEASE READ

This document has been produced by Cement Concrete & Aggregates Australia (CCAA) in good faith to assist its members to improve the interface between the cement and premixed concrete industries. Specifically, it is intended to help ensure bulk cementitious products are delivered efficiently, safely and with a minimum risk of contamination into silos located at premixed concrete batch plants.

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1. BACKGROUND

The Pre-mixed Concrete Committee of Cement, Concrete, and Aggregates Australia have prepared this document to improve the interface between the cement and premixed concrete industries to help ensure bulk product is delivered efficiently, safely and with a minimum risk of contamination into customer's silos.

Although virtually all deliveries of cementitious products are made without problems, instances of product contamination still occasionally occur, usually when product is delivered into an incorrect silo. Although the impact may be relatively minor if the error is detected early enough, lack of detection could involve risks to structural integrity and the prospect of severe financial loss incurred in addressing the resulting problems.

Consequently it is critical for all parties to ensure that the correct product can be delivered safely and without contamination, spillage or emission into the customer's silo, irrespective of the time of delivery.

Although there is already a considerable degree of uniformity in the delivery process by most suppliers, it is generally acknowledged that a more uniform approach to tanker unloading methods and the design and operation of the receiving silos should offer improved environmental, logistical and operational benefits to all parties. To help achieve these objectives, this document describes the basic equipment and operational requirements needed to standardise tanker unloading and silo operations and thereby minimise the likelihood of product spills, contamination or equipment damage. This document also provides information on plant design and equipment selection, use and maintenance to help guide future development of loading facilities and further consolidate the standardisation of work systems.

A further problem which also arises occasionally during tanker unloading is that of silo over-pressurisation. There are a number of situations which may contribute to this problem, but the consequences can be catastrophic if acceptable silo pressures are exceeded. In addition to the risk of silo rupture and equipment damage, excessive transfer pressures have been known to blow dust filter units off the top of silos, endangering property and personnel on the ground below. This document examines some of the reasons for this problem and offers a number of potential actions for mitigating this risk.

This guideline is intended as a reference document that will be reviewed as required to accommodate feedback from interested parties and address areas of concern raised between the cement and premixed concrete industries.

2. SCOPE AND APPLICATION

This document is intended primarily to provide a standardised approach for the pneumatic transfer of bulk cementitious powders into silos used by the premixed concrete industry.

It is also intended to provide general guidance in the operation and maintenance of equipment associated with unloading and storing bulk cementitious powder products.

The guidelines are also intended for application in the design and upgrading of bulk cementitious storage installations used by the premixed concrete industry. However, it remains the responsibility of the designer to check and confirm the information presented in this document is correct and appropriate for use in any given application. In addition, the designer must conduct a suitably detailed hazard and risk assessment for the proposed installation as an integral part of the design process.

3. OBJECTIVES

These guidelines have been developed to help establish a common, industry-wide approach for delivering bulk cementitious products efficiently and safely into premixed concrete plant silos while minimising the risk of product contamination, spillage, equipment damage or environmental harm.

4. REFERENCED DOCUMENTS

Guidance to Prevent Over-pressurisation of Storage Silos during the Delivery of Powder in the Cement, Concrete and Quarrying Industries – Quarry Products Association June 2001 ISBN 0-9540853-0-2

5. DEFINITIONS

Bin-Dicator – a proprietary sensor which uses a diaphragm and pressure actuated switch to detect material in a silo has reached a certain level.

Camlock fitting – a proprietary brand of pressure-resistant coupling used with a pressure hose to connect between the bulk tanker discharge and silo fill pipe.

Cementitious materials – materials including general purpose cement, flyash, ground granulated blast furnace slag and blends of these materials.

Dust filter or dust collector – a device for removing particulate materials from the air stream leaving the silo and returning the captured material back to the silo.

Fabric filter with mechanical shaking – a dust filter which uses mechanical shaking to clean dust from the collecting fabric.

Guided radar – a method which detects material level in a silo by sending a microwave pulse down a rod or cable and measuring the return time.

Microwave level detection – a method for detecting material level by sending a microwave pulse onto a surface and measuring the time of return.

Over-pressure – excessive pressure created when air blown into a silo is not adequately vented, exposing the silo structure and associated equipment to structural failure and presenting a serious risk to personal safety.

Paddle sensor – a device which relies on material contacting and stopping a rotating paddle to detect material level has reached a certain point in a silo.

Pneumatic transfer – Conveying method using compressed air to fluidise and transport material through a pipeline under pressure.

Pressure Relief Valve (PRV) – a mechanical valve or venting system which opens at a preset pressure and allows excess air to be vented from a silo.

Pulse jet filter – a dust filter which relies on a pulse of compressed air to clean the dust from the collecting fabric.

Safety strap or "whip check" – an additional short cable or strap connected between the discharge hose and silo fill pipe and from the bulk tanker to the discharge hose to restrain hose should the coupling fail under pressure.

Silo fill line – the pipe used for discharge of bulk cementitious material into a silo.

Silo isolation valve – a valve, usually electrically controlled, fitted to the silo fill line to limit the risk of incorrect material being pumped into the silo.

Silo vent system – a pipe or duct system used to carry air discharged from the silo dust filter and/or pressure relief valve and vent it at ground level.

Triboflow detector – a proprietary brand of sensor used to detect dust in an air stream by measuring the charge transferred as the particles collide with a probe.

Ultrasonic level sensing – a method which uses changes in the speed of a sound wave to detect the level of material in a silo.

6. OVERVIEW OF THE DELIVERY PROCESS

The majority of cementitious materials sold in Australia are delivered to customers using bulk road tankers of various capacities and configurations. Although the largest proportion of bulk deliveries are made to premixed concrete plants and similar operations during normal working hours, after-hours deliveries, especially to unmanned metropolitan plants, frequently occur. These after-hours deliveries remove the distraction of tanker unloading during the periods of highest demand, allowing the plants to operate more effectively and without interruption.

In a typical delivery sequence to a premixed concrete plant, the tanker driver first confirms the product type, quantity and silo destination with the plant staff, before positioning the tanker safely for product discharge. After unlocking the designated silo fill pipe, and checking the integrity of the flexible connecting hose, seals and "Camlock" fittings, the driver connects up to the silo fill pipe, ensuring the hose is in contact with the ground or as close to as possible, and couples the hose safety strap after ensuring that the product will be delivered into the correct silo. The driver then checks the silo high level alarm function before starting the silo dust filter, which also opens the interlocked silo fill valve and permits product transfer to occur.

After starting the truck-mounted compressor, the driver adjusts the airflow pressure and distribution so that the product in the tanker is first fluidised and then transported under pressure through the discharge pipeline and into the receiving silo. As the compressed air enters the silo and expands, the powder falls into the silo while the transport air is filtered of any entrained dust by the dust filter and the cleaned air is released to the atmosphere through the vent pipe. To ensure dust emissions are minimised, the collected dust is automatically cleaned from the filter bags at regular intervals and returned to the silo. Frequent removal of the dust from the filters also helps ensure the large volumes of transport air pumped into the silo can be rapidly vented, minimising the risk of silo over-pressurisation and subsequent damage to equipment or injury to personnel.

During the unloading process, the driver continually monitors equipment operation and ensures pressures are kept within the required range, and any potential problems are identified and immediately addressed. While discharging fill hoses frequently kick, as a result no one should step on or over the hose whilst pressurized and maintain a suitable distance to ensure the hose does not collide with any body part.

After the tanker has been emptied, the driver shuts off the compressor, carefully vents any excess pressure from the tanker and closes the silo fill valve. The connecting hose is removed and stored and any spills are cleaned up before the driver closes off the silo, finalises the associated delivery documentation and departs.

7. BULK ROAD TANKERS

Most deliveries of bulk cementitious materials are made using vehicles equipped with either steel or aluminium tanks which are designed and operated as pressure vessels. Bulk tankers may be operated with single tanks of up to 42 m^3 capacity (Figure 1), or as B-doubles, which are fitted with a pair of tanks with individual capacities of up to~30 m^3.

The tanks are typically subdivided into a number of interconnected compartments, or pots, each of which is fitted with aeration or distribution pads to help fluidise the powder before it is pneumatically discharged. Once fluidised, the powder can be delivered through a large bore rubber hose fitted with 100 mm diameter Camlock fittings and gas-tight seals into the receiving silo. Although these fittings can normally withstand much higher working pressures than those actually used for product delivery, they must be regularly maintained and checked before each use to make sure they remain safe to use. Particular care is needed to make sure that the fittings have no cracks or chips, and the seals are in good condition.

Compressed air for product transfer is supplied from a truck-mounted compressor or blower which works at pressures of up to ~160 kPa, although with properly designed and maintained fill pipes, delivery pressures of ~100 kPa are sufficient to discharge the tanker quickly and safely. Tank pressure is monitored using a fitted pressure gauge and adjusted using a series of regulating valves to control the product discharge and successively empty each compartment.

Careful and timely operation of the regulating valves by the driver is critical for efficient product transfer. With proper aeration, the powder will be properly fluidised, allowing rapid transfer into the silo without the need to use excessive pressure. This in turn will reduce the tendency for silo over-pressurisation with the consequent risk of equipment damage and danger to nearby personnel. Careful airflow regulation is particularly critical as the tanker approaches empty, when low powder density and the potentially large volume of pressurised air remaining in the tanker can cause a surge of air into the silo, greatly increasing the risk of over-pressurisation. To avoid this problem tanker pressure is gradually reduced by the driver as the tanker contents are emptied.

To accommodate the specific requirements such as traffic flow, equipment operation, environmental or other constraints which apply at individual sites, each tanker driver should also be provided with procedures or instructions which identify what these requirements are and how they should be addressed.

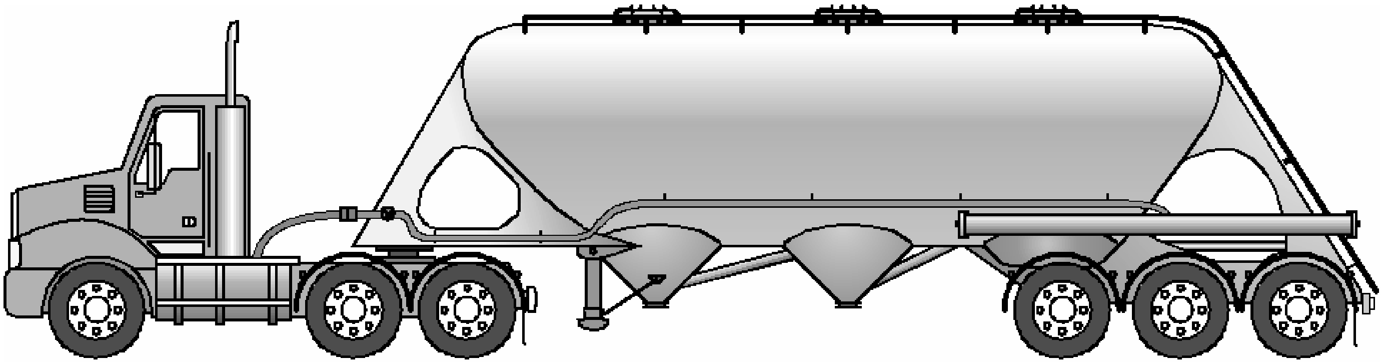

Figure 1 – Typical 3 compartment bulk road tanker used for delivery of cementitious powders

8. PREMIXED CONCRETE PLANT ACCESS AND LAYOUT

There are a number of essential requirements in plant design and layout if product is to be delivered efficiently and safely without unnecessarily compromising normal operations. Some of the more critical aspects include:

- safe entry to, and exit from the plant
- isolation of mobile equipment and pedestrian traffic
- safe access to operational areas and office
- clear access and adequate parking adjacent to the silo fill point
- level footing free of slip or trip hazards
- clear access to the unloading controls and switchgear
- clear view of controls and alarms while unloading
- silo control equipment fitted adjacent to silo fill and venting lines
- clearly labelled silo fill pipes to identify silo contents
- silo fill line connections placed at an appropriate height
- adequate lighting where after-hours deliveries occur.

A more extensive list of plant requirements is detailed in Appendix C.

9. SILOS AND ASSOCIATED EQUIPMENT

Silos for cementitious materials may be designed in a range of widely varying shapes, sizes and configurations, and although some are configured in multi-compartment arrangements, most silos are now self-contained. Storage silos are now typically fabricated from steel and installed with sufficient height to allow relatively free flow of the reclaimed material. For safe access to the silo roof it should be fitted with a properly designed guardrail and access equipment, while the silo interior should also be treated as a confined space and labelled accordingly.

Silo roof hatches, covers, plates and joints should be designed so that they can be securely sealed to make them weather proof and dust tight. To minimise the risk of water entry and dust escaping, silo hatches and joints should only be opened when absolutely necessary and not on a routine basis. To allow dipping of silo levels, a short standpipe of convenient height welded to the silo roof and equipped with a "Camlock" or similar fitting may prove beneficial. Alternatively, if the standpipe pipe is equipped with a threaded section it could be fitted with a screw cap and "T" bar lever welded across the top to allow easier opening.

During the delivery process each silo is subjected to a slight overpressure as the transport air and product from the tanker are released into the silo. However, most silos are not designed for any significant level of overpressure and pressures as little as 7 kPa above atmospheric pressure may be sufficient to cause silo or equipment damage, exposing operations personnel to potential harm from pressure suddenly released.

Although the overpressure is significantly influenced by the pumping pressure, volume flow rate and powder fluidity, it is also affected by many factors associated with silo design and maintenance. These factors include silo volume, design, sizing and maintenance of dust filters and pressure relief valves, fill pipe resistance and many other issues which are determined at the design stage. As an example, silos with a capacity not much greater than that contained in a single delivery have a much greater risk of overfilling and over-pressurisation than a more generously sized silo fitted with a high level alarm set well below the roof of the silo. Consequently silos with adequate free space are preferred to small capacity silos, or those designed with multiple compartments. However, taller silos require higher pressures to overcome the increased gravity effects, so shorter silos of the same capacity will generally require less delivery pressure to achieve a given delivery rate than taller silos with similarly configured pipework.

While many of these factors cannot be readily modified for existing silos, designers of new installations should recognise the potential effect these factors have on overpressure and should design new silos and their associated equipment accordingly. By recognising and addressing these issues during the design stage, and ensuring equipment is properly maintained and operated, it should be possible to incorporate a series of safeguards which will virtually eliminate the risk of silo over-pressurisation.

In addition to the silo itself, a range of associated equipment is also needed to control, monitor and protect silo operation as well as reduce the risk of product contamination.

This ancillary equipment includes:

- Camlock fittings
- safety strap or "whip check"
- silo fill pipe
- silo isolation valve
- loading controls and alarms
- pressure relief valve (PRV)
- dust filter
- silo vent pipe
- silo high level detection systems
- product identification plates.

A typical arrangement for this equipment is shown in Figure 2, while an example of a checklist used to assess essential equipment requirements is detailed in Appendix B.

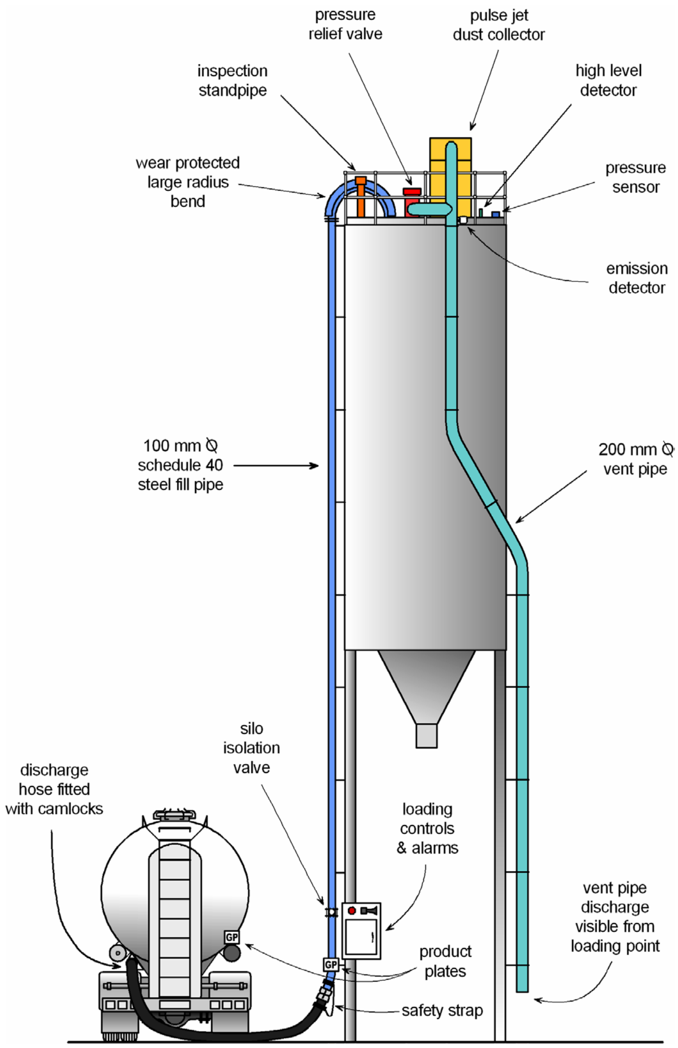

Figure 2 – Typical components of a silo loading system for bulk cementitious powders

9.1 Camlock Fittings

Silo fill points are usually fitted with alloy Camlock fittings to permit coupling with compatible fittings used by the bulk tankers. These fittings are equipped with rubber sealing rings and locking levers which permit rapid connection between the tanker and silo fill pipe. As all these fittings operate under considerable pressure, only hoses and fittings which comply fully with the necessary standards and/or have been sourced from an assured supplier should be used.

To minimise the risk of contamination, the silo fill pipe should be fitted with a Camlock or similar cover when not in use. As a basic security measure, the fill pipe cover should also have provision for fitting a padlock, so that the fill pipe can only be accessed after obtaining the key from the plant batcher.

9.2 Safety Strap

To reduce the risk of the delivery hose becoming detached from the fittings, or failing under pressure, a safety strap or "whip-check" should also be connected between the silo fill pipe and the tanker fill hose and from the bulk tanker to the discharge hose.

9.3 Silo Fill Pipe

Because silo fill pipe diameter, length and number of bends determines how much pressure is required to pump material into the silo, fill pipe design plays a critical role in allowing silos to be filled rapidly with a minimum risk of over-pressurisation. Each fill pipe should be clearly labelled with the maximum allowable pumping pressure.

To reduce the pressure needed to transfer product into the silo, the piping should be 100mm in diameter, internally smooth and as short as possible, with the absolute minimum number of bends. Horizontal sections, which increase pipe resistance and impede delivery, should not be used, but where they cannot be avoided, they should be located at ground level, where pumping pressures are highest. All fill pipes should be fitted on the outside of silos so that any leaks or problems can be easily identified and fixed. Pipes fitted internally or passing through adjacent silos may leak, causing cross contamination and making repair difficult without emptying the affected silo(s).

Changes in direction of the fill pipe should be designed using large radius bends so that lower transfer pressures can be used. Elbows or right angle bends require higher pumping pressures and so they should be avoided as far as possible. Where a right angle bend cannot be avoided, a standard tee section fitted with a cap on one leg generally offers similar performance to an elbow, but with better wear resistance.

Although larger radius bends create less of a pressure drop in the pipe-work, they are prone to developing holes from abrasive wear, even with the Schedule 40 steel pipe typically used for filling lines. Apart from using bends fabricated from special wear resistant materials, common solutions to minimise wear effects include fitting bends so they can be readily replaced, sleeving the outside of the bend with a second skin, or fitting the pipe with an external pocket filled with concrete and extended at least half a metre past either end of the bend.

9.4 Silo Isolation Valve

Each fill pipe should be fitted with an electrically actuated isolation valve as the primary method for protecting against product contamination and safeguarding against overfilling and other potential problems. The silo isolation valve must be opened before tanker unloading can commence, and this is usually the responsibility of the batcher during normal operating hours. For after-hours operations the valve is usually opened by the driver using the loading controls.

The isolation valve is normally configured so that it is open only when energised, so the valve closes when power is shut off or operation is interrupted by activation of an alarm. It is also normally interlocked with the silo dust filter unit so that the isolation valve can only be opened when the dust filter is operational. To allow time for the driver to safely respond to an alarm condition, the isolation valve is usually set to close after a time delay of ~ 60 seconds when an alarm condition has been activated:

If shutdown is initiated by an alarm condition, the silo isolation valve is usually configured with a delay of several minutes before the valve can be re-opened. This is to allow sufficient time for the alarm condition to be resolved before delivery can recommence. So the driver can confirm the valve position, the isolation valve should also be fitted with an indicator which shows whether the valve is open or closed.

The isolation valve should be constructed with an integral fail-safe spring closing mechanism and to allow ready access and maintenance, the valve should be positioned no more than 2 metres above ground level. As the valve internals are exposed to abrasive material travelling at high velocity, the valve body and wear components should be manufactured from wear resisting alloys such as Keystone 'Figure 100', or similar materials.

9.5 Loading Controls and Alarms

All controls and switches used by the tanker driver should be readily accessible and clearly identified and be fitted into a protective cabinet or other secure location mounted adjacent to the silo fill point to allow proper monitoring while unloading. Any warning sirens should also be positioned so that the tanker driver will be in no doubt when an alarm is triggered. Ideally the controls for each silo should be located in a separate cabinet adjacent to the silo loading point, but where multiple silos are served from a single cabinet, each set of switches, gauges and the corresponding alarms must clearly identify to which silo they are dedicated.

Ideally, the loading equipment should be configured so that it can be operated with a single, clearly marked switch, which starts or stops the system. The control panel should also be fitted with an accompanying pilot light which clearly shows whether the control system is on or off. The switch should be interlocked so that turning it on starts the dust filter cleaning system, activates the alarm sensors, and opens the silo isolation valve. When the system is switched off, the isolation valve should shut down the alarm sensors, while the dust filter continues operating for a further 15 minutes to clean the filter media, before it also switches off.

Alarm sensors which should be incorporated into the control circuit include:

Silo High Level Alarm – this alarm indicates that the silo is almost full and the driver must stop delivery immediately to avoid overfilling the silo. The alarm threshold must be set to allow sufficient space in the silo for the driver to shut down the system and clear the delivery lines.

Dust Filter / High Pressure Alarm – activation of this alarm indicates excessive pressure has been detected across the dust filter or in the silo and shut-off of the isolation valve is imminent to avoid over-pressurisation.

Dust Emission Alarm – activation of this alarm indicates dust emissions have been detected from the dust filter, typically through bag failure, excessive delivery pressure and/or venting of the pressure relief valve.

As a minimum, the control system should incorporate a test switch for checking operation of the high level sensor and the corresponding alarms. Pilot lights are also recommended for each type of alarm sensor to help the tanker driver identify which alarm condition has been activated.

The loading control cabinet should also contain a copy of any site procedures or instructions considered necessary for operating the plant equipment and ensuring the unloading process is conducted safely and efficiently. Similarly, all switches, alarms and indicator lights should be clearly labelled so that the driver can easily troubleshoot delivery problems which may occur.

9.6 Pressure Relief Valve (PRV)

To protect against excessive overpressure and reduce the risk of damage to equipment or personnel, silos must also be fitted with suitably sized pressure relief, or "silo-saver" valves. The type and design of pressure relief valve used in a particular application depends on factors such as the expected flow rate of air into the silo and the maximum allowable silo or dust filter pressures.

The most common valve designs are based on either a deadweight valve, and to a lesser extent, a spring loaded valve, both of which are designed to open when a pre- set pressure is exceeded. Both are normally placed on the top of the silo and arranged so that any expelled gas is directed into the vent line. They should also be positioned so that they cannot be isolated from the silo which they are protecting. Due to the differences in silo design and construction, the PRV required for a given installation should be designed by a suitably qualified engineer or specialist so that the PRV release point is appropriate and allowable silo pressure levels are not exceeded.

The deadweight valve consists of a weighted disc seated over a suitably sized vent. When the pressure in the silo exceeds the weight of the disc, the pressure in the silo lifts the disc, allowing the excess pressure to be vented. When the excess pressure has been vented, the disc resets itself as it settles back on the vent (Figure 3). The pressure relief valve must be designed so that the opening pressure is below the maximum operating pressure of the silo, but not so low that it is actuated by normal operating pressures and volumes. The PRV must also be able to vent the maximum expected flow of air into the silo at a relatively small overpressure to ensure silo pressure limits are not exceeded.

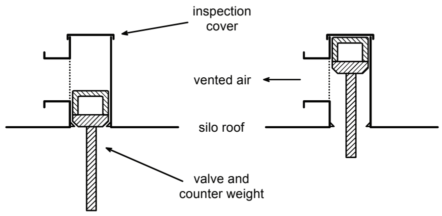

Figure 3 - An example of a deadweight pressure relief valve in both closed and fully open positions

The spring-loaded PRV uses a spring, rather than gravity to provide opening resistance. When the internal pressure exceeds the pre-set limit, the valve opens, resetting itself when the excess pressure has been vented.

Both types of valves are susceptible to buildups which may cause malfunctioning so they should be inspected and checked weekly by the plant operational staff to ensure they are clean and functioning correctly.

9.7 Dust Filter

Dust filters, sometimes known as dust collectors, are fitted with bags or cartridges to remove entrained dust from the transport air and return the filtered material to the silo before the cleaned air is released to the atmosphere. Individual dust filters should be fitted to each silo where different product types are stored, although a single large unit can be used to service multiple silos which contain the same type of products. To reduce the chance of pressurising the silo and damaging it, it should not be possible to isolate the dust filter from the silo.

As air volumes of 35 m³/min or even more may be discharged into a silo when pneumatic discharge from the tanker is completed, silo dust filter size must be designed with an adequate cloth/air ratio to avoid bag blinding and loss of collecting efficiency. Although static type bag filters are sometimes used, they do not generally perform consistently and only dust filters which incorporate some method for actively removing the collected dust should be used. The two most common types of dust filter used for silo venting are:

- jet pulse fabric filters, and
- fabric filters using mechanical shaking.

Jet pulse fabric filters are now preferred for silo dust collection because the method and frequency of cleaning allows the filter bags to readily accommodate the air surge from the tanker as it is finally emptied of product. However, for proper cleaning, jet pulse dust filters must be supplied with compressed air which is oil and moisture free.

To clean the bags a blast of air is injected as a short, high pressure pulse into the open end of the bags, against the normal airflow direction. The pulse of air creates a shock wave which moves down the bag, dislodging powder from the outside surface of the filter, which then falls back into the silo. The process is repeated at regular intervals to prevent the bags becoming blocked or "blinded". The method of operation is shown in Figure 4.

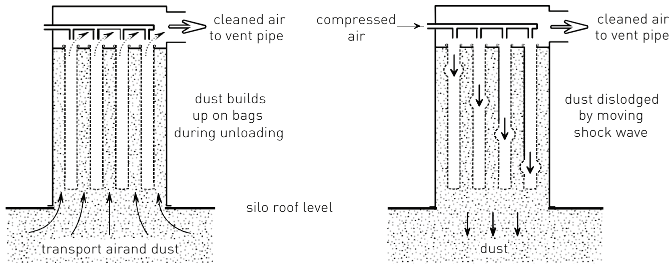

Figure 4 - Jet pulse filter operation and cleaning

Where clean compressed air is not readily available, fabric filters using mechanical shaking are an option (Figure 5). With this method of cleaning the bags are mechanically shaken for a predetermined length of time at regular intervals, but due to the less effective method of cleaning they generally have more resistance in handling the final air surge as the tanker is emptied. For silos fitted with shaker type filters it is important to ensure the filter bags are fully cleaned between each tanker discharge operation.

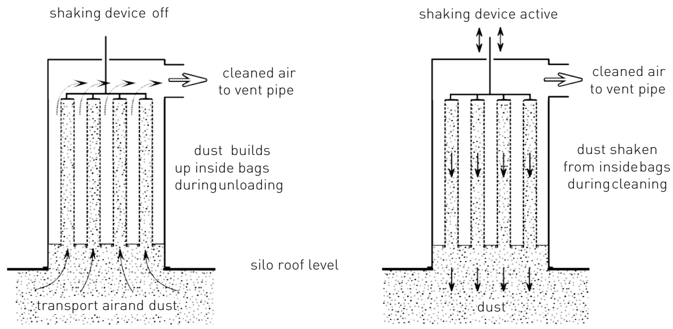

Figure 5 - Fabric dust filter with mechanical shaking

Due to the more efficient cleaning mechanism used in pulse jet fabric filters, dust filters using pulse jet technology can operate with a much smaller filter collection area than shaker type systems of equivalent cleaning capacity. Where a shaker type dust filter may require 32 m² of bag collecting area to accommodate the dust loading from a typical product silo, a pulse jet filter normally requires only ~ 20 m² of filter area for equivalent cleaning capacity. This also means that a jet-pulse dust filter system is physically smaller than a shaker type filter of equivalent cleaning capacity.

Whichever type of fabric filter is used, it is important to ensure the dust filter is adequately sized. Although bag filters with marginally less cloth area may operate satisfactorily under most conditions, they are more highly stressed and tend to require more attention to ensure collecting efficiency is maintained. This, in turn makes the silo more likely to experience over-pressurisation.
To reduce this risk the dust filter must be capable of filtering vented air at the maximum delivered rate without incurring a significant drop (eg ← 0.35 kPa). The actual pressure drop values deemed acceptable in a given application are dependent on the design of the filter and this data should be obtained from the filter manufacturer or supplier.

To ensure the dust filter is operating correctly, and to minimise the risk of over-pressurising the silo or dust filter housing, a differential pressure (DP) indicator, such as "Magnahelic" detector, should also be fitted and positioned so that the pressure can be continuously monitored by the truck driver during unloading. The detector should also be configured so that when the differential pressure is in excess of allowable limits an alarm is raised to alert the driver and initiate closure of the silo isolation valve after a delay of ~ 30 seconds.

To further reduce over-pressurisation risks, it is also important to ensure the dust filter housing is properly fixed to the silo structure. Inadequate fixing makes the dust filter housing a weak point in the structure which could become separated and be blown off the silo roof in the event of a severe over-pressurisation incident.

9.8 Silo Vent Pipe

Air vented from the silo dust filter and that released from the pressure relief valve should be routed through a common 200 mm duct and vented just above the ground adjacent to the silo fill pipe. This will allow the tanker driver to closely monitor airflow and emission levels during the filling operation and respond immediately should a problem become apparent. Where possible, the ducting should also be positioned so there are no horizontal runs where powder may deposit and that any potential overflow or resulting spillage is contained, or directed into a container.

To reduce the risk of dust emissions, the vent pipe should be fitted with a dust emission detector, such a "Triboflow" unit or similar device, which will activate the silo fill pipe shutdown procedure after detecting excessive dust emission levels. The shutdown procedure should include an audible alarm, flashing light and be sequenced to ensure closure of the silo isolation valve after a short interval of ~30 seconds, thereby allowing the driver time to safely stop the delivery process.

Where common venting ductwork is used for several silos, placement of the emission detector in the final duct section will allow a single dust emission detector to provide emission control protection for all of the interconnected silos.

9.9 Silo High Level Detection Systems

The silo high level detector should initially activate an audible alarm and flashing light on the control panel, and then after a delay of ~60 seconds to allow the driver to clear the delivery line, the fill pipe isolation valve should be closed. The maximum fill height limit selected for each silo will depend on the silo design and construction and sensor position but it should be set to allow for the material which will be added after the alarm has been triggered. In some instances this may mean that the detector may need to be positioned up to a metre below the top of the silo. However, the optimum height must be determined for each individual installation so that sufficient warning is given before the silo is actually full.

High level may be detected by a dedicated unit, such as a rotating paddle detector, or it may be raised as an alarm when a pre-set level is reached with a continuous silo measurement system, such as guided radar. Alternatively, both types of detection may be used in conjunction to provide high level alarm backup.

Silo shape and construction should also be considered when selecting and fitting a high level detector. The detector should be positioned so that it will function properly without being adversely affected during filling or operation of the dust collector. It must also be positioned so that it operates reliably and also gives a true indication that high level has been reached. Some level detection systems, such as ultrasonic, capacitance, tilt-switch and load cell systems have generally been found to perform poorly in cement silos, and should be avoided. Problems may also be experienced with paddle-type systems when low product density may not provide sufficient resistance to stop the paddle, but these problems can usually be minimised by proper placement of the detector and regular maintenance of the detector unit.

Whichever type of detector is selected, the high level alarm test cycle should be initiated automatically in the control circuit at the start of the fill sequence, so that any fault in the detector will activate the alarm and prevent filling of the silo until the problem is resolved. The level detector should also be regularly tested to ensure it provides a reliable indication of the actual level of the silo contents.

Units which require withdrawal of the detector from the silo to check detector operation should be avoided, so problems associated with extracting and replacing the unit correctly and ensuring proper sealing after re-installation are minimised. Externally placed units should also be protected from the weather, as far as possible.

Although dust emission detectors positioned in the silo vent pipe may also be used as a backup for high level indication, they must not be considered as a substitute for a properly placed and maintained high level detection and alarm system.

9.10 Product Identification Plates

To ensure product is delivered to the correct silo, each silo fill pipe must be clearly marked with a plate which identifies the product type contained in the silo. To further aid identification, the silo fill pipe may also be painted to match the colour code used by the (former organisation) National Ready Mixed Concrete Association. These colour codes are available upon request from Cement Concrete & Aggregates Australia.

10. TANKER UNLOADING PROCESS

10.1 Process Overview

After confirming delivery arrangements with the batcher, the driver positions the vehicle and connects the tanker and silo pipe-work with a flexible hose fitted with 100 mm "Camlock" fittings, the flexible hose should be of a suitable length to ensure it is in contact with the ground or as close to as possible. After confirming the product will be delivered into the correct silo and checking the function of the silo high level alarm, the driver starts the dust filter, which also opens the interlocked silo fill valve.

The driver then pressurises the tanker to the required level with the truck-mounted compressor and starts the product transfer. During the transfer, the driver continually monitors equipment operation to ensure pressures are kept within the required range and any potential problems are identified and immediately addressed. While discharging fill hoses frequently kick, as a result no one should step on or over the hose whilst pressurized and maintain a suitable distance to ensure the hose does not collide with any body part.

After the tanker has been fully emptied, the driver shuts off the compressor and after ensuring the tanker is vented, closes the silo fill valve. The connecting hose is removed and stored and any spills are cleaned up before the driver returns the key, finalises any delivery documentation and departs.

10.2 Description of the Tanker Unloading Process

Before the tanker is physically connected up to the customer's silo, the driver must make a number of checks to confirm that unloading will progress safely and that the correct product will actually be delivered. Although these checks will usually involve the batcher during normal plant operating hours, the driver will have full responsibility for ensuring the correct product is discharged safely into the correct customer silo.

For deliveries during plant operating hours, the driver should confirm the delivery details with the batcher when first arriving on site. In addition to confirming the product is correct and receiving instructions on the silo(s) to be filled, the driver should also verify with the batcher that the load will fit into the designated silo. In most cases the batcher will also need to sign the delivery docket to confirm acceptance of the load.

Any queries regarding the delivery should be directed to the batcher when the site is manned, or to the driver's supervisor during unmanned deliveries.

The driver should then follow the delivery instructions and safely park adjacent to the designated silo fill point. This must be clearly identified with the silo number and National Ready Mixed Concrete Association colour coded plate (or a similarly unique and clear identifier).

Before connecting to the fill point, the driver must ensure the "Camlock" fittings, seals and hoses are in good condition and suitable for safe use. Specific aspects the driver must check prior to connecting up include ensuring all contact surfaces are clean, each seal is in as-new condition and the "Camlock" fittings have no cracks or chips. All hoses and clamps must also be checked to make sure they are in good condition, the hose is of suitable length, the connections are a neat fit and that they are securely fixed prior to use. Any faulty or suspect equipment must not be used.

Once the delivery hose has been connected, the product type on the delivery docket must be checked against the product label on the connected fill pipe to make sure the product will be pumped into the correct silo. Once this has been confirmed the high level alarm can be tested.

The silo filter can then be started and the silo fill shut off valve opened. The truck compressor can then be started to pressurise the tanker to start the delivery, which should then follow the standard operating procedure specific to the tanker and silo system being filled. The driver must remain at the silo fill point during the pumping cycle to monitor and control the tanker pressures and flows, taking care not to exceed any specific silo pressure limits.

During product transfer the driver must also monitor the high level alarm and pressure drop across the silo filter, as well as checking the silo discharge points for dust emissions and other problems, which should be reported to the batcher. Discharge blockages in particular must be reported to allow the plant operator to have any spillage from the cleanout and restart operation cleaned-up quickly and efficiently.

Should the high level alarm sound during delivery due to silo overfilling, excessive dust emission or a high pressure drop across the filter, the driver needs to cease delivery immediately by first closing the tanker product valves. This will ensure that the silo fill pipe is not blocked when the automated silo fill pipe shut off valve activates. Throttling back the compressor will also ensure that the tanker pressure is lowered before isolation from the silo filter occurs.

At the end of the pumping cycle from the road tanker to the storage silo, the driver must act quickly to limit the surge of air into the silo. Although the driver's best indication of complete cleanout is rapid pressure drop in the tanker, an uncontrolled rush of air into the silo must be avoided as it will pressurise the vessel and could damage the silo, the dust filter and/or cause dust emissions.

Once the transfer has been completed and the tanker is empty, the driver shuts down and disconnects the truck compressor. After ensuring the tanker is vented, the silo fill valve is closed and the connecting hose is removed and stored. Any spills are then cleaned up before the driver returns the key, finalises any documentation and departs.

An example of a Driver delivery checklist is detailed in Appendix A.

11. MINIMISING THE RISK OF SILO CONTAMINATION AND OVER-PRESSURISATION

There are a number of requirements which must be in place to ensure product deliveries are made safely and with a minimum risk of contamination or over-pressurisation into customer's silos. Although a number of these requirements are mandatory at all plants, more sophisticated checks and controls are warranted where multiple product types are handled and product deliveries must be made to unattended plants.

The most common methods for assuring product delivery and minimising the risk of contamination and over-pressurisation include:

Batcher receival check – This is the primary quality assurance check conducted on deliveries conducted at most plants during normal operating hours, when the driver confirms delivery details with the batcher immediately upon arrival. In addition to confirming the product being carried is the one ordered, the driver also confirms with the batcher which silos are to be filled and that there is also sufficient room to receive the proposed load in the designated silo. As part of the normal process the batcher usually signs the delivery docket to confirm proof of delivery and acceptance of the load.

Capped silo fill pipes – Silo fill pipes are usually covered with blank Camlock caps when not being used to prevent product contamination or entry of foreign materials into the fill pipe. These also help keep the pipe internals dry, minimising the risk of lumps and buildups.

Labelled silo fill pipes – Each silo fill pipe must be clearly labelled with the product type that is in the receiving silo, preferably using product type plates such as those provided by the cement suppliers. This is a primary method for preventing material being delivered into the wrong silo.

Silo high level alarms – The silo high level alarm, coupled with automatic shut-off of the silo isolation valve, is essential for protecting against the driver overfilling, and potentially damaging, the receiving silo.

Silo pressure relief valve – The pressure relief valve is critical for preventing silo pressure reaching excessive levels should other preventive methods fail, making it essential for all silos.

Locked fill pipe – Where two or more products are handled at a plant, some form of physical lock should be fitted to each silo fill pipe to minimise the risk of the wrong product being pumped into a silo. In the simplest applications the pipes are locked using different padlocks, with the matching keys being retained by the batcher, and only the key needed to open the silo for the current delivery is handed to the driver. After the delivery has been completed the driver returns the key to the batcher. Where unattended deliveries are made, the appropriate key is typically left for the driver in the after hours box.

The fill pipe locks are used in conjunction with the silo isolation valves and do not replace them.

After-hours box (or letterbox) – This is a container or location used for leaving keys or messages for drivers when making unattended, or after-hours deliveries. The box is also used by the driver for leaving the paperwork associated with the product delivery and establishing proof of delivery, which can be verified by the batcher on the next working day.

Multiple isolation valve switching – Using paired switches instead of a single switch to control the silo isolation valve can also reduce the potential for discharging product into the wrong silo. Fitting an isolation valve switch in the batcher's office and a duplicate switch in the driver's control box, and configuring the electrics so that both switches must be on before the isolation valve on a silo can be opened, can provide additional security for handling after hours deliveries. Unless the switch for the required silo has been previously selected by the batcher, the silo cannot be accessed, even after the corresponding switch has been selected by delivery driver. This arrangement prevents product being put into the wrong silo while the plant is unattended but it does not provide adequate security if more than one type of product is to be delivered after hours.

Silo level monitoring – While guided radar or other continuous silo measurement systems cannot be used directly for preventing silo contamination, they are valuable for helping to determine what product actually went into which silo.

Daily stock check – Reconciliation of silo stock with overnight deliveries and previous silo stocks before the plant starts production will highlight potential discrepancies and unattended deliveries which may have gone into the wrong silo.

Electronic interlock systems – These systems use a variety of methods such as bar or swipe codes on the delivery docket, separate Dallas keys or other means to clearly identify the product carried in any particular delivery. This information is then used in conjunction with basic software and electrically actuated valves to determine which silo can be accessed for the product being delivered, making them potentially more flexible and secure than lock and key, and other basic interlock systems. Consequently they are well suited to minimising contamination risks for unattended deliveries of multiple product types in plants which have high throughputs.

These systems can also be integrated with silo level detectors to reduce the risk of overfilling and they also facilitate remote monitoring, which can be advantageous should suppliers wish to enter into just-in-time supply arrangements with the customer. However, reliable and accurate silo level monitoring systems, such as guided radar, increase the associated system costs.

Although electronic interlocks undoubtedly minimise the risk of pumping product into the wrong silo, they do not totally eliminate the risk of contamination. Electronic interlock systems may have limited flexibility in some situations and can be compromised if tankers need to be diverted or plant software is not updated when silos are re-allocated. These systems do not replace the need for robust delivery systems or the need for driver checks to prevent contamination from product carryover or cross- contamination between loads.

11.1 Recommended Actions and Precautions

The methods actually used at a given plant for assuring product delivery and minimising the risk of contamination and over-pressurisation depends mainly on the number of products stocked at the plant, and whether the plant receives after-hours deliveries.

A plant which has only a single silo and a batcher always in attendance when deliveries are made can be expected to manage with fewer safeguards than a plant receiving after-hours deliveries of multiple product types.

The following list (Table 1) shows the minimum recommended actions and precautions considered necessary for reducing the risk of silo contamination and over-pressurisation while ensuring trouble-free delivery under various scenarios.

Number of Products stocked	1	1	2 or more	2 or more
Delivery	**Attended**	**Unattended**	**Attended**	**Unattended**
Batcher receival check	✓	-	✓	-
Capped fill pipes	✓	✓	✓	✓
Labelled fill pipes	✓	✓	✓	✓
Silo high level alarm	✓	✓	✓	✓
Silo pressure relief valve	✓	✓	✓	✓
After hours box	-	✓	-	✓
Locked fill pipes	-	-	✓	-
Multiple switching	-	-	✓	✓
Silo level monitoring	-	-	-	✓
Daily stock check	✓	✓	-	✓
Electronic interlocks	-	-	-	✓

Table 1 - Minimum requirements for reducing the risk of contamination and over-pressurisation

12. PLANT MAINTENANCE

Each plant should have a regular, documented maintenance program for dealing with on-the-job maintenance by the plant operator, (i.e. visual detailed inspections), and a second level of planned maintenance performed by mechanical/electrical personnel.

The plant operator should make a routine inspection of all areas of the plant as part of the normal daily operations and also monitor functions such as lubrication, air pressure, leaking oil or compressed air, etc.

On at least a weekly basis, the plant operator should conduct a more extensive and critical examination of the plant in both the operating and shutdown conditions, with specific focus on the following items:

- dust filter operation
- dust emission levels
- silo roof cleanliness
- silo Camlock fittings
- silo fill pipes
- silo isolation valve operation
- silo relief valves.

A regular monthly inspection and service should also be carried out to check:

- dust filter internals
- compressor equipment, lubrication devices, filters, etc
- correct operation of fail-safe devices such as high level and emission detectors, spring-return gates, etc.

All plant inspections and maintenance should be performed according to established and documented procedures. These procedures should include checklists for weekly and monthly inspections and programmed maintenance. Inspection report sheets which detail what is required should be completed with each inspection.

12.1 Silo Dust Filter Maintenance

The plant operator should inspect the silo dust filters on a weekly basis, to ensure that the bag shaker system or the air jet cleaning system is operating satisfactorily.

A check should also be made for high-pressure air, where this is used, as well as dust leakage.

The silo dust filter internals including the dedusting mechanism, fabric filter bags, cages and associated gear should be inspected by suitably trained personnel at regular intervals in accordance with the manufacturers recommendations.

A high standard of maintenance for the silo dust filter and associated equipment is essential if delivery airflows are to be vented rapidly and with minimum emissions. Dust filters in poor condition greatly increase the risk of silo over-pressurisation and subsequent plant damage.

APPENDIX A – EXAMPLE OF DRIVER'S CHECKLIST (ATTENDED DELIVERY)

	ISSUE	Y/N
1	Confirm with batcher that destination, product type and load size are correct and sign off docket	
2	Obtain silo isolation key, confirm silo to be filled and sign off docket	
3	For unattended deliveries above checks to be done by Driver	
4	Position tanker for safe connection to silo fill pipe causing minimum obstruction	
5	Put on PPE before leaving truck cabin - normally eye and hearing protection, gloves and high visibility clothing. A hard hat may also be required.	
6	Remove silo fill pipe covers and check seals and hoses are in good condition	
	Visual inspection of the tanks pressure prior to removing camlocks	
7	Connect hose between tanker and fill pipe and fit safety strap	
8	Make sure product type on tanker load docket matches label on silo fill pipe and complete any acceptance paperwork. Sort out any problems with the batcher.	
9	Test silo level alarm for correct operation (unless noise restrictions are in place)	
10	Where necessary, unlock the silo isolation valve and start the dust filter	
11	Check tanker discharge valves are closed and booster or main valve is fully open / and boost lines are closed but the air to atmosphere or dump valve is open.	
12	Start blower/compressor and set engine rpm to required range	
	Close dump valve to begin pressurizing tank	
13	Open boost valve to check air is passing through fill line, close boost valve and monitor tanker pressure	
14	When operating pressure is reached open boost valve about halfway until pressure stabilizes slowly open first compartment until discharge valve is fully open.	
15	Adjust main valve as required so that hose is firm with small even pulsations and no whipping. Maximum tanker pressure should be kept as low as possible (typically ~100 kPa)	
16	Monitor silo alarms and pressures and check dust filter exhaust for dust emissions	
17	If an alarm sounds, stop product delivery immediately, clear delivery line and throttle back the compressor before isolation occurs	
18	Monitor compartment level and as the compartment empties and tank pressure drops, open the next compartment discharge valve. Continue monitoring pressure and as it drops close the first discharge valve.	
19	Close the aeration valve of the empty compartment, adjusting main valve as req.	
20	Repeat the discharge procedure on each compartment during the process.	
21	Control airflow pressures and volumes, especially during final stages of discharge to minimise the risk of over-pressurisation and equipment damage. This is done by rapidly opening and closing each product valve.	
22	When all product has been transferred and tank pressure has dropped to negligible levels, close all valves and depressurise the tanker through the bottom air dump valve.	
23	Shut down the compressor / blower	
24	Check tank pressure is zero	
25	Remove safety strap and hose from silo fill pipe and stow securely on the tanker	
26	Replace Camlock cap on silo fill pipe and clean up any spillage	
27	Change tanker product plate to a blank selection to denote tanker is empty	
28	Lock off access valve, remove key and return to batcher or secure storage	
29	Sign off necessary paperwork and depart	

Note : Any areas of concerns should be directed to the batcher and/or the Driver's supervisor for resolution.

APPENDIX B - EXAMPLE OF DRIVER'S SITE ASSESSMENT CHECKLIST

ISSUE	Y/N
Safe parking area to enter office for instructions and signing of docket	
Clear access to fill point	
Suitable lighting to approach fill point	
Appropriate and safe parking area at fill point.	
Fill pipe clearly labelled with current silo product	
Safe working area including	
- traffic control	
- even ground - Check for hazards, example slurry and water.	
- no work occurring above	
- adequate lighting	
- Camlock connection at waist height	
High level alarm installed	
High level alarm test point	
High level alarm clearly visible/audible to driver while operating tanker controls	
Silo pressure relief valve installed	
Relief valve discharge piped to within 1 metre of the ground	
Relief valve discharge clearly visible to driver while operating tanker controls	
Discharge contained in suitable area to limit safety risk & environmental impact	
Filter discharge piped to within 1 metre of the ground	
Filter discharge clearly visible to driver while operating tanker controls	
Dust detector installed in relief valve discharge piping	
Dust detector installed in filter discharge piping	
Silo overpressure gauge or dust filter differential pressure gauge	
Silo pressure gauge readout clearly visible to driver while operating tanker controls	
Delayed automatic fill shutdown on detection of	
- high product level	
- high silo pressure/ high pressure drop across filter	
- dust in silo discharge	
Clear exit from site	

Note : Any areas of concerns should be directed to the Plant Manager and/or the Driver's supervisor for resolution.

APPENDIX C – EXAMPLE OF PLANT SAFETY CHECKLIST

Used to assess the suitability of a premixed concrete plant for safe delivery of dry powder products. *(Typically completed by the Transport Representative in conjunction with the relevant Customer Representative.)*

PLANT NAME:			
DATE:		PLANT NUMBER:	

PLANT GENERAL	
Can the entry gates be operated safely?	Y / N
Is there unobstructed access to all silo fill points during the day?	Y / N
Is there unobstructed access to all silo fill points for night deliveries?	Y / N
Is there safe access to the plant from the entrance road? (no reversing/ pedestrians)	Y / N
Does the plant have a traffic management plan?	Y / N
Comments:	
COMPRESSOR	
Can the compressor be operated from near the fill point	Y / N
Does a remote switch for the compressor need to be installed	Y / N
Can the compressor switch be located by the driver without instruction	Y / N
Comments:	
LIGHTING	
Is yard lighting adequate?	Y / N
Is the light switch accessible to the driver?	Y / N
Do the lights illuminate the fill point adequately?	Y / N
Comments:	
SILOS	
Are silo fill pipes covered when not in use?	Y / N
Have Camlocks been fitted to all fill lines?	Y / N
Are Identification plates fitted to all silo fill lines?	Y / N
Are there Isolation valves on fill points?	Y / N
Are functional high level alarms fitted?	Y / N
Does the test circuit function correctly?	Y / N
Are pressure relief valves fitted to all silos?	Y / N
Are the signs clearly readable from the unloading point	Y / N
Silo vent pipe discharge visible from loading control point	Y / N
Comments:	

SILO DETAILS				
Silo ID	**Product Type**	**Capacity (T)**	**Pressure limit**	**Dust Filter Type**

Are there any special instructions/requirements relevant to these silos?	Y / N
Comments:	

POSSIBLE HAZARDS	
Are there any trip hazards, eg drains, uneven surfaces, etc?	Y / N
Is safe access provided to areas needed for operation (stairs, conveyor belts etc)?	Y / N
Is the area clear of obstacles?	Y / N
Is there a need to operate near conveyor belts (falling materials, etc)?	Y / N
Can equipment be safely operated while other vehicles are within the plant?	Y / N
Comments:	

PPE REQUIREMENTS	
High visibility vest	Y / N
Hardhat	Y / N
Hearing protection	Y / N
Eye Protection	Y / N
Steel capped boots	Y / N

GENERAL COMMENTS (special requirements, security, noise, operating hours, etc)

PLANT STAFF AFTER HOURS CONTACT DETAILS	
Name & Position	**Phone Number**
Name of Transport Manager/Representative:	Signature:
Name of Plant Manager:	Signature:

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