BLASTONE
SUPERIOR PERFORMANCE

DESIGN CONSIDERATIONS FOR CONTAINMENT AND VENTILATION

SPECIAL REPORT

www.BlastOne.com

Lead Paint Removal on Ryde Bridge over the Parramatta River, Sydney Australia

OVERVIEW OF CONTAINMENT SYSTEM REQUIREMENTS

The purpose of a containment system is to prevent or minimize the debris generated during surface preparation from entering into the environment (soil, air, or water) and to facilitate the controlled collection of the debris for disposal. The level and type of containment needed is dependent on the surface preparation method used. In addition, containment must be designed to reduce the workers' exposure to lead.

Containment can be as simple as ground traps or as complex as highly structured units with negative-pressure ventilation systems. Steel Structures Painting Council (SSPC) Guide 6I (CON) presents information to assist in specifying containment requirements. The SSPC Guide describes containment by the containment enclosure components and ventilation system components.

ADDITIONAL MOBILE SCAFFOLDING IS OFTEN NECESSARY INSIDE CONTAINMENT AREAS FOR ACCESS TO SURFACES

THE CONTAINMENT COMPONENTS INCLUDE FURTHER ASSISTANCE

- Containment materials (rigid or flexible).
- Air permeability of containment materials (air impermeable or air permeable).
- Support structure (rigid, flexible, or minimum).
- Joint (fully sealed or partially sealed).
- Entryways (fully sealed with airlock, overlapping door traps, or open seam).
- Air make-up points (controlled or open).

The containment materials are either rigid (such as playwood, metal, and plastic or similar materials) or flexible (such as traps, screens, drapes, and plastic sheeting). It is very difficult to construct a containment on a bridge solely of rigid materials, as connections to the structure will be required.

Air permeability of the containment material refers to dust and wind. Rigid materials are air impermeable. Traps, drapes, and plastic sheeting are examples of air-impermeable, flexible materials. Air-permeable, flexible materials are formed or woven panels that allow air to flow through them, but will retain some of the airborne particulates. Screen materials fall into this category. They are defined by the amount of light transmittance that is blocked by the screen. For example, a 95-percent screen blocks 95 percent of the light. This does not mean that 95 percent of the debris or dust particles will be retained by the material. Also, while some wind does pass through the screen at low air velocities that reduce wind load, above 16.1 to 24 km/h (10 to 15 mi/h) the screens are equivalent to solid tarps.

The support structure is either rigid, flexible, or minimal. Rigid support structures are comprised of scaffolding, pipe staging, or solid framing, which does not allow movement of the support structure. The containment materials are attached to the support structure. Flexible support structures include cables, chains, wires, etc., which allow some movement. Flexible support structures must be properly designed to prevent tarps from ripping in high winds. They should be positioned at regular intervals so that if high winds are encountered, the support structure picks up part of the wind load. Minimal support structure involves no support other than the attachments to the structure and perhaps to the ground or containment floor.

The joints are either fully sealed or partially sealed. Fully sealed joints require a complete mating of joints between containment materials, and between the structure and the containment materials. There are a number of methods of sealing joints, such as overlapping and securing traps, taping, caulking, or use of foams, weatherstripping rubber, etc. The choice of sealing materials depends on the surfaces to be mated. Partially sealed joints involve joining materials together without a complete seal.

Entryways to the containment can be either an airlock, overlapping traps, or open seam. An airlock is a fully sealed entryway with two doors that can be sealed and an intermediate area. One door is not opened until the other door is closed. This arrangement greatly minimizes air losses through the entryway. Overlapping door tarps involve the use of multiple flaps to minimize the amount of dust that can escape. Open seams allow entering and exiting through unsealed seams in the containment material.

GARNET ABRASIVE ON FLOOR OF CONTAINMENT READY FOR VACUUMING AND RECYCLING. IT IS CRITICAL TO KEEP CONTAINMENT TIGHT FROM RAIN AND WEATHER SO ABRASIVE DOEST GET WET

Make-up air points can be either controlled or open. Controlled make-up air points refer to the use of baffles, louvers, flap seals, filters, ducts, etc. so that dust and debris does not escape from these points. Open-air make-up points refer to openings between containment panels or openings put into the containment that do not have protective devices or features. Allowing for adequate make-up air on

THE VENTILATION SYSTEM COMPONENTS INCLUDE:

- Input airflow (forced or natural).
- Air pressure inside containment (instrument verification, visual verification, or not required).
- Air movement inside containment (minimum air movement specified or not specified).
- Exit airflow/dust collection (air filtration required or not required).

containments with ventilation systems is a critical

Input airflow can be either forced or natural. Forced input airflow involves the use of fans or blowers at air entry points. Input airflows by this method must be properly balanced with the exhaust air capacity so the containment remains under negative pressure. Proper design is also important so that dust and debris is not blown out through nearby openings and that dead spots are not created. Natural airflow consists of the draft created by dust collection equipment. The air make-up points are open and do not have fans or blowers pumping air into containment.

Air pressure inside containment is important, especially with high dusting methods of surface preparation, such as abrasive blasting, where negative pressure is required to minimize the escape of dust. Instrument verification of negative pressure involves measuring the pressure inside containment with a magnehelic gauge. A length of plastic tubing is attached to one of the ports of the gauge and placed inside containment. The other port on the gauge is left open to the atmosphere outside containment. An average minimum negative pressure inside containment of 0.8 mm (0.03 in) water column is currently recommended. Visual verification of negative pressure involves examining the containment from all sides to see if the walls are being sucked inward. This method can be used if the containment is constructed of tarps or other flexible materials. Visual verification can also be performed by use of a smoke bomb or other visible means that is set off inside containment. The smoke should not escape through seams, joints, etc. This method is more appropriate for containments constructed of rigid materials and can also be used on containments constructed of flexible materials. Containments without dust collection equipment do not require negative pressure.

Air movement inside containment either has the minimum air movement specified or not specified. The Industrial Ventilation Handbook recommends a minimum air velocity of 30 m/min (100 ft/min) in a cross-draft direction, and 18.m/min (60 ft/min) in a downdraft direction based on visibility. Higher airflows may be needed if one worker is downstream from another. It must be emphasized that these airflows are based on visibility and not on worker exposure to lead. The containment guide requires the specifier to include the minimum airflow.

The last item is the exit airflow, with air filtration required or not required. When air filtration is required, dust collectors or bag filters are used to collect the fine particulates exiting the containment. When air filtration is not required, there is little control of the debris emitted into the environment.

The components and subcomponents are combined in different manners to describe five classes of containment, with Class 1 being the most stringent (and most costly) and Class 5 being the least stringent and least expensive). The class of containment needed varies by surface preparation method and potential environmental impact.

Thus, dry abrasive blasting that generates a lot of dust would require a high level of containment, while a lower level of containment would be sufficient for hand-tool cleaning. Class 3 is the

CONTAINMENT SYSTEMS ON THE BEACH-FRONT NEED TO BE BUILT WITH ADDITIONAL STRUCTURAL TIE OFF POINTS SO THE SHEETING IS NOT DAMAGED BY WIND

lowest class of containment requiring a ventilation system. Experience to date indicates that a Class 3 containment system will meet EPA Air Quality Standards provided impermeable containment materials are used. The other requirements for a Class 3 system are: rigid or flexible containment materials; rigid or flexible support structure; fully sealed joint; overlap entryway; controlled or open air make-up; natural or forced-input airflow; visual verification of negative pressure; minimum air movement specified; and air filtration on the exhaust.

SSPC is in the process of revising Guide 6I(CON). Indications are that Classes 1 and 2 wlll be combined, as the differences between them are small. There will be only four classes of containment, with separate tables defining containment systems for hand- and power-tool cleaning, water blasting, and chemical stripping.

DESIGN OF NEGATIVE PRESSURE CONTAINMENT SYSTEMS

The engineering design of a negative-pressure containment system requires knowledge of air movement and ventilation principles. Once the theoretical design requirements are known and appreciated, practical containment designs can be developed.

Air Movement

Air must be continuously brought into an enclosure in such a manner as to keep the particulate and lead levels diluted so as to provide adequate visibility and to keep the workers' lead exposure to a safe level. Negative pressure alone does not suffice. There must be adequate air movement in the containment to control the fine particulates.

To understand how to provide adequate dilution air, a review of the basic principles of air movement is necessary. The volume of air moving through an enclosure (Q), the velocity of this air (V) being moved, and the cross-sectional area (A) across the enclosure are interrelated according to the following formula:

$$Q = V \times A$$

where:

- Q = quantity of air moved in m^3/min (ft^3/min)
- V = velocity of air in m/min (ft/min)
- A = cross-sectional area of the enclosure in m^2 (ft^2)

One point to note is that the cross-sectional area is a controlling factor and not the length or volume of, the enclosure.

If the velocity of an air stream of 30 m/min (100 ft/min) flows through an enclosure with a cross-sectional area of 9.3 m^2 (100 ft^2), then the quantity of air can be calculated as follows:

$$Q = 30 \text{ m/min (100 ft/min)} \times 9.3 \text{ m}^2 \text{ (100 ft}^2\text{)} = 279 \text{ m}^3\text{/min (10,000 ft}^3\text{/min)}$$

Air can only be moved by allowing it to flow from an area of high pressure to an area of low pressure. Thus, pressure differentials are critical to explain how to control air movement.

There are three types of air pressure measurements. These are:

- Velocity Pressure.
- Static Pressure.
- Total Pressure.

Velocity pressure (VP) is the force air exerts upon anything in the path of flow. For example, VP is the force felt on your hand when it is placed in front of a blowing fan. VP is a direct function of air movement (V) and can be described by the following formula:

$$V = 4005\ (VP)^{1/2}$$

where:

- V = velocity of air is measured in ft/min, and
- VP = velocity pressure of air is measured in inches of water column (WC).

VP will be zero if the air is not moving. However, VP can never be a negative value. Air inside an enclosure will exert another force that will be perpendicular to all surfaces regardless of whether or not the air is actually moving. This force is called the Static Pressure (SP). Since SP is not a function of air movement, it is independent of VP. Furthermore, if SP is less than the ambient pressure outside the enclosure, then the enclosure is referred to as being operated under negative pressure. The converse is that a positive value of SP would indicate that the enclosure would be operating under a positive pressure relative to atmospheric conditions.

Total Pressure (TP) is nothing more than the algebraic sum of VP and SP. The importance of this term lies in the fact that to provide sufficient dilution in an enclosure, enough horsepower must be available for the ventilation fans or blowers to provide the necessary TP to accelerate air from zero velocity, overcome all of the pressure losses and turbulence in the ducts, elbows, and fittings, and

WHILE IT IS EFFICIENT TO CLAD THE ENTIRE CIRCUMFERENCE OF A TANK, IT IS ESSENTIAL TO CREATE "MINI CONTAINMENTS" INSIDE WITH INTERNAL SHEETING WALLS TO REDUCE THE VENTILATED AREA finally pull the air through the filters.

Forced Draft vs. Induced Draft

There are two methods of moving air through an enclosure. The first is forced draft, which relies on the fan or blower forcing a draft into the enclosure. The other is induced draft, where the fan or blower pulls air out of the enclosure.

Forced air draft systems have been commonly used to provide ventilation for ship compartments, water tanks, and other similar containers. However, forced draft systems cause the interior of the tank to be maintained at positive pressure with respect to the ambient air environment. Tanks are, by necessity, airtight except at permanent hatches and vents. On the other hand, a temporary enclosure encompassing a portion of a bridge is usually constructed entirely with tarps or similar soft, flexible materials. Therefore, there are many holes, seams, access panels, etc. that provide numerous leakage points if the enclosure was maintained under positive pressure. Fans and blowers have been used on bridge enclosures as either entry air or for localized air movement near the blasters. The use of fans or blowers with "soft" enclosures is always in conjunction with induced draft

A negative pressure relative to the outside environment is maintained by continually pulling air out of the enclosure. Thus, most "soft" or temporary enclosures rely upon induced draft systems. The negative-pressure environment permits air to leak continuously into the structure causing dust and particulate to flow against the stream of incoming fresh air. It follows that maintaining an enclosure under negative pressure during abrasive blasting operations will correspondingly satisfy environmental air quality regulations. Small leakages of air at seams, pass-throughs, and other compromises to the "airtightness" of the enclosure are of minor or insignificant concern if the system is designed correctly.

COMPONENTS OF A NEGATIVE PRESSURE SYSTEM

The basic components of a blasting enclosure can be broken down into the following components:

- Air Entrance.
- Enclosure Structure
- Ventilation Duct(s)
- Dust Collector(s)
- Ventilation Fans

A major concern in proper design is minimizing pressure losses. Energy is consumed every time a flow of air changes direction, speed, or is forced against a resistance. The only energy source acting to move the air is the induced-draft fan creating pressure changes. It follows that every change in air direction or velocity, or increase in resistance, causes pressure losses across the entire enclosure system. As the pressure drop increases, the quantity of air moved and the corresponding velocity through the enclosure will decrease.

THE USE OF EXTRA WIDE (DOUBLE WIDTH) CONTAINMENT SHEETING ON LARGE VERTICAL CONTAINMENT WALLS ALLOWS FOR FASTER INSTALLATION OF CLADDING

Pressure drops are a critical design parameter in the fabrication, assembly, and operation of an enclosure with a ventilation system. For example, a typical dust collector may be rated at a certain maximum airflow (Q) at a specified SP. If the pressure losses in the system exceed the SP, airflow will decrease.

Air Entrance

An air entrance (make-up air entry) is needed to allow proper airflow through the enclosure. The air entrance should be positioned such that the air flows through the work area, cleaning the dust away from the workers. To date, many of the enclosures seen have not had adequately sized air entrances. It has been the thought of those who constructed enclosures that air would enter containment through seams, entry flaps, connections, and other leakage areas. However, large pressure drops result from forcing input air through such small openings. There is sufficient negative pressure, but the dust will hang in the air inside the enclosure as airflow is reduced.

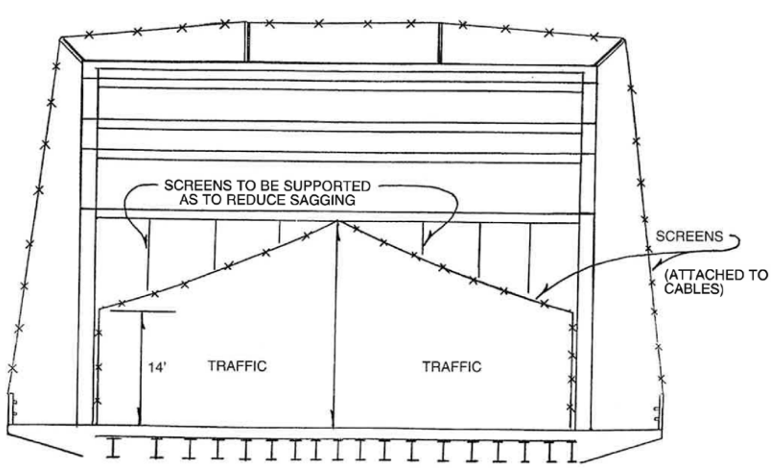
The preferred air make-up entryway would be an open-face entry for airflow considerations. There is nothing to restrict the airflow, so no pressure drops result. An open-face entry is the poorest design from a practical viewpoint. Airflows of only a few miles per hour are needed for ventilation purposes. Air/abrasive blasting is performed with a nozzle where the air/abrasive is travelling at transonic speed, i.e., several hundred miles per hour. Therefore, the airflow coming through the enclosure from the induced-draft system would not be sufficient to control dust blown in the direction of the open-face entry from a blast nozzle. Therefore, controlled air make-up entryways are preferred to deflect high-energy abrasive particles and dust from escaping against the countercurrent of incoming air.

An alternate method to an open-air entry that greatly reduces the entrance-pressure losses is to direct air into the enclosure with a fan. The fan must be rated at a lower capacity than the dust collector. If the entry fan is oversized, then the enclosure will be under positive pressure rather than negative pressure, and dust will be expelled through seams, gaps, and other openings.

Enclosure Structure

The basic design consideration for the enclosure is its size, or more specifically, the cross-sectional area. Current ventilation guidelines indicate a velocity of 15 m/min (50 ft/min) is recommended for steel abrasives, 22 m/min (75 ft/min) for GMA Garnet abrasive, 30 m/min (100 ft/min) for expendable abrasives, and higher velocities if there is someone working downstream from another blaster. These guidelines are based on visibility considerations and not worker exposure to lead. The cross-sectional area and dust-collector capacity must be matched. In the example given earlier, a cross-sectional area of 9.3 m2 (100 ft2) required a 279-m3/min (10,000 ft3/min) dust collector to maintain an airflow of 30 m/min (100 ft/min). Portable dust collectors range up to approximately 90 m3/min (30,000 ft3/min).

On large bridges, such as truss structures or girder bridges high in the air where the air can be moved in a downdraft direction, air velocity requirements would be lower. The guidance provided by the



Industrial Ventilation Handbook for visibility purposes is based on floor area, and is 28 m/min (90 ft/min) for 0 to 9.3 m2 (0 to 100 ft2), 21.5 m/min (70 ft/min) for 9.3 to 18.5 m2, (100 to 200 ft2) and 18.5 m/min (60 ft/min) for 18.5 to 37 m2 (200 to 400 ft2). Ventilation systems operated in the downdraft direction on bridges are usually attached to enclosures that have a floor area larger than 37 m2 (400 ft2) Lower air velocities may be acceptable, though guidance is not presented in the Ventilation Handbook.

Measurement of airflow inside a containment can be performed using either an anemometer or with smoke bombs. Either a hot wire or vane anemometer can be used, though both types of instruments will indicate air velocity only, and not direction. Smoke bombs will indicate direction (and uniformity) of air movement; velocity can be estimated by timing how long it takes the smoke to cover a premeasured distance.

It is important to remember that the critical place for airflow is in the vicinity of where work is being performed. On a large enclosure, the cross-sectional area can be reduced by using screens, tarps, plastic, plywood, or similar materials. Consideration must be given as to how air will be moved into the work area and how it will be moved out. Forced-air input can be used to create an effective curtain of clean air flowing past the worker. Thought must also be given to the placement of the dust collector duct(s). As an example, take the situation of total enclosure of the end span of a girder bridge with a sloped ground so that the configuration of the enclosure roughly approximates a triangle. While the simplest method is to park the dust collector near the shoulder of the road and draw the air out the bottom, this is the most inefficient configuration. The dust collector should be placed at the end of the bridge, with the air exit placed between the beams. The air openings should be located between the beams at the first span. In this way, the air will move between the beams where the blasters are working.

While properly designed enclosures should be effective at minimizing dust emissions, air flow cannot overcome the force of a blast nozzle. Some dust will escape, especially when work is performed near a seam or opening. A more practical solution is to require enclosure walls to be a minimum of 1.8 m (6 ft) from any steel to be blast-cleaned. This will give sufficient room for the blaster to reach all the surfaces, minimize damage to the side wall material from direct blasts, and allow the blaster to point away from the enclosure material when doing the majority of the work.

Ventilation Ducts

One of the most critical considerations in the design of a negative-pressure enclosure is the ducting from the containment to the dust collector. There are two important parameters - air velocity in the duct and pressure drop. The minimum air velocities for keeping the dust suspended is 1075 m/min (3,500 ft/min) for horizontal ducts and 1385 m/min (4,500 ft/min) for vertical ducts. Duct length, diameter, and bends in the duct significantly affect pressure drops in the system. The smaller the diameter of the duct, the greater the air velocity is inside that duct, but the greater the pressure drop, also. Pressure drops from friction in the ducts are one of the greatest pressure losses encountered in containment systems. Table 1 presents information on air velocity and pressure drops for different diameters of smooth, galvanized duct for various size dust collectors.

Being able to use straight runs on a bridge is not always possible, especially when the only practical placement of the dust collector is on the bridge deck. Each bend in a duct adds to the pressure drop. As a rule of thumb, a right-angle bend in a duct is like adding another 18 m (60 ft) of hose. To minimize pressure drops from ducts, it is important to use the largest diameter ducts that maintain the proper transport velocity for the dust, keep all ducts as straight and short as possible, and attempt to keep all turns at a minimum radius of two duct diameters.

Airflow within ducts can be measured with a pitot tube. The pitot tube is inserted into the duct and the velocity pressure is measured with a manometer. Air velocity can be calculated from the velocity pressure (VP). Airflow may not be uniform through the duct, so a 10-point traverse is performed to obtain an average. Whenever possible, the traverse should be made 7.5 duct diameters or more downstream from any major air disturbance, such as a bend. The usual method is to make two traverses through the duct at right angles to each other. The spacings of the 10 points is dependent on the duct diameter. The Industrial Ventilation Handbook presents the proper spacings, as well as tables to convert VP to air velocity. Measuring airflows in the duct will determine if the dust collector is running at its rated capacity. Significant reduction in actual airflow versus rated airflow indicates a design deficiency with the ventilation system.

Dust Collectors

There is a pressure drop associated with moving air through the filters that are designed to remove the particulates from the air. This pressure drop is usually a few inches of water column. The pressure drop increases as the filter cake builds up. Dust collectors are equipped with devices such as reverse, pulsating air jets to dislodge the majority of the filter cake during normal operation. Commercially available dust collectors have a magnehelic gauge to measure the pressure drop across the filters. Proper operation of the dust collector should include regular observation of this gauge to determine if the pressure drop is within the manufacturer's specified range. The pressure drop associated with the dust collector must be considered in the overall design of the ventilation system.

Good dust collectors have a high enough static pressure to overcome all system losses and maintain air volumes.

A MOBILE DUSTCOLLECTOR ALLOWS FOR EASY TRANSPORTATION AROUND JOB SITES AND BETWEEN PROJECTS

TABLE 1

Fraction losses for varying duct diameter for 30 m (100 ft) of straight duct.

Dust Collector	Diameter of Round Duct cm (in)	Velocity m/min (ft/min)	Pressure Drop in Water Column mm (in)
5,000 cfm	20.3 (8)	4359 (14,300)	88.9 (35.0)
	25.4 (10)	2774 (9,100)	27.9 (11.0)
	30.5 (12)	1951 (6,400)	11.7 (4.6)
	35.6 (14)	1433 (4,700)	5.1 (2.0)
	45.7 (18)	869 (2,850)	1.4 (0.55)
	61.0 (24)	488 (1,600)	0.33 (0.13)
	76.2 (30)	320 (1,050)	0.11 (0.042)
	91.4 (36)	216 (710	0.04 (0.017)
10,000 cfm	25.4 (10)	5578 (18,300)	88.9 (35.0)
	30.5 (12)	3871 (12,700)	45.7 (18.0)
	35.6 (14)	2896 (9,500)	20.3 (8.0)
	45.7 (18)	1737 (5,700)	5.6 (2.2)
	61.0 (24)	975 (3,200)	1.2 (0.5)
	76.2 (30)	625 (2,050)	0.41 (0.16)
	91.4 (36)	433 (1,420)	0.17 (0.065)
20,000 cfm	30.5 (12)	6100 (>20,000)	>255 (>100.0)
	35.6 (14)	6035 (19,800)	71.1 (28.0)
	45.7 (18)	3444 (11,300)	20.3 (8.0)
	61.0 (24)	1951 (6,400)	4.8 (1.9)
	76.2 (30)	1281 (4,200)	1.6 (0.62)
	91.4 (36)	869 (2,850)	0.61 (0.24)

FURTHER ASSISTANCE

Contact BlastOne for practical assistance and Bulletins on other related topics.

- Ventilation Testing
- Measurement of Duct Velocity
- Analytical Test Methods
- Containment Fabrics
- Waste Disposal Management & Testing
- Compliance Requirements
- Lead Testing
- Monitor Comparison
- Field Evaluation
- Worker Health and Safety
- Air Quality Regulations
- Surface Preparation Methods

BLASTONE INTERNATIONAL

4510 Bridgeway Avenue, Columbus
Ohio 43219

Toll Free 800-999-1881
Email sales.@blastone.com
www.BlastOne.com

NORTH AMERICA
Chicago | Columbus |
Los Angeles | Minneapolis

AUSTRALIA
Adelaide | Brisbane | Mackay |
Darwin | Melbourne | Sydney |
Newcastle | Perth | Port Hedland

NEW ZEALAND
Auckland | Christchurch

SOUTH EAST ASIA
Kuala Lumpur

UNITED KINGDOM
London

 B3610-2