Use of Overhead Protection Systems (OPS) in Refractory Lined Vessels.

Bill Roelofs and Michael Walton

Minvent Solutions
P. O. Box 314
Como
W. A. 6152

RefMet
P. O. Box 126
PRAHRAN,
Victoria 3181

ABSTRACT

In most cases a refractory repair involves dealing with used refractory linings above shoulder height. This paper details a method of personnel protection involving a low pressure inflatable 'balloon' system, installed to prevent the dislodgement and free-fall of in-situ refractories. The technique may also prevent larger scale collapses with higher internal operating air pressure being applied, but in general is designed to protect against the smaller falls from which most injuries result.

INTRODUCTION

In many refractory structures, interim repairs require entry of personnel to affect these. Often, significant scaffolding is required to allow personnel to reach the work face. Whether in the Steel, Non-ferrous, Cement or other Process industry, vessels of any size will have refractory, other brickwork or concrete at a level above head height. This constitutes an 'overhead refractory' where falls of surface material from walls or roof, during repairs present a safety hazard to those working in that area. This is particularly an issue shortly after cool-down when the surface temperature of the refractory lags that of the general environment. This means that the thermal contraction of the refractory has not been completed, and falls or spalling of material from the cooling surfaces is still likely.

This system, originally developed for underground mining to use in shafts, ore/waste passes, bins and chutes, has now been adapted for use in minerals and petrochemical process vessels. This has been called the 'Overhead Protection System' or OPS.

SAFETY PROTOCOLS

In the last decade or so, there have been two fatalities, and numerous other incidents involving overhead refractories or falls of objects within such process vessels under repair. The first of these, in 1997, led to a major revision in safety procedures relating to overhead refractories, with the Company involved developing more formal protocols for use in these situations. These, or similar protocols, are now the industry norm.

The general accepted approach to industrial safety hazards can be summarised in figure 1 below.

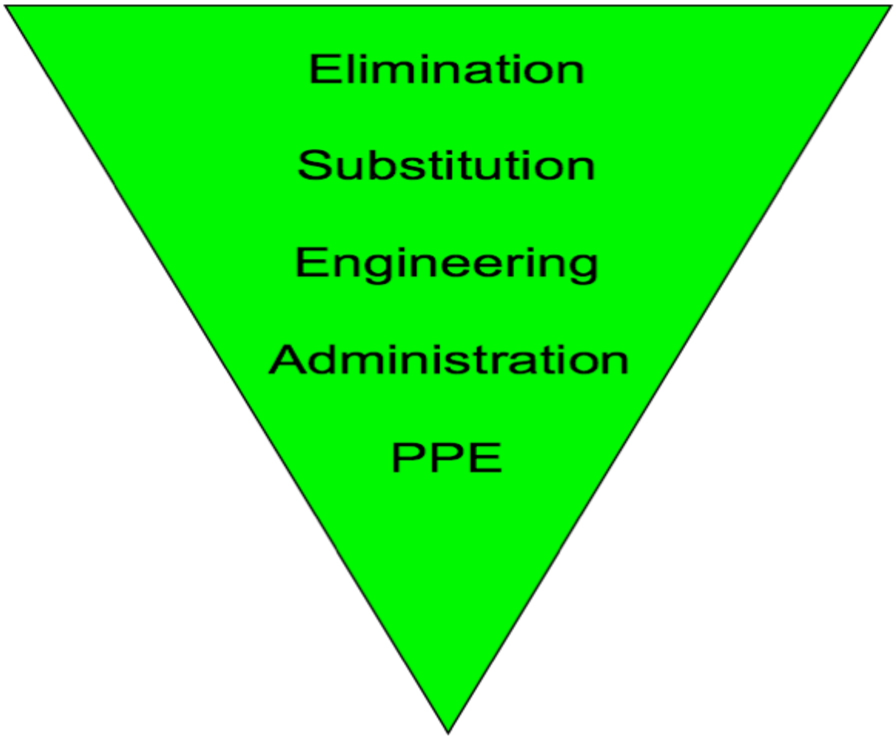

Figure 1: Safety hierarchy of actions.

In this hierarchy, the best method is not to invoke the hazard at all, or not to have personnel enter the area. This is quite often not a practical option. The next implies doing the job a different way, again not often practical. The third heading suggests imposing other engineering solutions to allow the job to be done, such as scaffolding protection etc. When faced with overhead refractories, the industry has taken the general approach of dealing with the issue by either demolition (level 1) or protection (level 3). It is in the latter where OPS applies.

CONSTRUCTION

The OPS 'balloon' is constructed from heavy duty PVC and PVC composites fabrics. The OPS is fully welded with all anchor and lifting/securing points attached to the inside of the fabric, shaped for the specific application, and welded together. When completed, the constructed shape has a nominal tensile strength of 3500 N/mm^2 (350 Kg per 50mm strip), puncture resistance of 1150 N and burst strength of 2950 N.

Coefficient properties at an internal air pressure of 1.5KPa will generate 250kg of positive pressure per square metre against the walls. A typical calculation is shown below as an example[1].

Example, Coefficient calculated force of an OPS

Coefficient/frictional resistance for OPS.
Coefficient of static friction for the PVC is 0.8

The calculated force at 1.5Kpa internal OPS air pressure is 250 Kg/m^2.

e.g. a Vessel (Quench Tower): 4.0m diameter x 4.0m high, sidewall only : 0.8(50.272 x 250) = 10054.445kg or 10.05 tonne. Additional frictional properties (positive pressure) from top panel contact to the roof area of the vessel have not been included.

Additional roof properties: 0.8(12.568 x 250) = 502.72 or 0.5 tonne

Thus total wall and roof contact properties equivalent to 10.55 tonne for this example.

MANUFACTURE

All inflatables are fully welded with a 50mm wide weld for each seam, the industry standard for this type of welding is 25mm to 40mm. The fabric is not stitched, as this creates a perforated tear line and also creates leakage. PVC and PVC composite fabrics have a density range in GSM (grams per square metre) from 900 to 1500, with operating temperatures of -30 to +70° for PVC and -30 to +100° for PVC composite. Each roll of fabric has a section cut out for quality control testing to ensure that the specification parameters are being maintained.
Tests for coating to scrim adhesion, coating to coating adhesion, scrim elongation, tear strength; fabric burst strength and puncture resistance are also conducted.

All webbing /slings and internal bulge restraint straps are rated and tested. The webbing and anchor points are rated for a minimum of 2 tonne. The inflation system is custom designed with a moulded Venturi inflator. The venture delivers 30 times the volume of introduced compressed air. Example: a 200 m^3 unit can be inflated in less than 5 minutes. All finished systems are pressure tested and leakage tested prior to dispatch.

For refractory systems where higher temperatures usually exist, an internal air purge is available; this assists with maintaining acceptable air temperatures within the OPS. Several types of materials are available with temperature ranges up to 100ºC. One such material is detailed below in table 1.

[1] Reference Fishbane et al (1993)

Technical Data PVC Composite

Fabric:		100% pes/1100 dtex	
Weight:		1020 gsm/ 35 oz/yd2	ASTM D 7581
Thickness		1.0mm / 0.04inch	ASTM D 751
Lacquering		Gloss	
Breaking Strength (Cut Strip)	Warp	3500 N / 770lbf	ASTM D 751
	Weft	3500 N /7700lbf	
Breaking yield strength (Grab tensile)	Warp	3000 N 660 LBS	ASTM D 751
	Weft	3000 N 660 lbs	
Bonded seam strength	Warp	3600 N 660 lbs	ASTM D 751
	Weft	3000 N 660 lbs	ASTM D 751
Tear Strength (tongue)	Warp	500 N 110 lbs	
	Weft	400 N 85 lbs	
Adhesion ply (film tearing) (2"/min)		130 N/5cm 15 lbf/inch	
Adhesion (heat sealed seam		150 N/5cm: 35lbf/2inch	ASTM D751
Abrasion		2000 cycles Max weight loss 50mg	5306 Taber Fed Std 191a
Puncture resistance		1150 N (MIN) 255 lbf (min)	ASTM D 4833
Bursting strength (Ball tip)		2950 N (min) 650 lbf (min)	ASTM D 751
Low temperature		-35 c / no cracking	
High temperature		100 c / 212 f minor softning	
Hydrostatic resistance		>540 N/cm2	ASTM D751-A

Table 1: Typical material properties.

The OPS may be constructed in natural form (e.g. with bulges each end, to suit brick domes etc), or constructed with internal bulge restrainers, as pictured below in figure 1, to form flatter ends to mitigate and/or control contact pressure.

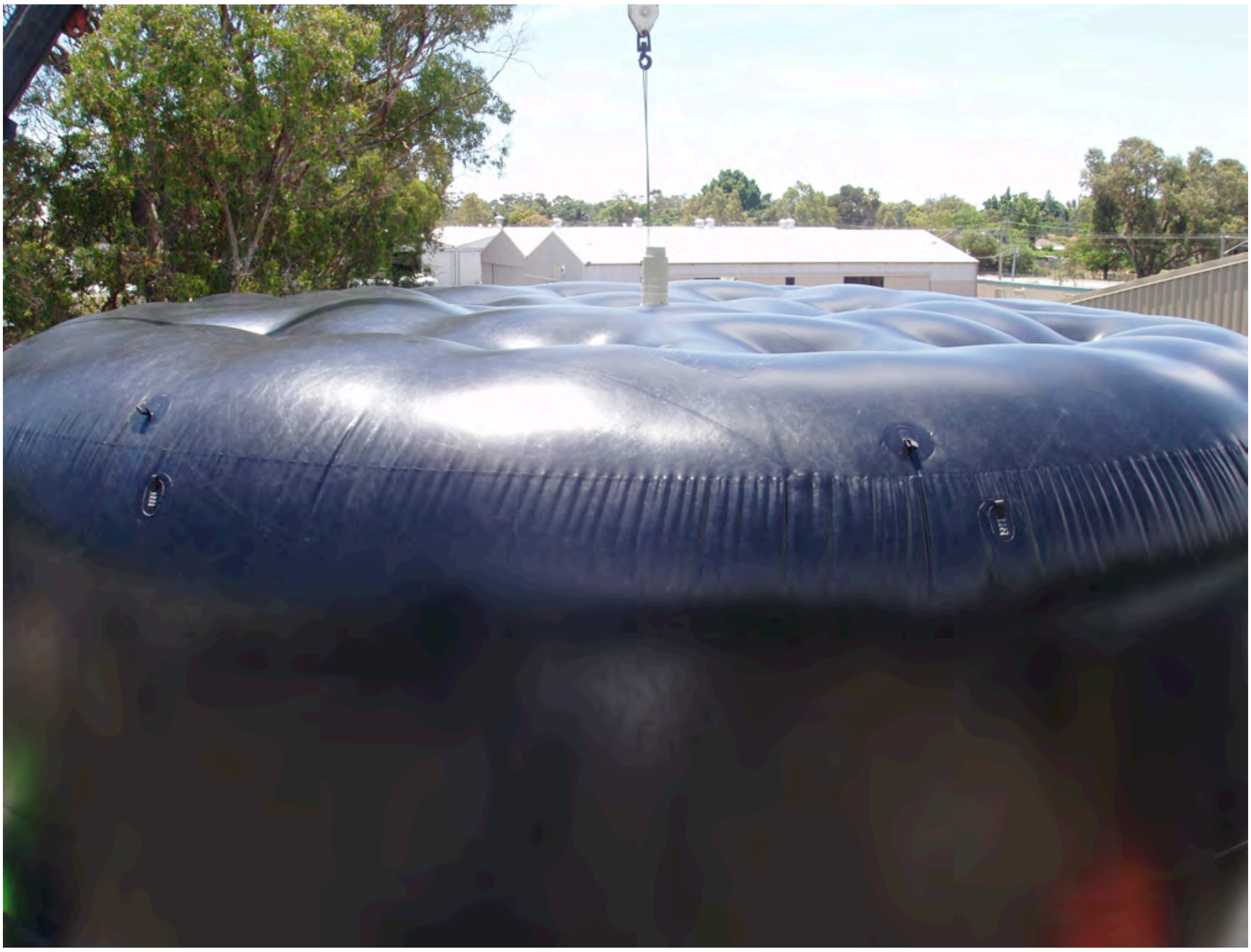

Figure 1: Large OPS with bulge restrainers to lessen top/bottom extension.

This type of bulge restraint is sometimes required when the roof may be compromised with internal upward pressure being applied, or when more working height is required underneath the OPS. This system also provides opportunity to inspect the roof from the top of the OPS if required.

INSTALLATION

Once completed, the balloon is generally installed with a crane or winch depending on size and circumstance, as the package can weigh up to 800kg. Large balloons can be laid out on custom designed trolleys or skids if access is through a small or restricted opening. It is usual for the balloon to be lifted or lowered by crane into its required position, then inflated in situ. Removal is the reverse procedure.

Figure 2: Large OPS undergoing inflation trials at factory in W. A.

OPERATION

The OPS is operated with pressures in the range 0-1kPa (to 5 PSI) depending on application. The system can be operated at higher pressures if circumstances require it to be so, (Over pressure tests have shown that these systems can be run at 5psi if required). The pressure is sufficient to gain intimate contact with the wall and roof surfaces, and this is maintained by an air delivery system, which can be plant air or (preferably) a mobile compressor with a pressure regulator. This pressure is also sufficient to hold it to a vertical wall without assistance from the crane (self suspend). The position of the OPS can be adjusted easily by taking the weight on a crane or winch once more, releasing the pressure, thus deflating the balloon, and simply repositioning and re-inflating.

Most OPS systems are designed as material freefall eliminators and not post incident systems such as nets and scaffolding which catch the falling material rather than prevent it from falling in the first instance. Full contact is the preferred installation methodology. The OPS system is generally not designed to protect from a major fall from a roof or upper wall, rather from small to medium fragments which often become loose from a refractory structure on cooling. These may be pieces of say up to 2-3kg, spalled by the cooling process, which occasionally fall when work below starts, dislodged by work activities, such as vibration of jackhammers and the like.
With the OPS in position, these will be restrained until the OPS is removed

To mitigate any potential free-fall, the OPS must be in contact with the relevant walls or roof.
Major falls may also be prevented by this full contact method when internal air pressure of the OPS is adjusted to the required weight bearing setting. Where situation occur that the OPS is not in contact with the roof for varying reasons, an impact cover for the top of the OPS can be provided.

The OPS operates on a continuous air trickle feed system through the Venturi, this mitigates any air leakage that may occur from cuts, holes and leakage from fittings. The Venturi simply replaces any lost air as and when required whilst ensuring optimum operating pressures are maintained. The Venturi also performs as an over-pressure valve, OPS systems also have comprehensive point of activity Audible/Visual alarm systems that provide warning for conditions such as mains power loss, OPS low & high pressure, Low pressure is generally the result of lack of air supply, or air loss due to damage such as cuts and holes, high pressure is generally the result of incorrect setting, to much air supply to the Venturi or top/side deforming of the OPS due to loading from debris. Each of these occurrences will result in the activation of the Audible and Visual alarm.

APPLICATIONS

To date, these systems have been applied to vessels/areas such as, but not limited to:

- Flash smelter reaction shafts.
- Fluid bed roaster domes and freeboard zones.
- Cement pre-calcination shafts.
- Acid plant towers.
- Combustors.
- Quench towers.
- Off-Gas Ducts.
- Venturi driers and cyclones.
- Scrubbers and cross-overs.

The figure below shows an actual installation of an OPS in a Flash Furnace reaction shaft.

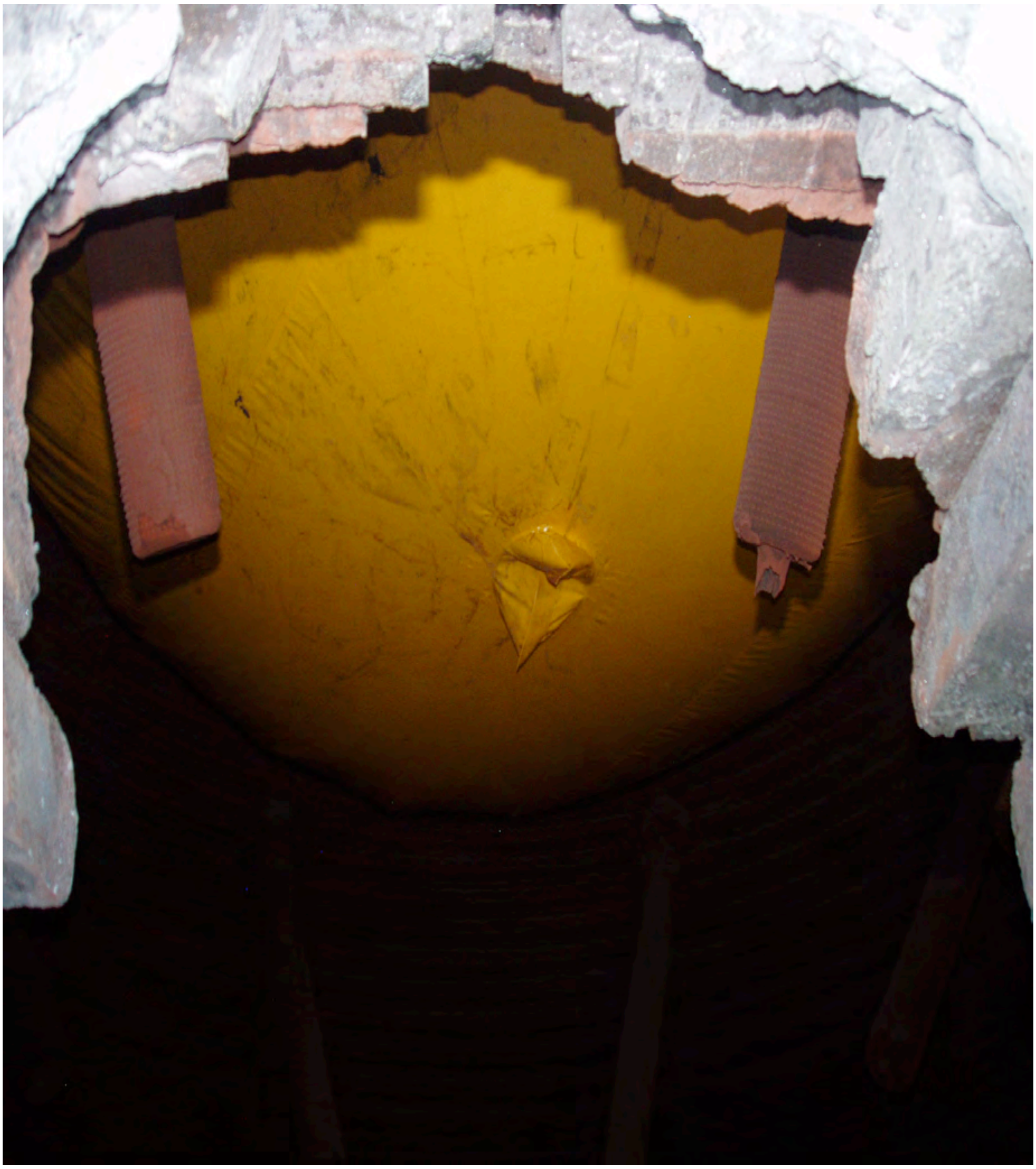

Figure 3: OPS installed/inflated in reaction shaft of Flash smelter

ACKNOWLEDGEMENTS

The authors wish to thank the management of RefMet and Minvent Solutions for permission to publish this paper.