POLYURETHANE FOAM FOR SEALING GRAIN STORAGES

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ABSTRACT

Polyurethane foam is a useful material for filling voids in the structure of grain storages so that they can easily be sealed by a membrane coating. It can be used as a sealant itself when applied in the full foam system over a complete roof or structure. Details are given of the physical properties of polyurethane foam and how it may be applied to storages.

INTRODUCTION

This paper makes no pretence to account comprehensively for one of the most recent interesting applications for polyurethane foams - sealing of grain storages. The applications of polyurethane foams are practically limitless and this paper is intended only to disseminate some knowledge of practical experience gained in application and to acquaint the reader with a basic technical background on polyurethanes.

CHEMISTRY OF URETHANE FOAMS

The chemistry of urethane foams is very complex. This summary gives a general presentation of the reactions of primary importance.

Polyurethane is the end product of the polyaddition reaction which takes place between a polyol (resin) and an isocyanate resulting in the formation of urethane macromolecules. A blowing agent is added to the reacting mix in order to obtain the cellular structure of a foam. The reaction follows:

$$\mathrm{R - NCO + R'OH \longrightarrow R - \overset{\overset{H}{|}}{N} - \overset{\overset{O}{||}}{C} - OR + Heat}$$

R NCO = A polyisocyanate. For production of rigid polyurethane foams the isocyanates proven particularly successful consist of polymers of 4'4 - diphenylmethane di-isocyanate (MDI).

R'OH = A polyhydroxyl compound - polyols, glycols, polyesters. As a general rule the end nature of the polyurethane foam produced is due largely to the character of the polyol selected e.g. flexibility.

Suitable catalysts such as metal compounds or tertiary amines influence the speed of the polyaddition reaction. Besides emulsifiers, polyglycol and silicone polymers are incorporated to control the cell formation.

The reaction of polyol and isocyanate is highly exothermic. If low boiling liquids, (e.g. fluorotrichloromethane) are added to the mix, these are volatilized by the reaction heat which is released and in this way the reaction mix expands.

PROPERTIES OF POLYURETHANE FOAM

Some general physical properties of polyurethane foam are summarised in Table 1.

Thermal Conductivity

The closed cell structure and the presence of fluorotrichloromethane (freon R11) as a blowing agent ensure that urethane foams are unsurpassed with regard to low thermal conductivity.

Chemical Resistance

As a cross linked plastic, polyurethane has good resistance to water, washing liquors, diluted acids and alkalis and aliphatic hydrocarbons.

Temperature Behavior

Under changing temperature, a mechanical stress is exerted on the foam structure of closed cell polyurethane.

With correct choice of material, proper application and appropriate density, polyurethane can be used in a temperature range extending from -200°C to above +100°C.

Mechanical Properties

Excellent dimensional stability, compressive strength and fluexural strength.

The mechanical properties of polyurethane depend to a large extent on density. Generally speaking, linear or very nearly linear graphs of density versus a mechanical property are obtained, except when thermal or chemical effects are introduced (Fig. 1).

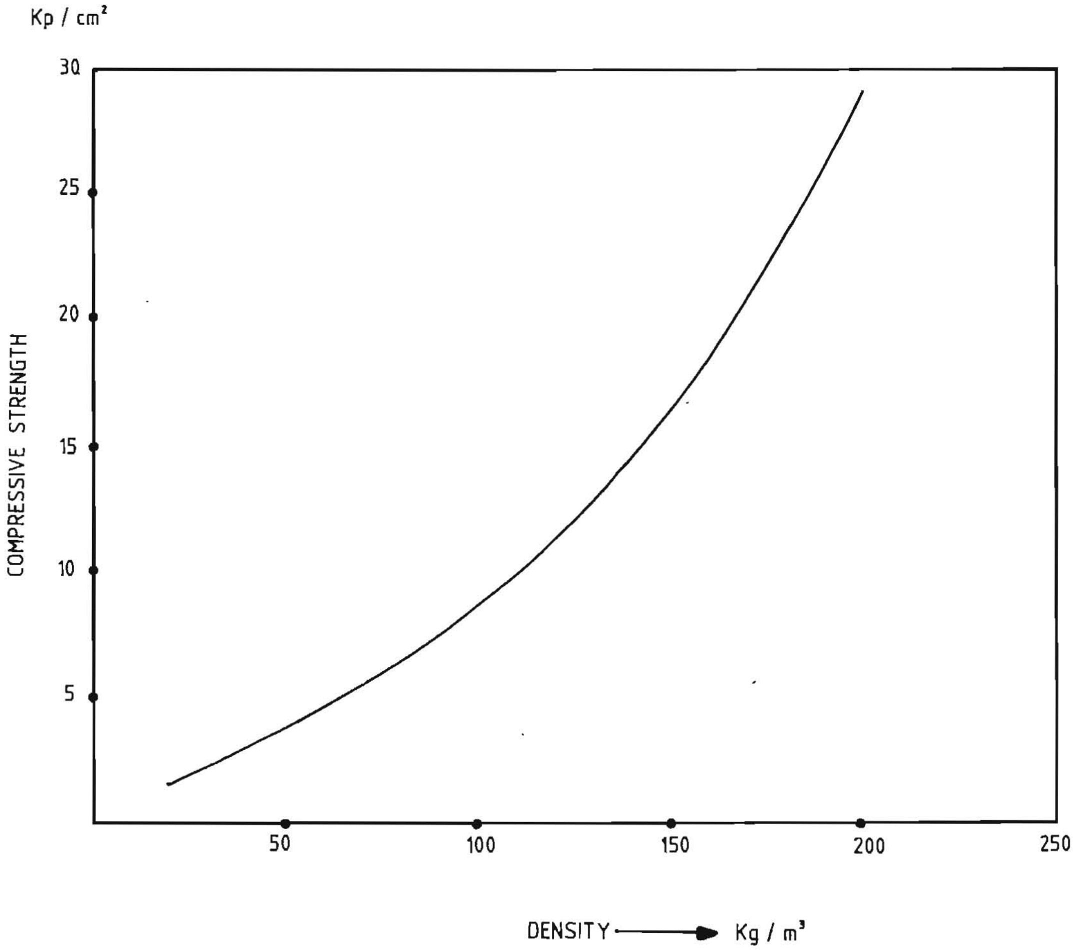
Adhesion

Polyurethane foam produces a strong, permanent bond with many materials.

Table 1 Physical properties of rigid cellular polyurethane (Australian Standard 1366, Part 1 - 1981)

PHYSICAL PROPERTY	UNIT	LIMIT	METHOD
Compressive stress at 10 percent deformation; minimum	kPa		AS2498.3
- Parallel to rise		175	
- Perpendicular to rise		100	
Rate of water vapour transmission; maximum - measured paralled to rise at 38°C	$mg\ m^{-2}s^{-1}$	1300	AS2498.5
Dimensional stability of length; maximum	Percent After 20h		
@ 70°C and 95 ± 5% r.h.		3	AS2498.6
@ -15°C		1	
Closed cell content (uncorrected). Minimum	Percent	85	AS2498.7
Thermal conductivity; maximum (at a mean temperature of 25°C)	$Wm^{-1}K^{-1}$	0.027	AS2122.1
Flame propagation characteristics			
- Median flame duration; maximum	S	8	
- Eighth value; maximum	S	12	
- Media mass retained; minimum	Percent	55	AS2122.1
- Eighth value; minimum	Percent	50	

FIG. 1. COMPRESSIVE STRENGTH OF POLYURETHANE FOAM VARIATION WITH DENSITY (THE USUAL DENSITY FOR SPRAY LIES BETWEEN 35 - 50 Kg m^{3}. FOR HIGH LOAD BEARING APPLICATION SYSTEMS UP TO 100 Kg m^{3} ARE AVAILABLE)



Other properties

Polyurethanes are resistant to rot and, since they have no food value, do not support fungi and do not attract termites, rodents or insects. Being odourless (when cured) polyurethane is suitable for food processing and storage plants.

Table 2 and Fig. 2 give some typical physical properties for a commercial foam.

Table 2. Typical average physical properties of sprayed foam - commercial system

Physical Property	Unit
Cut foam density	45 Kg m^{-3}
% closed cell	94%
Compression at 10%	290 kPa
Water absorption after 7 days	1 vol %
Thermal Conductivity	0.023 W m^{-1} k^{-1}

Dimensional stability: 14 days

	L	W	T	
-30°C	0	0	0	%
+100°C	+0.4	+1.1	+0.3	of
70°C/100% RH	+0.9	+0.4	+0	original

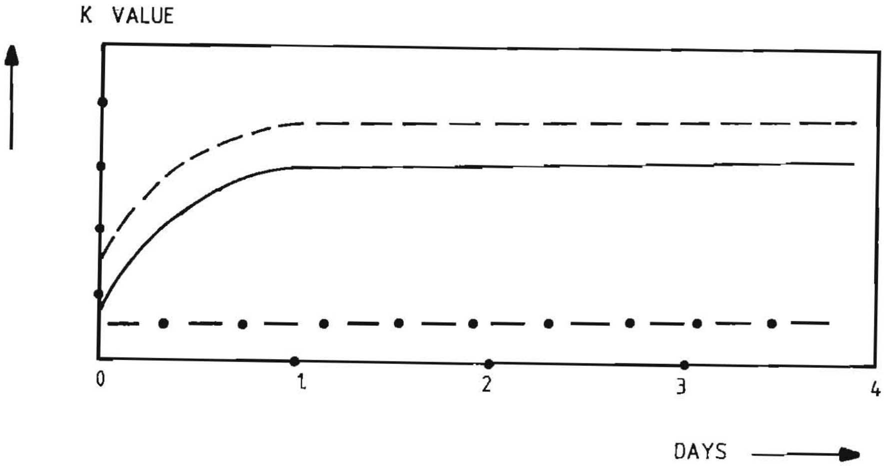


FIG. 2. CHANGE IN THERMAL CONDUCTIVITY WITH TIME FOR POLYURETHANE FOAM
—•—•—•— WITH DIFFUSION - TIGHT FACINGS :
———————— WITH NORMAL SURFACE SKIN
– – – – – – – – WITH CUT SURFACE

APPLICATION - SEALING GRAIN STORAGES

Initially the predominant application for polyurethane foams was insulation. However, polyurethane foam is excellent for filling even the most complex cavities. The reaction mix, which expands 30 - 40 times in volume, can be formulated in such a way that the rising foam will pass through narrow gaps, flow around edges and penetrate into the farthest corners. Combined with the fact that polyurethane can be sprayed or poured, these properties have led to the acceptance of polyurethane as an important component necessary for the process of sealing grain storages.

In practice it should be said that the polyurethane is not used to seal grain storages. It is utilized to fill voids and holes thus providing a suitable surface for the subsequent application of a continuous membrane.

The critical areas of a shed-type or 'horizontal' store to be sealed (filled) prior to membrane application are shown diagramatically in Figs. 3, 4 and 5.

The following areas are treated in the so-called 'partial foaming' system:

Penthouse (Control Room)

The penthouse is generally the weakest structural point and most subject to damage by the environment.

Full foaming is used in practice to achieve:

(a) Void Filling

(b) Minimal temperature/pressure variation

(c) Inherent strengthening of structure.

Ridge Capping (Detail A, Fig. 4)

Polyurethane is used to seal ends of roof sheets and fill voids under ridge capping to prevent build up of grain and provide suitable base for membrane.

Side Wall (Detail B, Fig. 5)

As shown.

End Wall

Sealing of all laps in sheeting and filling gable ends.

Polyurethane is particularly useful for the sealing of old structures. Physical damage, loosened fasteners and general disrepair lead to voids and gaps which cannot be bridged using membranes alone.

In full foam technique the entire roof area and vertical metal cladding are sealed with foam. This full foam technique may be necessary in storages in very bad repair as the foam provides long term structural strength, reducing maintenance costs.

Although in practice the partial foam system is employed for economic reasons it may be that "full foam" technique will be more viable in future. The technical advantages are-:

(a) Minimal variation in temperature within the storages leading to economies in gas usage.

(b) Strengthening of overall construction.

(c) Minimization of expansion/Contraction of the structure.

Insufficient data is currently available to substantiate this concept to say that results obtained from the only fully foamed storage in Western Australia (Burracoppin, 25,000 tonnes capacity) are apparently superior at present to those in which the 'partial foam' system has been used.

EQUIPMENT REQUIRED FOR POLYURETHANE FOAMING

The polyurethane foam is generally applied by the spraying method. Commercially available equipment for spraying urethane foams falls into two categories: low pressure or hydraulic high pressure units. The production of good quality polyurethane foam is highly dependant on efficient mixing of the components. The high pressure equipment is favoured by the majority of applicators as it offers several advantages. These include:

Highly efficient mixing via high pressure counter current injection. Current designs of mixing head (spray gun) are hydraulically controlled, permitting instantaneous shut off. This not only ensures essential automatic clean out of the mix chamber but prevents feed-back into delivery lines.

Extremely accurate metering of component ratios via positive displacement piston pumps or high pressure axial piston pumps.

High pressure units are essentially sealed systems and experience has proven them to be reliable and cost effective. It should be stressed that the application of successful spray urethane systems is no job for amateurs.

PREPARATION OF SUBSTRATE

Sprayed urethane foam can be applied to a wide variety of substrates. This property is one of its most important features. However, it is extremely important that proper adhesion be achieved by correct surface preparation prior to application. All substrates should be clean, dry and free of grease, oil, looses scale or rust. Substrates should be physically tested by scraping to ensure that the area immediately below the surface is of sufficient strength to support the urethane foam once applied. In general, porous surfaces should be sealed and metal surfaces primed.

Surfaces likely to be encountered in grain storages are:

Galvanised Steel

New galvanised steel should be washed with a solvent or acid, then with water and finally primed. Weathered galvanised steel can generally be washed with water and primed.

Whilst polyurethane foam generally does not contribute to corrosion, under some conditions of service it can do so. It is important to be aware that urethane foam is not a vapour barrier. All organic materials will allow some moisture to penetrate to a metal surface, and some additional means of preventing corrosive attack by this moisture should technically be provided. In grain storage application the urethane is protected by the metal sheets on one side and the sealant membrane on the other so, hypothetically, moisture ingress is minimal. It can be readily perceived however that the initial cleanliness of the metal surface and the adhesion of the foam are important factors in reducing the potential for corrosion at the surface.

Concrete

Concrete is one of the most difficult substrates to treat with foam because of the possibility of the presence of excessive moisture. The moisture content should be checked and the suggested maximum content for spraying is 10%. Excessive salt precipitation should also be removed. (e.g. with muriatic acid).

Pre-painted Surfaces

Pre-painted surfaces may not readily accept polyurethane foam because of the smoothness of the surface. Mechanical scoring or abrasive blasting will increase surface area and improve adhesion.

ENVIRONMENTAL CONDITIONS FOR POLYURETHANE FOAMING

Substrate Temperature

Optimum results are generally obtained with substrate temperatures of 20 - 25^{o}C.

Moisture/Humidity/Condensation

Care must be taken whenever the relative humidity rises above 80% as this could adversely effect physical properties, particularly adhesion.

Wind

Wind is generally not of major concern when spraying externally. However, allowance may be necessary for lowering of substrate temperature in calculating curing times.

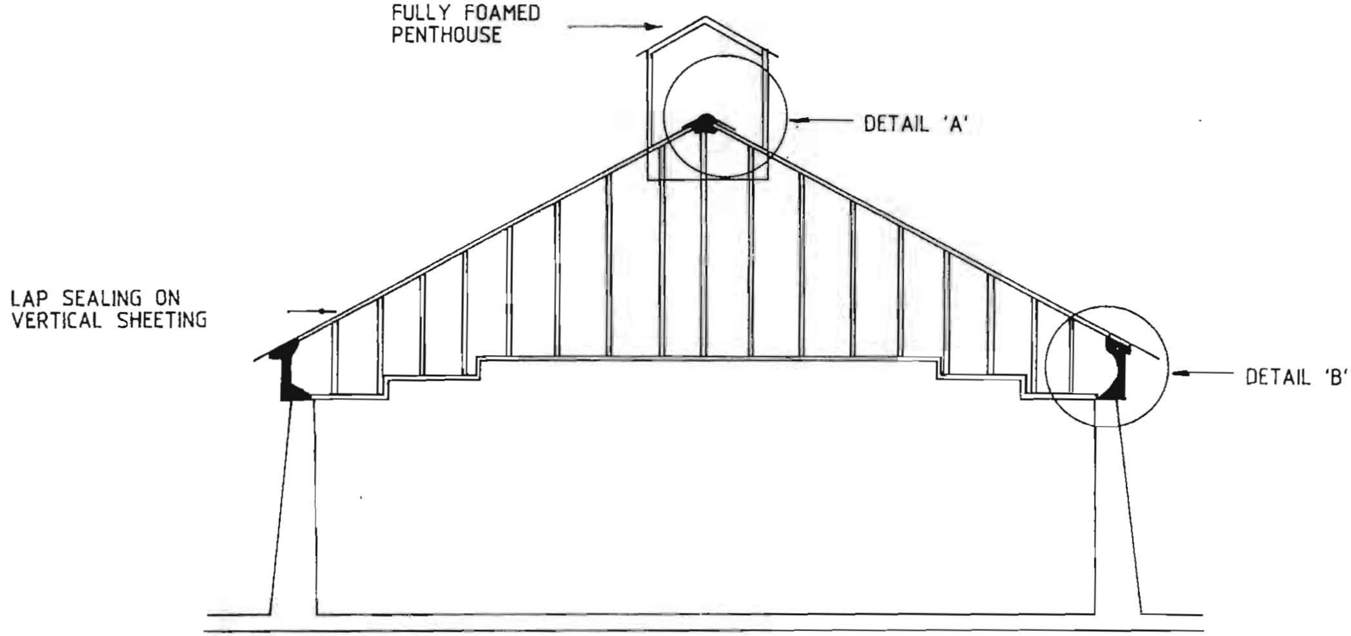
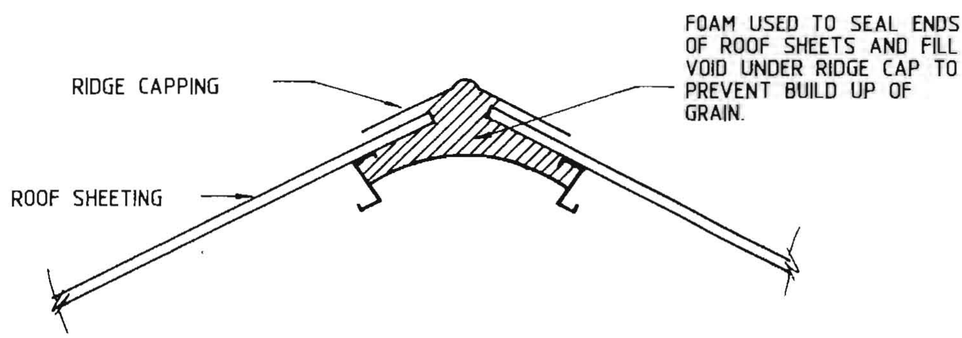


FIG. 3. END ELEVATION OF A TYPICAL HORIZONTAL OR SHED-TYPE STORAGE SHOWING REGIONS WHERE POLYURETHANE FOAM IS USED.



DETAIL 'A'

FIG. 4. DETAIL OF USE OF FOAM POLYURETHANE TO FILL IN VOIDS IN RIDGE CAPPING.

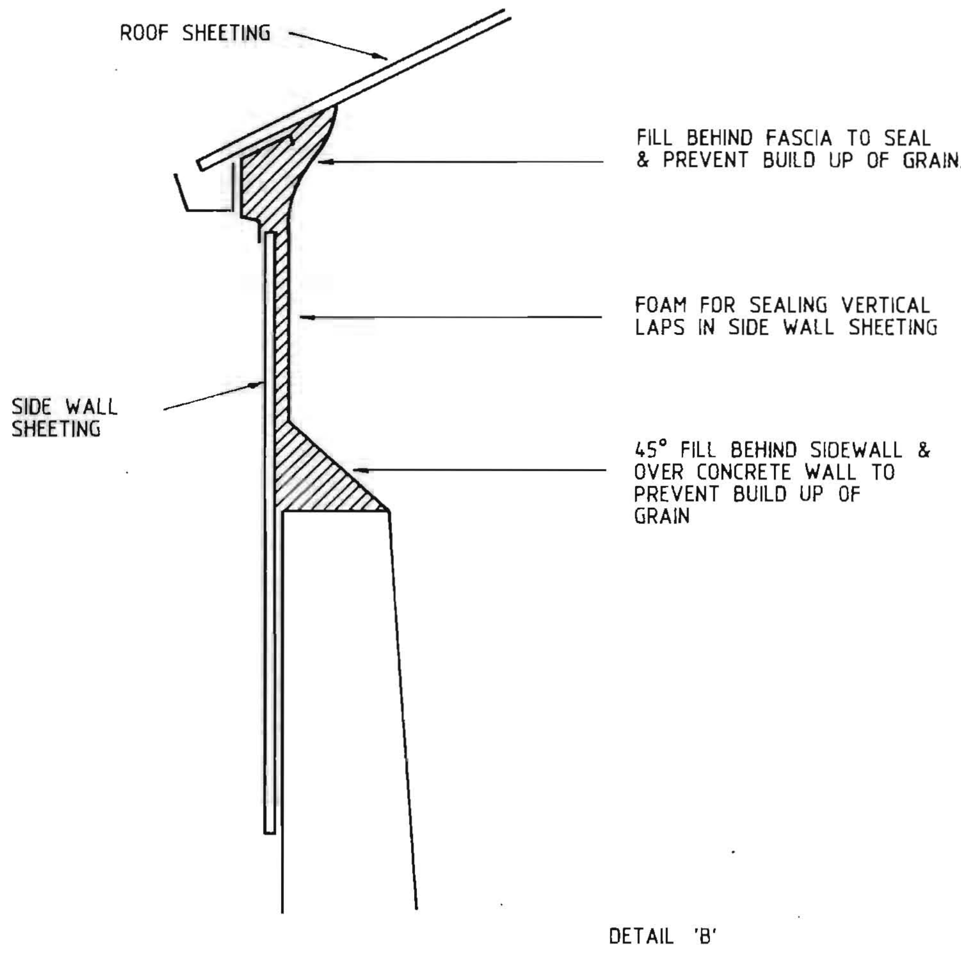


FIG. 5. DETAIL OF USE OF FOAM POLYURETHANE TO FILL WALL - TO - ROOF JOIN IN A STEEL - CLAD HORIZONTAL STORAGE.

SPRAYING TECHNIQUE

It is important that sprayed polyurethane foam be applied in a way that maximizes physical and thermal properties and appearance. This can only be achieved by applicators trained in its proper use and familiar with its limitations.

The spray gun is handled in a similar way to normal paint spraying. The gun is always held perpendicular to the substrate being sprayed. Spraying at an angle can cause elongation of cells in the foam with reduced physical and thermal properties.

At any point where two foam layers meet the edges should be allowed to feather-off as this allows subsequent passes to be blended in giving an even, smooth surface free of ridges and built up sections. A good practice is to allow an overlap of at least 80% on successive passes. If spraying roof areas, cross hatching of successive passes helps in resisting dynamic forces on the foam from the roof.

APPLICATION TIME AND COSTS

Naturally each and every grain storage has different factors influencing time for foam sealing and cost.

If we take a typical 'Warehouse' or 'horizontal' storage of 20,000 tonnes capacity, and discount variables such as location, state of repair, weather conditions etc, it can be assumed that an efficient contractor would complete a 'partial foam' sealing in one week. The average cost is currently around $10,000 to $12,000 for 'partial foam' sealing, i.e. 50 - 60¢ per tonne capacity of grain. The contracting team generally consists of 2 men and cost indicated includes all provisions including travelling, accommodation and meals.

In contrast 'full foam' sealing would require two teams, (4 men), and take around 3 weeks to complete at an indicative cost of $3.50 per tonne capacity. Subsequently, membrane application costs would be somewhat lower. However, overall a 'full foam' system would be 25 - 30% higher in cost. As previously stated, long term data regarding likely cost effectiveness of 'full foam' vs 'partial foam' techniques is not available.

SAFETY PRECAUTIONS

All persons concerned with the handling of isocyanates and isocyanate-containing products must be conversant with the associated hazards and trained in the recommended normal and emergency handling procedures.

The "Threshold Limit Value" or TLV is currently set at 0.02 p.p.m. (0.14mg/m^3) isocyanate vapour in air.

The hazard from vapour and airborne droplets (aerosols) is increased when spraying polyurethane foam. The vapour and aerosols will irritate the eyes as well as the mucous membranes of the nose, throat and lungs. Inhalation must be avoided.

Standard on-site practice should include:

(a) Efficient ventilation. Applicators must be provided with efficient respirators, preferably breathing apparatus with independant air supply.

(b) Overspray should be limited to ensure clean, efficient working conditions and to prevent the spread of material in a hazardous form.

(c) Safety goggles, rubber gloves and protective clothing must be worn.

(d) Suitable eyewash liquid should be near at hand.

(e) Prohibit smoking and eating in proximity to foaming.

(f) Store liquid chemicals out of direct sunlight in well ventilated areas.

Detailed information relative to standard safety precautions is readily available from suppliers of raw materials.

Precautions Against Fire

Like most organic materials, polyurethane foam is combustible. Therefore all safety practices specified against fire hazard during and subsequent to installation must be followed. Manufacturer's and applicator's specifications and codes of practice should be checked and strictly adhered to.

CONCLUSION

Due to the unique properties of polyurethane foam, it is an ideal material to facilitate efficient sealing of grain storages. Full foam sealing may prove to have significant advantages in future, particularly as the excellent insulation value of urethane foams could facilitate pest control via temperature control, such as with the use of refrigerated aeration systems.

ACKNOWLEDGEMENT

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