Managing the Environmental Impact of Bulk Explosives in Open Cast Mines

Case study of on-bench spills from mobile manufacturing units

by

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SAFEX Topical Papers Series
Paper no 04/2007

About the author

Peter P. McLachlan joined the mining industry in the late 60's and spent some 15 years in underground gold and coal mines. Thereafter he joined Boart International as a sales engineer. In 1985 he joined AECI/African Explosives Ltd (AEL) and held various positions in different regions; these included open cast, quarries, base metal and diamond mines.

Some 4 years ago AEL formed the Best Practices Team to attend to needs arising in the mining industry. Peter's contribution to this team utilised his vast experience to up-lift On Bench Practices and assisting Business Managers in auditing and advising Directorate on Quality and SHE issues.

Peter has been instrumental in rolling out the product stewardship code in liaison with legislators, customers and suppliers with regard to the ever growing needs and awareness of environmental trends world-wide.

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1 INTRODUCTION

AEL has embraced a "cradle to grave" philosophy for the products it manufactures. This is embodied in its Product Stewardship Charter which depends on partnering with stakeholders such as the relevant authorities, customers and suppliers. In addition to compliance with all relevant legislation, the Company has backed up its commitment with an ISO 14001 listing. There is, therefore, every expectation that AEL will operate in an environmentally responsible manner.

A particular challenge was to manage bulk explosives waste produced on a bench in an open cast mine. Proposed legislation on destruction methods of explosives require "the manufacturer of explosives to prescribe the manner in which any explosives supplied must be destroyed if no other means of disposal is suitable". AEL uses on-site Mobile Manufacturing Units (MMU's) to produce the bulk explosives open cast customers require. The MMU employs a computerised process which enables the operator to control the loading of blast holes so that spills can be prevented. Base emulsion is rarely spilled on bench. Occurrence of gassed product spilled is common but contamination will be minimal. However, process and operator errors do occur during on-bench operations resulting in the production of waste. Furthermore, the start-up, shut-down and cleaning procedures create a certain amount of waste spill on the bench. There is also some waste associated with the 20kg calibration bucket test of the MMU.

The problem was to assess on-bench activities and services in order to identify aspects that have an impact on the environment. This would enable the Company to implement the necessary corrective action in line with its Product Stewardship commitment.

It was decided to conduct trials on the destruction of explosives manufactured by MMU's to arrive at a safe and environmentally acceptable solution for managing any on-bench spillage.

2 METHODOLGY

The obvious way to dispose of on-bench waste is to load it into a borehole and shoot it. However, it is not known how this waste would behave in those circumstances. It was decided to design a series of trials to determine to what extent flawed product would detonate and thus be safely removed as a source of contamination. The detonation can be monitored in three ways:

a. Measuring the velocity of detonation (VOD) of each shot
b. Taking a post blast photo of each trial showing the final result.
c. Checking visually for any unexploded product in the muck-pile

The destruction trials were based on the range of emulsion products and compositions normally produced by the MMU's. These can be summarised as follows:

- Base Emulsion classified as UN 3375. According to UN series 8 tests, Base Emulsion is non-detonable as it does not contain gassing solution. This distinguishes it from detonable emulsion that is sensitised with gassing solution.

- Ammonium Nitrate Porous Prill (ANPP) classified as UN 1942.
- Gassing solution classified as UN 3139.
- Fuel oil classified as UN 1202.
- P100 consists of 100% emulsion and gassing solution.
- P400 Blend consists of 80% emulsion and 20% ANPP with gassing solution.
- P700 Blend consists of 65% emulsion and 35% ANPP with gassing solution.
- Energan which is a product that is rarely used. The ANPP content of Energan is greater than that of the P700 range.

A toe charge of 25kg quality P400 blend emulsion was placed in each test hole. The "test sample" of either in-spec or flawed product, such as out of spec product or product contaminated with dirt, was loaded on top of it. A "contaminated" sample comprised a mixture of approximately 40% dirt and 60% explosive blend that was mixed at the collar of the hole and then shovelled into the blast hole with a spade. Hole diameters that are larger than the test holes can improve the in hole-coupling ratio when disposing the spilled product with shovels in the hole. The trials were conducted under safe controlled conditions at the same venue. This was a Swiss owned quarry for which the blast parameters can be summarised as follows:

- Rock type: Granite.
- Hole diameter: 115mm.
- Hole conditions: Varied from dry to wet.
- Hole depths: Varied between 5m to 13m.
- Stemming material: 13.5mm aggregate.
- Initiating system: Electronic detonators with 400g pentolite primers.
- Product cup density ranges: 1.08 – 1.10g/cc for gassed and 1.27 – 1.30g/cc for un-gassed product.

The blast consisted of 5 or 6 rows of holes with only the back row used for the trial. In this way the risk of evidence being destroyed in the event of failure is minimised. Results could then be assessed both in terms of breakage and misfires as evidenced by remaining product in the muck pile.

Two different types of VOD recorders were used. For the first two trials a Speed VOD was used and a Micro Trap was used in the third trial. Both types of recorders are reliable and could not be responsible for any differences in results

3 OBSERVATIONS

3.1 FIRST TRIAL

This trial assessed the effect of different ungassed products used on top of an in-spec toe charge. Each product was loaded in a different hole as follows: -

a. Hole 1: Ungassed, clean base emulsion charge.
b. Hole 2: Ungassed, contaminated base emulsion.
c. Hole 3: Ungassed, clean P400 emulsion. This blend was loaded directly on top of the base charge with the use of the charging hose.
d. Hole 4: Ungassed, contaminated P400 emulsion.

The configuration of each hole is summarised in the following table:

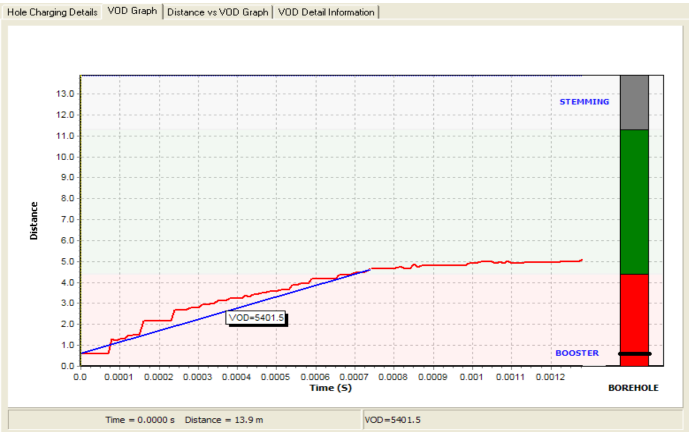
Hole no. & condition	Actual depth of hole	25kg Toe charge in spec	Out of spec charge	Total Charge	Stemming	Product used
1 Dry	13.9m	4.4m	6.9m	11.3m	2.6m	Base P100
2 Dry	13.8m	3.9m	5.9m	9.8m	4.0m	Cont P100
3 Dry	13.5m	3.9m	7.3m	11.2m	2.3m	Base P400
4 Dry	13.7m	3.9m	8.8m	12.7m	1.0m	Cont P400

The holes were fired and their performance assessed by recording the velocity of detonation (VOD) of each hole and examining the muck-pile after the shot. The results were as follows:

3.1.1 Traces of Individual hole VOD recordings

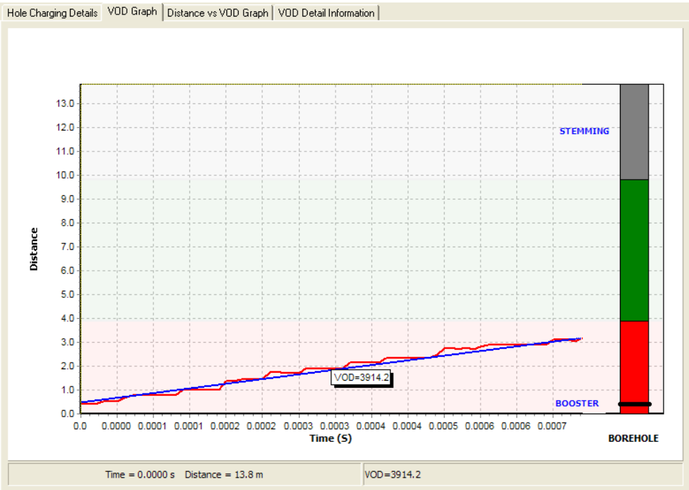
a. Hole 1: Un-gassed, clean base emulsion.

Hole No. 1	VOD trace 1
	4.3m @ 5401.5



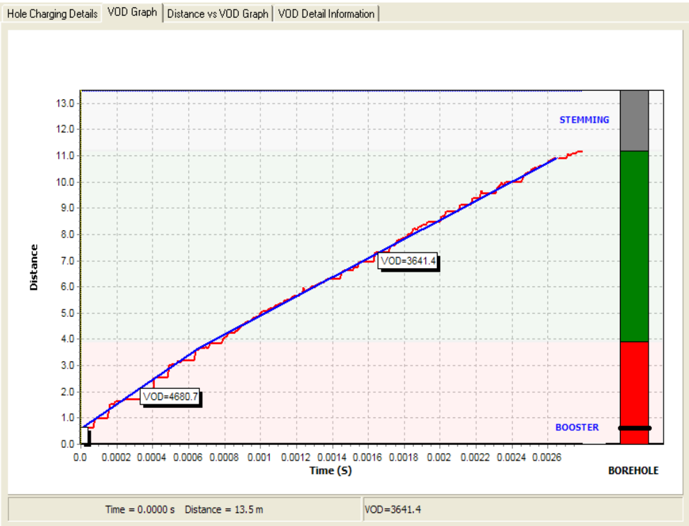
b. Hole 2: Ungassed, contaminated base emulsion

Hole No. 2	VOD trace 1
	3.3m @ 3914.2



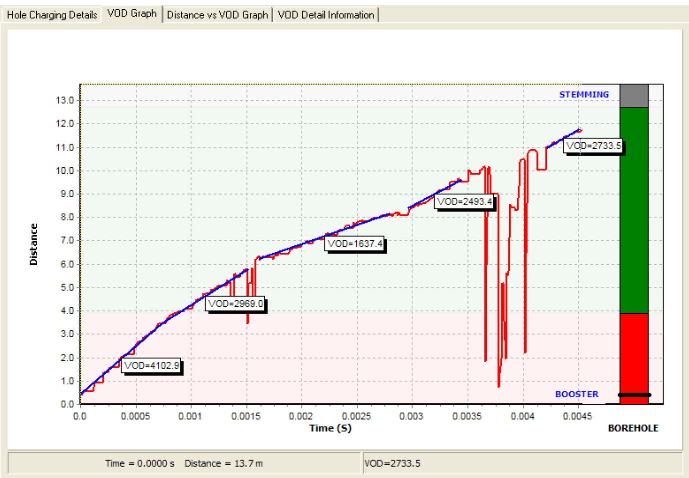
c. Hole 3: Ungassed P400 blend

Hole No. 3	VOD trace 1
	3.9m @ 4680.7
	VOD trace 2
	6.1m @ 3641.0



d. Hole 4: Ungassed, contaminated P400 Blend

Hole No. 4	VOD trace 1
	3.5m @ 4102.9
	VOD trace 2
	2.4m @ 2969.0
	VOD trace 3
	2.3m @ 1637.4
	VOD trace 4
	1.3m @ 2493.4
	VOD trace 5
	1.8m @ 2733.5



3.1.2 Muck-pile analysis

The photograph below clearly illustrates the effects of the base emulsion in 2 holes with clear evidence of oversize rocks. There were no visible traces of product in the muck pile.

3.1.3 Conclusions as result of first trial

An analysis of the VOD traces from the respective holes shot in this trial suggests:

a. Base emulsion above the toe charge did not detonate or deflagrate in holes nos. 1 and 2. The conclusion is that the product was chemically converted in both these cases. "Chemically converted" means that high burning temperatures and large pressures rapidly decompose the product. The decomposition products are gasses such as CH4; H2O; CO; H_2S; SO_2; CO_2; N_2; NA_2CO_3; H_2; NO; NH_3; and O_2. There was some NO_x noticeable after this trial blast.

b. The ungassed, clean P400 blend used in hole no. 3 detonates and all the explosives is destroyed.

c. The ungassed, contaminated P 400 blend in hole no. 4 was progressively destroyed by sporadic detonation. This blend contains AN prill which provides sufficient sensitivity to permit detonation.

3.2 SECOND TRIAL

The object of this trial was to simulate a process failure during manufacture of the explosives in the MMU using different products. As with Trial 1, each product was loaded on top of an in-spec toe charge in separate holes as follows:

a. Hole 1: Gassed, clean, out-of-spec mix that simulates a process failure. “Out-of-spec” product is product not complying with the product specification.
b. Hole 2: Contaminated out-of-spec mix to simulate a process failure
c. Hole 3: Contaminated out of spec mix to simulate a process failure. This is a duplicate hole to allow for possible voids which could be created by loading wet holes with spades.
d. Hole 4: Ammonium nitrate (AN) prill with no fuel oil (f/o) added. This hole was charged with ammonium nitrate porous prill only
e. Hole 5: Full charge of quality P400: - benchmark hole.

The configuration of each hole is summarised in the following table:

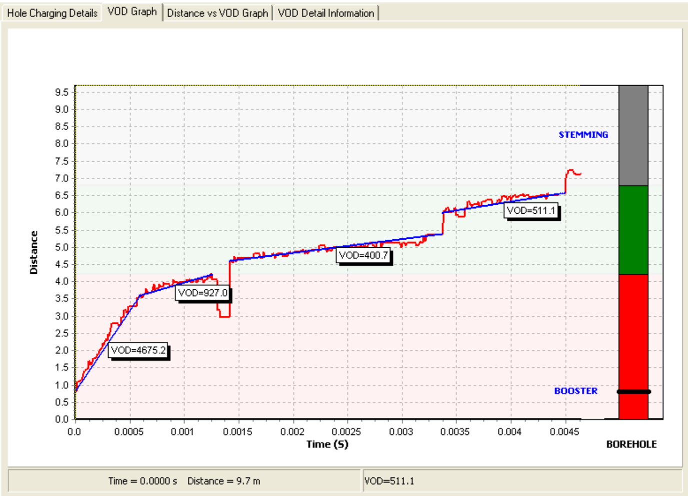
Hole No.	Actual depth	25kg Toe charge in spec.	Out of spec charge	Total charge	Stemming	Out of spec product used
1 Wet	9.7m	5.5m	1.3m	6.8m	2.9m	Full mix
2 Wet	9.3m	5.6m	1.4m	7.0m	2.3m	Cont mix
3 Wet	9.6m	5.6m	1.5m	7.1m	2.5m	Cont mix
4 Dry	9.3m	5.3m	2.1m	7.4m	1.9m	Prills no f/o
5 Dry	9.1m	1.8m	N/A	7.3m	1.8m	Good prod

As in the case of Trial 1, the performance of each hole was assessed by recording its velocity of detonation (VOD) after firing and examining the muck-pile after the shots. The following results were obtained:

3.2.1 Traces of Individual hole VOD recordings

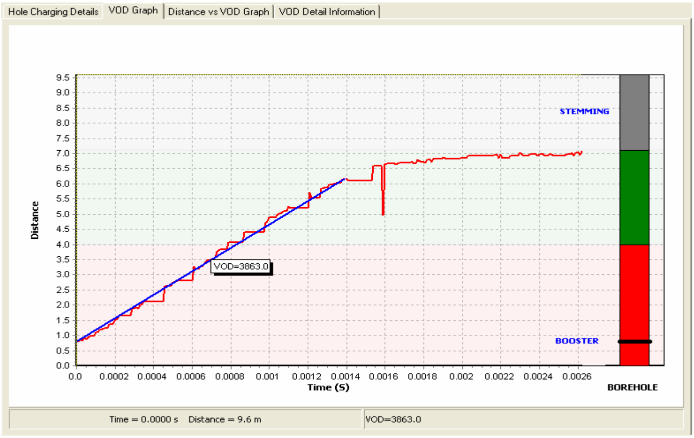
a. Hole 1: Ungassed out-of-spec product mix

Hole No. 1	VOD trace 1
	2.9m @ 4675.0
	VOD trace 2
	3.3m @ 927.0
	VOD trace 3
	0.8m @ 400
	VOD trace 4
	0.6m @ 511



b. Hole 2: Ungassed, contaminated out-of-spec product mix.

Hole No. 2	VOD trace 1
	6.2m @ 3863.0

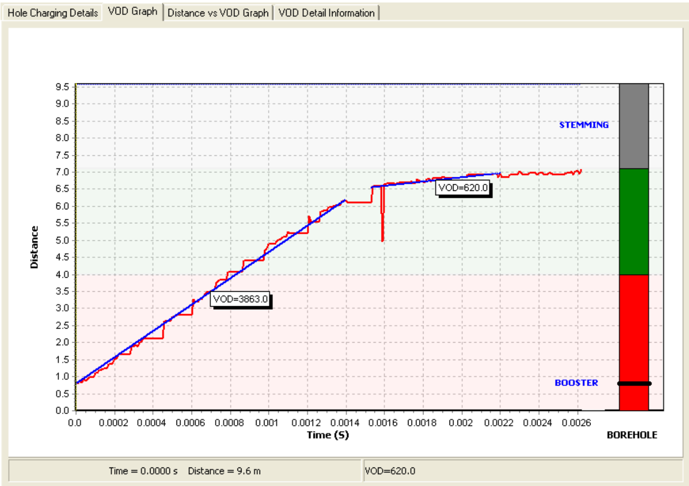


c. Hole 3: Ungassed, contaminated out-of-spec product mix

Readings were sporadic which indicated that something happened. The only conclusion is a chemical reaction took place but that the manual loading with spades affected the outcome. The important thing is that no product was noticed in the muck pile.

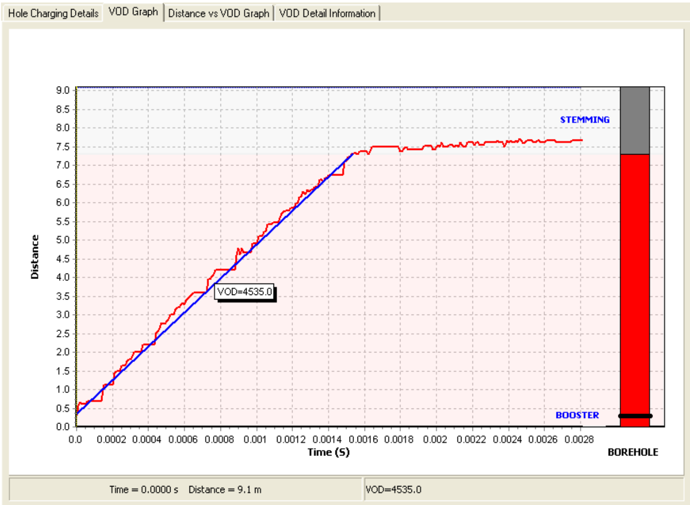
d. Hole 4: AN prills with no fuel oil added

Hole No. 4	VOD trace 1
	3.1m @ 3863.0
	VOD trace 2
	1.2m @ 620.0



e. Hole 5: Good quality P400 - Benchmark.

Hole No. 5	VOD trace 1
	7.0m @ 4535.0.0



3.2.2 Muck-pile analysis

Judging by the picture on the next page this trial produced good ground movement with no large oversize rocks evident. Once again there were no visible traces of product in the muck pile.

3.2.3 Conclusion as result of second trial

The test columns in this trial were shortened due to an unintended loading error. This did not affect the result in any way. The VOD traces from the holes shot in this trial indicated that:

a. The clean, ungassed, out-of-spec product mix in hole no. 1 deflagrated sporadically which destroyed the product above the base charge. The deflagration takes place at rates that vary from a few centimetres per second to approximately 400m per second resulting in a sporadic chain reaction. Again no traces of explosives found after blasting.
b. There was no trace of VOD's in holes 2 and 3 which contained the contaminated, ungassed, out-of-spec product mix. Loading of product in wet holes with a spade suggests that voids had been created that resulted in the chemical conversion of the product.
c. In hole no. 4 containing the AN prills without the addition of fuel oil a lower order detonation had occurred.

d. The results for hole no. 5 loaded with in-spec P 400 provides the benchmark for the test results.

3.3 THIRD TRIAL

This Trial focused on the P700 product which is the most used product in our market. As with the previous trials, the different products were loaded in different holes on top of the same toe base-charge as used previously.

a. Hole 1: Gassed, contaminated P 700.
b. Hole 2: Gassed, contaminated P700
c. Hole 3: Ungassed, contaminated P700
d. Hole 4: Ungassed, clean P700.

The following table summarises the configuration of each hole:

Hole No.	Actual depth	25kg Toe charge in spec	Out of spec charge	Total Charge (m)	Stemming (m)	Out of spec. product used
1 Dry	7.8m	2.1m	5.7m	6.1m	1.7m	Cont P700
2 Dry	7.8m	1.8m	6.0m	5.8m	2.0m	Cont P700
3 Dry	9.3m	1.4m	7.9m	7.3m	2.0m	Cont P700
4 Dry	8.3m	1.8m	6.5m	5.8m	2.5m	Full P700

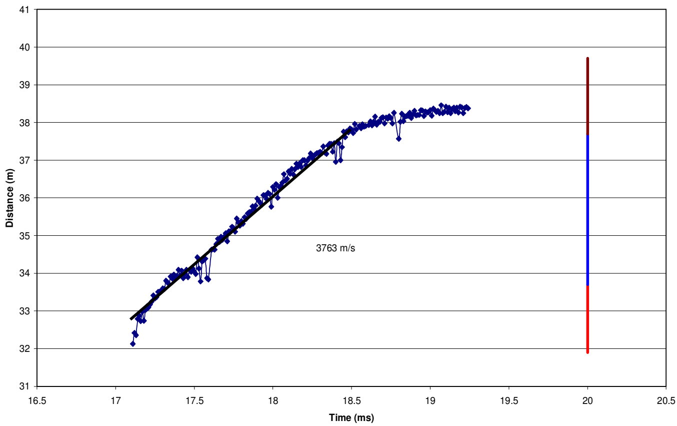
As with the previous trials, the performance of each hole when fired was assessed by recording its velocity of detonation (VOD) and examining the muck-pile after the shot. The results can be summarised as follows:

3.3.1 Traces of Individual hole VOD recordings

a. Hole 1: Gassed, contaminated P700 blend
VOD trace was too noisy and sporadic and could not be used

b. Hole 2: Gassed, contaminated P700 blend

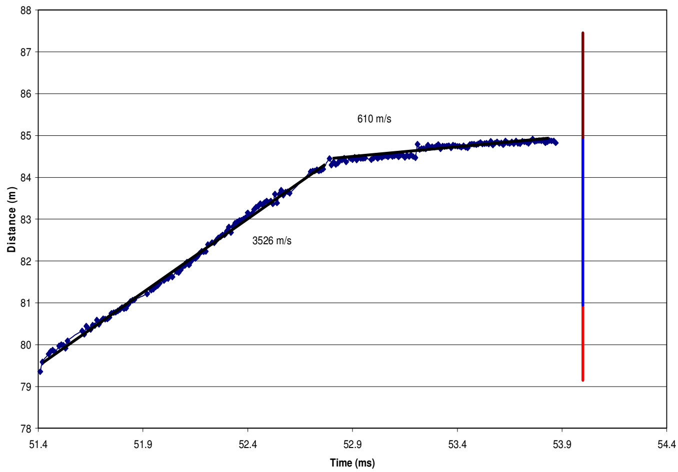
Hole No. 2	VOD trace 1
	5.63m @3763



c. Hole 3: Ungassed, contaminated P700 blend
VOD trace was too noisy and sporadic and could not be used

d. Hole 4: Ungassed, clean P700 blend.

Hole No. 4	VOD trace 1
	4.55m@3526
	VOD trace 2
	0.68m@610



3.3.2 Muck-pile analysis

The photograph on the next page shows a few large oversize boulders because of the low VOD's from the explosive used. As in the previous trials there were no visible traces of product in the muck pile.

3.3.3 Conclusions as result of third trial

The following can be concluded from the VOD traces obtained in this trial:

a. No conclusions can be drawn from the noisy and sporadic VOD traces of holes nos. 1 and 3. Traces indicated that something did happen. It is suspected that product was so contaminated that it resulted in a low order sporadic detonation.

b. Holes nos. 2 and 4 shows that a detonation had occurred.

4 CONCLUSIONS

Alternative methods of on-bench waste disposable include using an emulsion breaker on bench or establishing a burning site for destroying the waste. Off-site disposal is deemed not to be safe or environmentally friendly. A safer and environmentally superior method for disposing waste material is by consumption in a borehole as outlined in this paper.

As for any explosives operation, the disposal method must be agreed with the relevant authorities in order to obtain the necessary permit/licence. Once this has been done the following can then be implemented:

- A Code of Practice must be developed with each customer on the methods of destruction pertaining to that site .This should be agreed by all and documented.
- The manufacturer can then build the procedure into its own auditing system.

P. McLachlan.

6th November 2006.