USE OF ANHYDROUS AMMONIA AT UBOMBO RANCHES

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Abstract

Anhydrous ammonia (82% N) is the cheapest form of nitrogen fertilizer available and is landed on Ubombo Ranches in Swaziland at less than 75% of the cost of urea per unit of N. To ensure minimal loss of anhydrous ammonia to the atmosphere, techniques have been developed for its application to more than 4 000 ha under most soil conditions, including heavy clays. No differences in cane yield were observed when using ammonia or urea. For efficient operation a high standard of management and adequate safety measures are required.

Introduction

Anhydrous ammonia (NH3) has several characteristics which make it an efficient nitrogenous fertilizer. It can be adapted to a wide range of soil types; it may be applied to soil without climatic constraints; equipment can be adapted to apply it; it is an economical source of nitrogen (82% N); and it has a low labour requirement. About 20 million tons are applied world-wide to a variety of crops. It is the main nitrogen carrier in the USA, where almost five million tons are applied annually. Experimental work in Britain and the USA has shown it to be equally effective as urea as a nitrogenous fertilizer. (Mc Vickar *et al.*, 1966).

Andydrous ammonia is a liquefied gas and must be handled under pressure at all times. When injected into the soil, it dissolves in the soil moisture, and the ammonium ions gradually become adsorbed onto the clay minerals. Soils of high clay content will retain more NH3 than soils of lower clay content. Moist soils retain more applied NH3 than do dry soils of similar clay content.

Anhydrous ammonia was first used at Ubombo Ranches in November 1969 to reduce the cost of nitrogenous fertilizer. Initially two tines per interrow were used, but this left a hard ridge in the mid-interrow, which had to be broken down in a follow up operation to create a tilth for middle-busting and furrow formation. The original applicators, mounted on the three-point linkage at the rear of the tractor, frequently left an open tine channel from which NH3 would escape if soil conditions were unsuitable, as they often were in Arcadia or Rensburg form soils. In 1988 they were replaced with a single, mid-interrow tine mounted on hydraulic rams immediately in front of each rear wheel of the tractor. This virtually eliminated the escape of gas, even in the most cloddy soils.

Operations procedure

Handling and transport

As shown in Figure 1 the NH3 is delivered by the manufacturers in 30 ton rail tankers to the local railway siding where there is a vapour compressor plant. It is transhipped into a 12 ton road tanker and hauled 14 km to a number of 'mother' storage tanks, each of which has its own liquid transfer-vapour recovery compressor (see Figure 2). The transfer of NH3 from a delivery tanker to a mother tank involves compressing ammonia in the vapour space above the liquid in the delivery tanker; the difference in pressure so created between the two tanks causes the liquid ammonia to flow into the mother tank.

Bulk storage tanks

Siting of the mother tanks is made with due regard to accessibility by road tankers and possible difficulties in the event of a serious spillage of ammonia. The following requirements have been met in the design of storage tanks:

Material mild steel
Design pressure (48°C) 1 825 kPa
Routine test pressure 2 380 kPa

Nurse tanks

These are the small units used to transport NH3 from the mother tank to the field applicators. They are fitted with a small compressor pump for filling the applicator tanks. The capacity of the nurse tank is two tons. The following items of equipment are also an essential part of the operation:

- an NH3 vapour compressor pump at each mother tank
- NH3 level indicators on each mother tank
- flexible connections on the steel pipes
- wire-braid reinforced flexible hose pipes
- excess flow control valves
- pressure relief valves on all tanks.

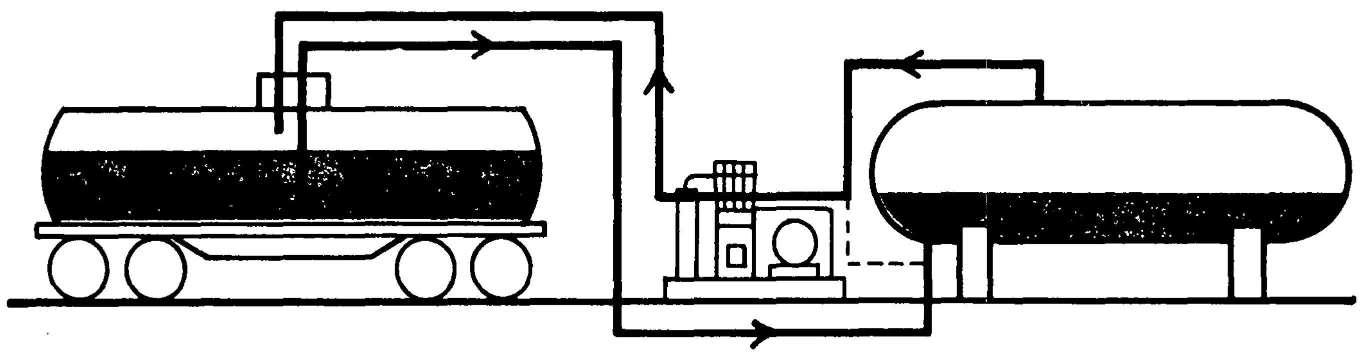
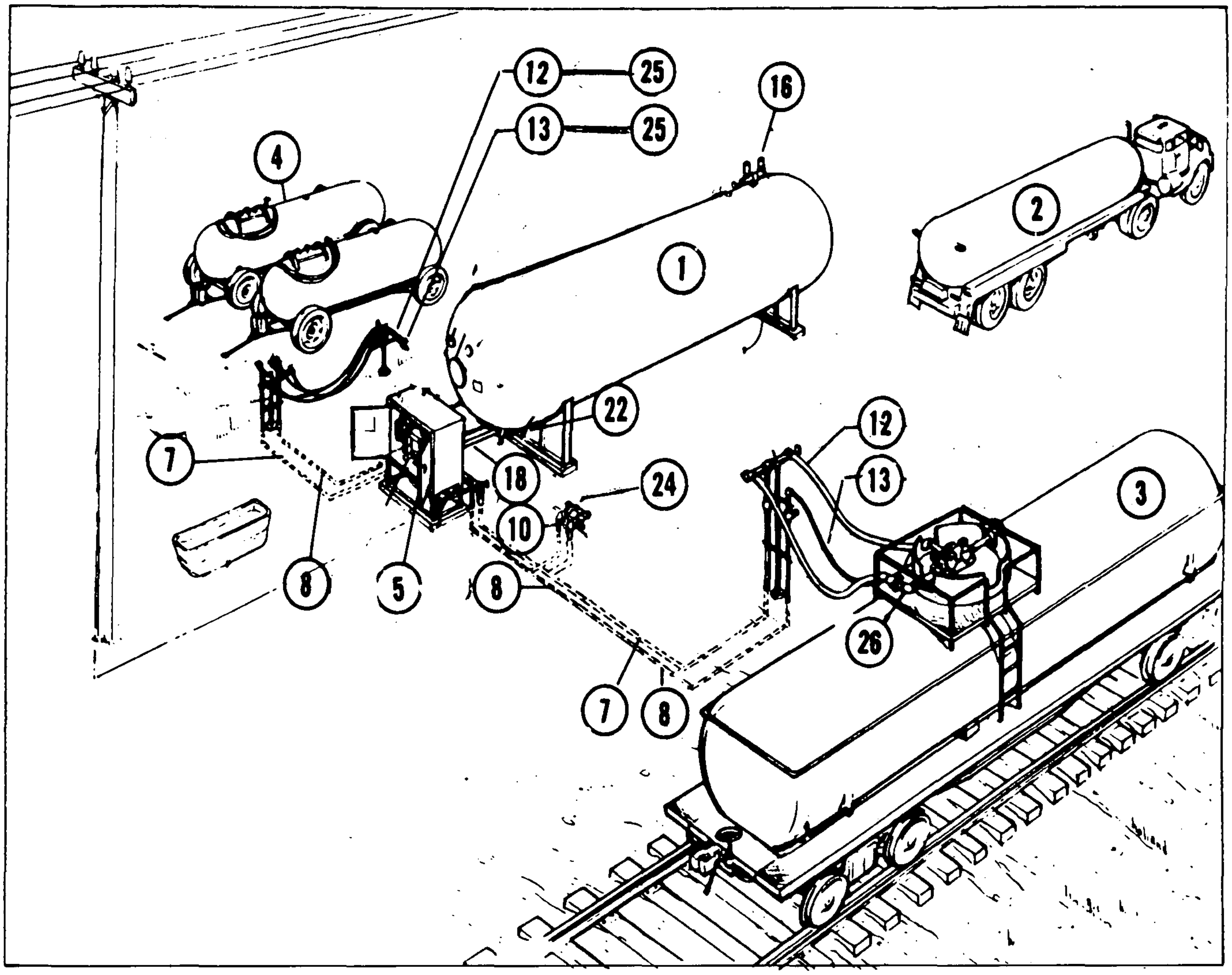


FIGURE 1 Delivery by rail of anhydrous ammonia to vapour compressor plant



1. Mother tank
2. Road tanker
3. Tank car
4. Nurse tank wagons
5. Compressor cabinet
7. Extra heavy liquid piping
8. Extra heavy vapour piping
10. Transport connections
12. Liquid hoses
13. Vapour hose
16. Relief valve manifold
24. Transport coupling
25. Hose end valve and couplings
26. Bleeder valve

FIGURE 2 Sample plan layout

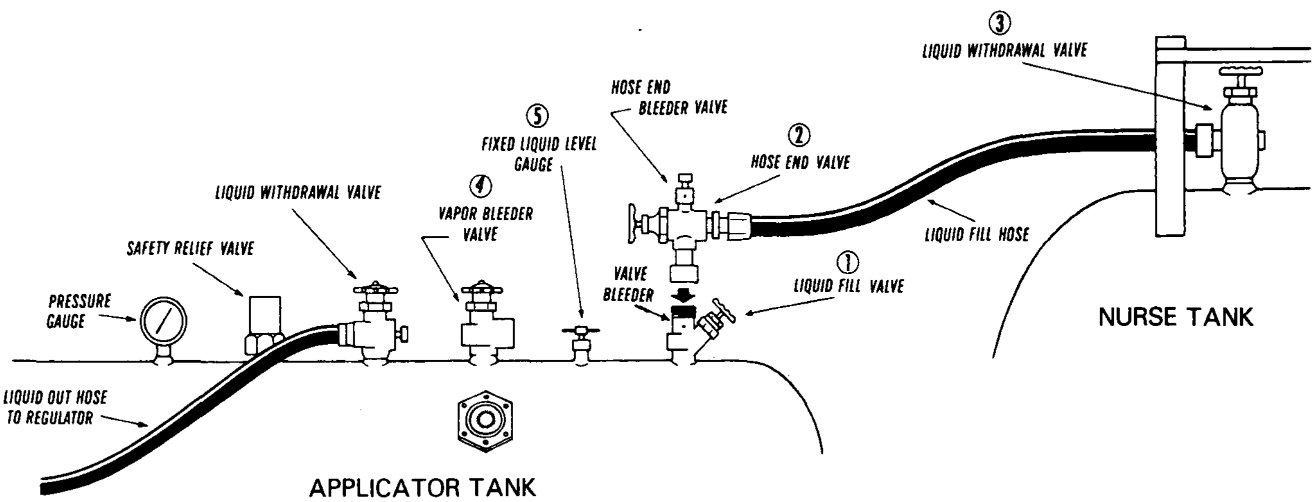


FIGURE 3 Field procedure for transfer of ammonia from nurse tank to applicator

Infield application

The following equipment is used for applying up to 850 tons of NH3 to 4 000 hectares annually:

- three nurse tank trailers, drawn by a single 32 kW tractor in 'relays'
- seven applicator tanks of 900 kg capacity with injector tines, each mounted on a 68 kW, two-wheel-drive tractor.

Injector tines

Each tine is fitted with a steel NH3 delivery tube, which runs down the back of the tine as far as the point. There is an outlet on either side of the tube, at right angles to the line of travel. This arrangement gives the best lateral penetration of NH3 into soils of varying firmness.

Selection of cane fields suitable for NH3 application

As a prerequisite to the operation, cane tops must be burnt after harvest in all furrow irrigated fields; in sprinkler irrigated fields this is not necessary. Very stony fields and fields with less than 300 mm soil depth are avoided because of damage to tines and the poor soil seal obtained.

The presence of soil moisture is important both for injector-tine channel sealing, and for maximum retention of NH3. At the correct tilth for NH3 tining, soils of the Shortlands and Hutton forms need contain no more than 15% of their available water content for effective retention of NH3. At Ubombo Ranches it is usually necessary to reduce the hardness of the red and brown orthic soils with a clay content of more than 30%, with a pre-irrigation of about 75 mm. On drying out a few days later, a suitable tilth is obtained for tining, and undue compaction is avoided. Vertisols normally retain adequate moisture for NH3 incorporation, and their self-mulching nature ensures correct surface tilth. Sandier soils of alluvial origin, such as the Dundee or Oakleaf forms, also retain suitable tilth but may require pre-irrigation to restore moisture.

Placement depth

This is maintained at 200 mm. Research in the USA and Britain has shown that the best results are obtained at depths ranging from 200 to 400 mm (Goodson, 1973). Reasons for placement at a depth of not less than 200 mm are: sufficient overlying soil is provided for injector channel sealing, a zone of adequate soil moisture for creating the ammonium solution is present, and loss of NH3 by volatilization is delayed allowing time for NH3 retention by clay adsorption.

Sealing of the injector tine channel

This is accomplished by the rear wheels of the applicator tractor which run directly behind the tines. The tined soil flows around the tine and is immediately pressed into the channel by the wheel. NH3 vapour loss is insignificant under almost all conditions and if losses occur they are immediately apparent.

Infield procedure

The seven applicator tractors normally work as a team, served by one 32 kW tractor drawing a full NH3 nurse tank. The tractor driver lowers the injector tines into the cane interrows, slightly outside the edge of the field, and works steadily across the field in a low ratio gear to the other side, where the NH3 delivery valve is shut off and the tines are simultaneously lifted out of the ground. In the case of furrow irrigated fields with mid-field concrete furrows, the tractor has to shut off the NH3 and withdraw the tines one tractor length from the furrow, to turn and reverse into the next cane rows.

Problems

Volatilization of NH3 can occur at the point of injection if the tine channel is not closed quickly and thoroughly. The tractor drive-wheel method of channel sealing gives acceptable results, but occasionally leaves a depression in surface irrigation furrow profiles. The irrigation furrow profile problem has been tackled by attaching paired mouldboards to the injector tines to gather displaced soil back into the depression. This has had limited success because of the presence of cane tops from the previous crop. Tractor turning at mid-field irrigation furrows also causes slight under-application of N, and a supplementary dressing of urea is required.

Response to NH_3 versus urea

A field trial with sugarcane was conducted in association with the Swaziland Sugar Association on an Arcadia form soil to determine whether responses were equal from anhydrous ammonia and urea fertilizers, and whether nitrogen use efficiency could be improved under conditions conducive to nitrogen loss, by using N-serve which is a nitrification inhibitor. The following treatments were replicated six times:

- NH3: 160 kg N/ha
- NH3 + N-Serve: 160 kg N/ha with 2 l/ha N-Serve
- Urea: 160 kg N/ha
- Urea + N-Serve: 160 kg N/ha with 2 l/ha N-Serve

In the NH3 + N-Serve treatment, the N-Serve was mixed with 535 l/ha water and injected alongside the NH3 applicator tines. The urea was applied by hand and buried after the application of N-Serve, which was sprayed into the fertilizer furrow using a knapsack sprayer. The cane and sucrose yields for the various treatments are summarised in Table 1. Results showed that the two forms of nitrogen fertilizer were equally effective and N-Serve did not improve the efficiency of the fertilizers tested.

Table 1

Summary of crop yield (mean of six replicates)

Treatments	Cane t/ha	Sucrose %	Sucrose t/ha
NH_3 (160 kg N/ha)	103	16,18	16,7
NH + N-serve	103	15,73	16,1
Urea (160 kg N/ha)	99	16,09	15,9
Urea + N-serve	103	15,95	16,5
Mean	102	15,99	16,3
Mean trial	102	15,99	16,3
SE	7	0,30	1,2
CV%	7	1,90	7,6
Significance	NS	NS	NS

Safety

Safety of personnel, and prevention of loss or damage to materials receive continual attention at Ubombo Ranches. The legislated procedure regarding annual inspection of pressure vessels by recognized personnel is strictly followed. All NH3 installations are laid out and sign-posted in accordance with National Occupational Safety Association (NOSA) specifications.

Personnel are issued with standard cotton overalls, rubber boots and neoprene gloves for normal daily20operations. A full-face gas mask with respirator cartridges is available should the operator require it while bleeding off vapour during transhipping. Complete sets of gas-tight respirator suits are stored at sites remote from any installation in case of a major spill, where they may be safely donned before approaching the scene. Water hydrants and hose pipes with multiple spray jet nozzles are provided on site for washing spillages on the body.

Costs

Costs of the NH3 operation were compared with those for the application of urea (Table 2). Fertilizer prices quoted were as landed on the estate in 1990. Tractor costs were based on an internal charge-out rate of R15/h for a 68 kW tractor used for NH3 application, and R11/h for a 51 kW tractor used for urea application.

Table 2

Comparative costs of NH_3 and urea

	NH_3	Urea
Cost of N per kg	R1,12/kg	R1,53/kg
Cost of N at 160 kg/ha	R179,20/ha	R244,80/ha
Handling bagged urea (160 kg N/ha) (three operations)		R 1,24/ha
Urea:		
MF275, banding at 2,5 ha/h		R4,40/ha
MF275, cultivator at 1,85 ha/h		R5,95/ha
NH_3		
MF375, on sprinkler fields at 0,95 ha/h		
MF375, on furrow fields at 0,62 ha/ha		
MF275, nurse tanker, R6,00/h (using the mean value)	R20,00/ha	
Total cost per 160 kg N/ha	R200,32/ha	R257,92/ha

Table 3

Capital costs of equipment

NH_3 reduced to annual cost			UREA reduced to annual cost	
MF390	R65 000	6 = 10 833	MF375	= R9 667
Injector assembly	R6 000	6 = 1 000	Spreader	= R3 000
Applicator tank	R6 000	6 = 1 000	Trailer	= R 417
Nurse tanker	R18 000	15 = 1 200		
Hoses & valves	R4 000	1 = 4 000		
Maint. costs	R1 000	1 = 1 000		
NH_3 hose	R2 500	1 = 2 500		
Compressor	R2 500	4 = 625		
Ripper	R1 200	1 = 1 200		
NH_3 spares	R3 500	1 = 3 500		
Annual cost		R26 858		R13 084

Over a season and for an area of 4 608 ha, there was a cost advantage of R265 420 in favour of NH3 compared with urea. Offset against this is the greater cost of NH3 equipment, and the larger tractors required. Storage tanks remain the property of the NH3 suppliers, and were therefore not costed in the exercise. NH3 applicators cost more than urea spreaders, but last at least six years without appreciable costs for repairs. Granular urea spreaders on the other hand, have to be replaced every two years due to corrosion and wear. Comparative costs of equipment are shown in Table 3. Over the past six years the average annual cost benefit from the use of NH3 compared with urea was R250 000.

Discussion and Conclusion

From experience gained at Ubombo Ranches, NH3 works at least as effectively as urea as a sugarcane fertilizer. There is a considerable cost saving on the price of ammoniacal nitrogen when compared with that of other N fertilizers, as well as long term cost benefits from the operation as a whole.

The nature of the world NH3 industry is such that it is generally possible to import from other sources at prices competitive with those of the local product.

Training in safety and technical procedures is well within the scope of a large farming enterprise, provided the initial size of the operation is not too ambitious.

Some of the advantages of NH3 are: it is effectively buried in the soil thereby largely eliminating N loss by volatilization, labour requirements are much less than for bagged fertilizer, and the risk of theft is eliminated.

Disadvantages are the high capital cost of equipment, and the need for expert maintenance and operation of pressure storage vessels.

Anhydrous NH3 will continue to be the major N carrier on the estate, and modifications to the tine assembly are being considered to improve the quality of the furrow left behind in flood irrigated fields. The necessity for denitrification control will also be investigated.

Acknowledgements

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REFERENCES

Goodson, GR (1973). Agronomic aspects of ammonia application. Agricultural Ammonia Symposium. Great Britain.

McVickar, MH, Martin, WP, Miles, IE and Tucker, HH (1966). Agricultural anhydrous ammonia technology and use. Agricultural Ammonia Institute, Memphis. American Society of Agronomy, Madison. Soil Science Society of America, Madison.