

*Cotton Research and Development Corporation*

**PROJECT DAN 116C**

**FURTHER DEVELOPMENT OF THE  
CURRENT ANHYDROUS AMMONIA DISTRIBUTOR  
FOR COMMERCIAL APPLICATION**

**FINAL REPORT**

**Neville Gould and Pat Weldon**

**Agricultural Engineering Research Unit**



**NSW Agriculture**

**Trangie Agricultural Research Centre**

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## **BACKGROUND TO THE PROJECT:**

Research into the issue of poor anhydrous ammonia application and its potential cause of striping in cotton began in 1990 with Cotton Research and Development Corporation projects DAN55C and DAN87C. This research confirmed that anhydrous ammonia metering systems were accurate at dispensing the desired kg/ha application rate, but that conventional distribution systems (*ie.* the manifold and associated distribution hoses and lines) were unable to evenly distribute this rate across the application rig. Indeed, variations as high as 100% (*ie.* some rows receiving twice as much as other rows) was common place and hence the occurrence of striping in cotton fields.

The Agricultural Engineering Research Unit at NSW Agriculture's Trangie Agricultural Research Centre (TARC) undertook to correct this problem. Their research resulted in the development of a new prototype distributor. This new distributor reduced distribution variation in each distribution line to less than 5% of the mean total flow, substantially less than any other commercial manifold. However, all experimentation with regard to the development of this new anhydrous ammonia distributor had only been performed on 8-row systems. Further research was needed to broaden the understanding of the performance of the distributor under a wider range of operating parameters.

In addition, commercialisation requires a degree of "production engineering" to test the ability of various individual distributor components, and indeed the complete distributor, to perform in a robust and efficient manner across that wider range of environmental and application conditions. A range of prototype distributors had been manufactured to test different materials and these were tested during lay-by applications of anhydrous ammonia in Qld and NSW. Further research was also needed to determine the effect of other operating conditions on the performance of the manifold and on the anhydrous ammonia metering and distribution system as a whole.

## **PROJECT OBJECTIVES AND EXTENT TO WHICH THEY WERE ACHIEVED:**

1. To assess the performance of the new distributor across a wide range of outlet numbers, flow rates and tank pressures with both conventional gas and Cold-flo product.
2. To assess the performance of the new distributor in conjunction with a range of metering devices (*ie.* both controllers and regulators).

These objectives were achieved in all aspects, except for testing with Cold-flo. Whilst Cold-flo has been used in field applications through the prototype and commercial distributors since 1996, the larger turn-around time between runs in the research laboratory precluded its use in a meaningful and practical manner, *ie* it was impossible to keep the Cold-flo "pots" cold enough for them to perform correctly during short experimental tests.

Additional experiments resulted following the release of the commercial distributor into the market. Information on these is also supplied.

**HOW HAS YOUR RESEARCH ADDRESSED THE CORPORATIONS THREE OUTPUTS; SUSTAINABILITY OF NATURAL RESOURCES, PROFITABILITY AND COMPETITIVENESS, AND/OR PEOPLE AND COMMUNITIES?**

The project has addressed the Corporations outputs in the following manner:

- The issue of striping was thought to be due to the inaccurate or uneven application of anhydrous ammonia. Our research has shown that variation between distribution rows could be as high as 300% and typically over 50% using existing application equipment. This has meant that whilst some cotton rows were receiving too little nitrogen (hence the light colouring of specific rows leading to a striped-effect), other rows were receiving too much nitrogen. It has been suggested that this would lead to off-site environmental impacts through excess (unused) nitrogen leaching into water systems, such as has occurred in the USA. The more even application of anhydrous ammonia through the development of the *Trangie Rotaflow* will substantially reduce the likelihood of this outcome and hence increase the sustainability of our natural resource.
- The development of the *Trangie Rotaflow* in combination with improved metering equipment has already led to a revision of nitrogen application rates by a number of Australian cotton growers. Given that the risk of under- or over-application of anhydrous ammonia is substantially reduced with these improved systems, the need to use compensating rates of anhydrous ammonia has been averted, leading to a substantial reduction in input fertiliser costs. The correct application of anhydrous ammonia has also been shown to increase lint yields and potentially lint quality. These outcomes will improve the industry's profitability and competitiveness.

**RESEARCH METHODOLOGY AND JUSTIFICATION FOR ITS USE:**

Prior to the research, data from recent field tests was analysed and discussed with the commercial partners, H.I. Fraser Pty Ltd. As a consequence, an experimental prototype distributor was designed and manufactured for inclusion in the experimentation process.

A need to change the measurement system to allow testing of 6-, 8- and 12-row application systems using a range of metering equipment was determined. This work preceded the research to enable the conduct of the following experiments in a safe, efficient and accurate manner. The research involved two aspects:

*Goal 1. To assess the performance of the new distributor across a wide range of outlet numbers, flow rates and tank pressures with conventional NH<sub>3</sub> gas.*

The existing test rig at Trangie ARC was modified to permit load cell weighing of the output from up to 12 distribution lines, thereby allowing simulation of both 6 and 12 row rigs, to add to the existing data on 8-row simulation.

Replicated experiments over typical field pressures (nominally 70-140 psi) and flow ranges using gas were carried out using the final prototype distributor design connected to a commercial regulating meter (Continental Metermatic or John Blue Nitrolator).

*Goal 2. To assess the performance of the new distributor in conjunction with a range of metering devices (ie. both controllers and regulators).*

These experiments were limited to the 8 row configuration applying anhydrous ammonia only in the gas form at a single tank pressure at a range of flow rates. The 3 most common commercial controllers (RAVEN SCS 440 and ACCU-FLOW System, DICKEY-john DjCCS100 and Microtrak MT3000) were sought and obtained. However as most farmers were purchasing RAVEN systems, only this controller system was used as the metering device, in conjunction with the Continental standard regulator used as the control.

To address these Goals, the research facility at TARC was modified using project funds and a total of five experiments were completed.

### Experiments

1. **Comparison between final Trangie prototype and Continental RPR- December 7-8, 16-18, 1997**

### Background

Data from previous experiments (from only 8-row systems) suggested strongly that the Trangie prototype distributor was able to distribute anhydrous ammonia with far less variation than either the John Blue or Continental RPR manifolds. In typical field situations, the distributor could be fitted to 6-12 row systems which would experience a range of field conditions in terms of flow rates and operating temperatures and pressures.

No information was collected on the prototype that would provide the necessary understanding of whether the performance of the distributor was robust enough to proceed to commercial production. In order to determine the capacity of the Trangie prototype to perform under typical field conditions, an experiment was designed which compared the performance of the it against the most common commercial manifold in use in Australia and the USA, the Continental RPR.

### Materials and methods

The modified research facility at the Trangie ARC was used. An experiment of the following design was conducted:

- **Treatments : 2**

1. Manifold – Trangie Prototype Gold (used in the field over the preceding 3 cropping seasons)
2. Manifold – Continental RPR

- **Pressures : 3**

1. 70 psi (nominal tank pressure)
2. 100 psi (nominal tank pressure)
3. 140 psi (nominal tank pressure)

- **Flow rates : 4**
  1. 40 kg N/ha
  2. 80 kg N/ha
  3. 120 kg N/ha
  4. 160 kg N/ha

- **Outlets : 3**
  1. 6 hoses
  2. 8 hoses
  3. 12 hoses

- **Design:**

This procedure was performed as three separate experiments, one for each of the three pressures (not randomly assigned to experimentation days). For each nominal pressure, the design is a replicated split-split-split plot experiment, with replicates corresponding to days. Within each day, the two distributors were allocated to whole-plots comprising 12 plots for the Trangie distributor and 4 plots for the Continental RPR. Within each whole-plot corresponding to the Trangie distributor, the 3 Outlets were randomly assigned to sub-whole-plots and the 4 Flows then randomly assigned to the split-plot within each sub-whole-plot. For the Continental RPR distributor, the allocation is slightly different depending on the sub-experiment. For the sub-experiment with Pressure set at 100 psi, all tests were performed with 8-outlets and the four Flow levels were randomly allocated within each Day. Hence there are 3 replicates for each Flow Rate when Distributor=Continental RPR, Pressure=100 and Outlets=8. For each of the other two sub-experiments, *ie* Pressure=70 or 100, a different Outlet number was allocated randomly to each Day, and the Flow Rates within each Day.

## 2. Comparison between H.I. Fraser Mark I design and Trangie prototype - November 10-17, 1998

### Background

Initially in commercialising the manifold, it was necessary to determine the compatibility of the internal components and their ability to handle the environment into which they were to be placed. Another prototype, similar to that used in Experiment 2, which had been in the field for 3 cropping seasons, was modified with some changes made to the upper thrust and axial bearings to stabilise the rotor rotation.

### Materials and methods

An experiment with the following design, which compared the performance of the two manifolds, was then conducted at the modified research facility at Trangie ARC.

- **Treatments : 3 (see Table 1)**
  1. *Manifold - Trangie Prototype Gold*
  2. *Manifold - H.I. Fraser Mark I*

- **Flow rates : 3**
  5. 1000 lb N/hr
  6. 2000 lb N/hr
  7. 3000 lb N/hr
- **Replication : 2**
- **Design : fully randomised split plot**

The experiment was conducted over 5 days from September 10-12, 16-17, 1998 in typical application conditions. All tests were conducted using a typical 8-row configuration.

### 3. Effect of hoesail intrusion distance on distribution performance of *Trangie Rotaflow* Mark III - September 21-23, 1999

#### Background

Upon the release of the *Trangie Rotaflow* anhydrous ammonia distributor (Mark I) onto the Australian market in early 1999, it was discovered that some minor design changes had occurred which could possibly result in changes in its distribution performance and accuracy. These design changes involved a decrease in the distributor wall thickness and a maximum tolerance allowance on the distributor outlet ports. This could enable the hoesails, when fitted, to intrude into the delivery chamber between the rotatable distributor passage and the outlets ports in the wall of the distributor housing. In fact, in the worst case scenario, the hoesails could be inserted so far into the chamber as to contact the rotatable distributor and slow, or even stop, its rotation.

An experiment was therefore designed testing the hypothesis that "the intrusion of hoesails into the delivery chamber would adversely effect the distribution accuracy of the distributor". No attempt was made to re-test the situation where the rotation of the distributor was stopped as this has already been shown to adversely effect the distribution accuracy. An alarm light system was fitted to the *Trangie Rotaflow*, which in the event of the speed of the rotatable distributor slowing substantially, would turn the indicator light from "green" to "red", indicating a problem requiring immediate rectification.

#### Materials and methods

The experiment of the following design was conducted at the research facility at Trangie ARC.

- **Treatments : 3**
  1. *Position 1*- 6 hoesails with no intrusion, 2 intruding 1.6 mm, 2 intruding 3 mm and 2 hoesails intruding 4.5 mm,
  2. *Position 2*, same as *Position 1* but with a different hoesail configuration,
  3. *Position 3* -no intrusion (control).

- **Flow rates :** 3
  1. 1000 lb N/hr
  2. 2000 lb N/hr
  3. 3000 lb N/hr
- **Replication :** 3
- **Design :** fully randomised split plot

The experiment was conducted over 3 days from September 21-23, 1999 in typical application conditions with tank pressures in the region of 90-120 psi. All tests were conducted using a typical 12-row configuration.

The *Trangie Rotaflow* Mark I distributor was connected to a Continental C4100 Metermatic meter. Twelve outlets were used, each hosetail being drilled with a "N" drill before fitting to provide evenness of flow resistance. Hosetails were evenly spaced around the perimeter of the distributor and were connected via 4.43 meter long, 3/8inch I.D. distribution lines to the collection drums. All tests ran for 60 seconds.

#### **4. Effect of *Trangie Rotaflow* on metering and distribution performance of Raven SCS and ACCUFLOW System - October 7, 1999**

##### **Background**

The introduction of electronics to agriculture has seen the rapid move by users of anhydrous ammonia to purchase control systems incorporating the ability to change the rate of application on-the-go and also to compensate for speed (and therefore mass flow) variations of the application vehicle. At least three of these systems are being used in Australia at present, the Raven SCS 440 with ACCUFLOW System, the DICKEY-john NH<sub>3</sub> Control System CCS1000 and the Microtrak NH3350/NH3500 Anhydrous Ammonia Kits.

Given the rapid recent uptake of controller systems by Australian growers, it was felt necessary to determine whether the same improved distribution characteristics observed with regulating systems when the *Trangie Rotaflow* distributor was used could be realised with the controller systems. Additionally, it needed to be determined whether the new distributor had any adverse effect on the overall operation of the controller system.

##### **Experimental design**

The research facility at Trangie ARC was used to conduct the experiment. An experiment was conducted to test the performance of the new *Trangie Rotaflow* distributor when connected to a Raven SCS 440 system. A Continental A-6006 B 14 1/4inch (01-07) outlet ductile iron manifold was used as the control against which the *Trangie Rotaflow* was compared when connected to the Raven controller. The connection for both manifolds was via the vertical one inch inlet section of a one inch T piece. The Continental manifold is the standard recommended manifold for Australian application systems (pers.comm. Greg Rigby, Incitec Fertilizers).

Both manifolds were tested across a typical range of flow rates; 40, 80, 120 and 160 kg N/ha. With an 8-outlet system, and a simulated travel speed of around 9kmh, this equates to a field application rate of 236, 472, 708 and 945 kg NH<sub>3</sub>/hr. The 8 1/8inch NPT (A-6132) steel hose barbs were positioned as equidistant as possible around the 14 outlet Continental manifold. For the *Trangie Rotaflow*, hose barbs were positioned at every third outlet on the 24-outlet distributor. Manifolds were connected via 4.43 meter long, 3/8inch I.D. distribution lines to the collection drums. Three replications were conducted of each treatment in a standard split block design. The hose barbs were all reamed to a 7.1mm ID with a letter "N" drill.

### Materials and methods

- **Treatments : 2**
  1. Raven SCS 440 system connected to a Continental "Red" A-6006B manifold.
  2. Raven SCS 440 system connected to a *Trangie Rotaflow* distributor.
- **Flow rates : 4**
  - 1) 40 kg N/ha
  - 2) 80 kg N/ha
  - 3) 120 kg N/ha
  - 4) 160 kg N/ha
- **Replication : 3**
- **Design : fully randomised split plot**

The experiment was conducted over 3 days from January 27-29, 1999 in typical application conditions with tank pressures in the region of 120-150 psi. All tests were conducted using a typical 8-row configuration. All tests ran for 45 seconds.

### **5. Effect of hosetail size on distribution performance of *Trangie Rotaflow* Mark III - November 12, 1999**

#### Background

Previous experiments with the *Trangie Rotaflow* distributor led to the conclusion that there was a need to investigate a means of reducing the distribution variation at lower flow rates. These variations seemed to be much higher than those able to be achieved at the higher flow rates, although still significantly better than those being achieved using alternative manifold systems.

An experiment was therefore designed testing the hypothesis that "smaller hosetail orifice size would improve the distribution accuracy of the distributor at lower flow rates (<1000 lb/hr)". Incitec Fertilizers suggest that for low flow rates an orifice size of 1/16inch should be used in order to increase back-pressure to between 35-40 psi.

### **Materials and methods**

An experiment of the following design was conducted at the research facility at the Trangie ARC.

- **Treatments : 2**
  1. *Hosetail size* - 1/16inch (approximately 1.56 mm)
  2. *Hosetail size* - 7.6 mm (N size drill through a normal 9/16inch hosetail)
- **Flow rates : 4**
  - i. 1000 lb N/hr
  - ii. 2000 lb N/hr
  - iii. 3000 lb N/hr
  - iv. 4000 lb N/hr
- **Replication : 3**
- **Design : fully randomised split plot**

The *Trangie Rotaflow* Mark III distributor was connected to a Continental C4100 Metermatic meter. Eight outlets were used for each hosetail size, either 7.6mm or 1/16inch (as supplied by Incitec Fertilizers). Hosetails were evenly spaced around the perimeter of the distributor and were connected via 4.43 meter long, 3/8inch I.D. distribution lines to the collection drums.

## DETAILED RESULTS (including statistical analysis of results)

### 1. Comparison between final Trangie prototype and Continental RPR- December 7-8, 16-18, 1997

#### Results and discussion

##### **Flow Rate**

At all flow rates passed through 6-, 8- or 12-row distribution systems, highly significant differences ( $Pr=0.001$ ) were found between distributors. Distribution efficiency was expressed as either coefficient of variation (see Figure 1), maximum row-to-row differences (Maximum RTR = Maximum outlet weight / Minimum outlet weight) (see Figure 2) or mean variation (data not shown). In keeping with previous tests conducted with only 8 row distribution systems, the distribution efficiency improved as flow rate increased across all distribution systems. Indeed at flow rates above 1000 lb  $NH_3/hr$ , typical of field application rates, the coefficient of variation and maximum row-to-row difference were less than 15% and 50% for the Trangie prototype respectively, compared to nearly 40% and 85% for the Continental RPR. Below a flow rate of 1000 lb  $NH_3/hr$ , the distribution efficiency increased markedly on some occasions.

##### **Tank pressure**

At all tank pressures in either 6-, 8- or 12-row distribution systems, significant differences ( $Pr=0.05$ ) were found in distribution efficiency between distributors. Distribution efficiency was expressed as either coefficient of variation (see Figure 3), maximum row-to-row differences (see Figure 4) or mean variation (data not shown). The distribution efficiency generally improved as flow rate increased for the Trangie prototype, but was typically worse at high flow rates for the Continental RPR, indicating a potentially different operating principle for the Trangie prototype that is not as pressure dependent.

##### **Manifold pressure**

Figures 5 and 6 display respectively the coefficient of variation and maximum variations in the row-to-row differences as a function of manifold pressure for both the Continental 4100 RPR manifold and the Trangie prototype distributor. The data is further broken down into simulated implement size, either 6-, 8- or 12- row systems. The data clearly shows that at any manifold pressure, the distribution efficiency, expressed as either coefficient of variation of flow or maximum row-to-row variation, of the Trangie prototype is significantly better ( $Pr=0.05$ ) than that of the Continental RPR. Whilst this difference is perhaps not as marked at lower pressures, it is highly visible when the manifold pressure is greater than 10 psi (70 kPa). At this point, row-to-row differences are less than 40% in most circumstances and coefficients of variation generally average less than 10% and more commonly are around 6-7% of flow rate.

Incitec Fertilizers have recommended that when using the C-RPR that the manifold meant that orifices were required to be inserted in the hose tails to increase the back-pressure in the manifold. This data tends to verify the need for this recommendation, with row-to-row differences falling from over 160% to, on average, around 60% in this recommended range. However, the Trangie prototype behaves differently, in that there is insignificant variation in the distribution efficiency over most of the manifold pressure range, suggesting that there is no need to use orifices in hose tails. The only exception to this is when manifold pressures are below 10 psi, where distribution inefficiency tends to increase reasonably sharply.

### **Rotor speed**

Some commercial companies, including H.I. Fraser Pty Ltd, had shown interest in the possibility of being able to predict and monitor anhydrous ammonia flow rate during field application, given real time rotor speed and other operating data. An attempt was therefore made to correlate rotor speed data to other operating data for this experiment. The correlations were found to be extremely variable and the idea of developing a monitor based on this principle was therefore dismissed.

### **Conclusions**

In this experiment, the Trangie prototype has shown that its operating principles can accommodate a range of operating conditions, typical to that which it would experience under field conditions. Distribution efficiencies remain remarkably low compared to the Continental RPR manifold, giving increasing confidence that the design is robust and the distributor is worth pursuing as a commercial entity.

## **2. Comparison between H.I. Fraser Mark I design and final Trangie prototype - November 10-17, 1998**

### **Results and discussion**

The H.I. Fraser Mark I manifold had less increase in drum weight (ie less anhydrous ammonia was allowed through the manifold) at both the 1000 and 2000 lbN/hr but a greater increase in drum weight at the 3000 lb N/hr flow rate than the Trangie prototype.

**Table 1 - Effect of flow rate and manifold type on average drum increase.**

<b>Flow Rate (lb N/hr)</b>	<b>H.I. Fraser Mark I (kg/drum)</b>	<b>Trangie prototype (kg/drum)</b>
1000	0.80	0.92
2000	1.90	2.16
3000	2.75	2.65

The H.I. Fraser Mark I manifold exhibits much less distribution variation than the Trangie prototype at both the 1000 and 2000 lbN/hr but not at the 3000 lb N/hr flow rate.

**Table 2 - Effect of flow rate and manifold type on distribution variation**

<b>Flow Rate (lb N/hr)</b>	<b>H.I. Fraser Mark I (CV%)</b>	<b>Trangie prototype (CV%)</b>
1000	7.9	23.1
2000	4.7	13.1
3000	5.6	5.3

### **Conclusions**

It is recommended that the new design, ie the H.I. Fraser Mark I be accepted as the manifold to take to commercial production based on its generally superior distribution efficiency over the wider range of flow rates.

### 3. Effect of hosetail intrusion distance on distribution performance of *Trangie Rotaflow* Mark III - September 21-23, 1999

#### Results and discussion

Results from the experiment are presented in Tables 4 and 5, which show the coefficient of variation (CV) and row to row ratio (RTR) for the various treatments. Figure 7 displays the relative effect of hosetail intrusion on hosetail flow properties. The results are a depleted set, with data from collection drum R3 removed. The load cell on this drum was found to have given false (lighter than expected) readings due to a physical interaction between the plug actuator and the plug rod. Calculations with R3 data included made no difference to the overall outcome or conclusions, although it did enlarge the overall CV and RTR values.

Tables 4 and 5 data indicate that there is no effect of hosetail intrusion on distribution performance (*ie* the null hypothesis holds). The results, presented in either CV or RTR form, indicate that for the two positions where hosetails intruded into the delivery chamber (Positions 1 and 2), the performance was very similar to the control (Position 3) performance. The differences were not statistically significant (data not shown).

The effect of flow rate on performance is typical of previous experiments where both the CV and RTR values are seen to diminish with increased flow rates. Indeed CV and RTR results at 3000 lb N/hr are extremely low (5-8% and 121-132% respectively). Results at 2000 lb N/hr are also quite reasonable, but the results at the lowest flow rate of 1000 lb N/hr indicate that there is room for improvement.

However, whilst the overall effect of hosetails intruding to various degrees was negligible, it would appear from Figure 7 that there is some interaction between hosetails and their relative intrusion distance.

The results from Position 1 indicate that those hosetails fitted flush allowed a similar flow to those intruding 4.5 mm, whereas those intruding 1.6 and 3 mm received similar flows, but lesser than the aforementioned. In Position 2, the situation altered, with greater flows resulting from greater intrusion, except for flush hosetails, which received similar flows to those intruding 3mm. This result, whilst interesting, does not bear further investigation at this stage.

#### Conclusions

The experiment, whilst limited in its range of variables, covered a number of potential scenarios for field application with the *Trangie Rotaflow* Mark I. The results suggest the principles behind the distributor performance are quite robust, capable of handling a range of manufacturing variables without dramatic effect on distribution variability. It could be assumed that there would therefore be no adverse effect of variable hosetail intrusion on field application distribution variability of anhydrous ammonia and therefore no adverse effect on crop growth.

The results indicate however that there is a need to investigate a means of reducing the distribution variation at lower flow rates. These continue to be much higher than those able to be achieved at the lower flow rates, although still significantly better than those being achieved using alternative manifold systems.

Location	Hosetail Penetration Distance (mm)		
	Position 1	Position 2	Position 3
1	1.6	4.5	0
2	0	0	0
3	4.5	0	0
4	1.6	1.6	0
5	0	0	0
6	0	3	0
7	0	0	0
8	3	3	0
9	4.5	0	0
10	0	0	0
11	3	4.5	0
12	0	1.6	0

Position	Flow Rate	Rep 1	Rep 2	Rep 3	Mean	Overall Mean
1	1000	13	12	18	14	10
	2000	6	13	8	9	
	3000	7	8	6	7	
2	1000	13	11	22	15	11
	2000	10	9	9	9	
	3000	8	7	7	7	
3	1000	17	14	17	16	10
	2000	10	4	9	8	
	3000	6	5	7	6	

Position	Flow Rate	Rep 1	Rep 2	Rep 3	Mean	Overall Mean
1	1000	146	140	215	167	144
	2000	119	170	128	139	
	3000	128	130	121	126	
2	1000	151	144	205	167	142
	2000	133	137	131	134	
	3000	132	124	124	127	
3	1000	201	154	172	176	144
	2000	153	113	134	133	
	3000	124	121	123	122	

#### 4. Effect of *Trangie Rotaflow* on metering and distribution performance of Raven SCS and ACCUFLOW System - October 7, 1999

##### Results and discussion

- **Flow rate**

Figure 8 shows a graph of application rate setting (kg/ha) versus actual flow rate (kg NH<sub>3</sub>/hr). The data shows a strong correlation between setting and actual flow rate for both the *Trangie Rotaflow* and the Continental manifolds;  $R^2=0.9597$  and  $0.9598$  respectively. It could therefore be assumed that the distributor has little bearing on the overall metering rate performance of the Raven system. It is however interesting to note the *Trangie Rotaflow* regression line passes through the Y-axis closer to zero (-22.15 compared with -37.8), indicating that the Raven, when connected to the *Trangie Rotaflow*, is responding more quickly to the "On" signal than when connected to the Continental.

- **Pressure**

Figure 9 shows the relationship between tank pressure and manifold pressure (as measured at the outlet of the manifold or distributor). Little difference exists between the two distribution systems in terms of manifold pressure, ie the *Trangie Rotaflow* could be considered to offer the same level of resistance (back pressure) to the flow of anhydrous ammonia as the Continental manifold. Of concern is however the level of manifold pressure given the high tank pressures of > 120 psi. Manifold pressures were all less than 25 psi and some as low as 1 psi, the lowest typically being with the *Trangie Rotaflow*. Given the desired operating range of manifold pressure, as stated by Incitec Fertilizers, is between 25-40 psi and ideally greater than 10 psi, to achieve more even distribution, the results for distribution variation may well have been improved if hose tail inserts had been used to increase flow resistance.

- **Rotor speed**

Rotor speeds varied between 922 and 1415 rpm for the range of flow rates but a very poor correlation was shown to exist between the 2 variables ( $R^2 = 0.1974$ ), even when runs at low flow rates were removed ( $R^2=0.6624$ ). This is consistent with previous data from runs with the *Trangie* prototype and *Trangie Rotaflow* connected to the Continental 4100C meter. This poor relationship therefore cannot be construed as being a unique feature of the Raven controller system. It is considered that the issues of manifold temperature and respective proportions of liquid and vapour anhydrous ammonia will have a bearing on the rotor speed, in addition to flow rate and tank pressure.

- **Distribution variation**

Significant differences ( $P=0.05$ ) were found between the distribution patterns of the *Trangie Rotaflow* and the Continental manifold at all flow rates.

**Table 6: Anhydrous ammonia output variability of manifold outlets on an 8-row applicator.**

Treatment	Coefficient of Variation (%)	Average % outlet difference	Maximum difference ratio
Continental A-6006B manifold	24a	15a	2.13a
Trangie Rotaflow	14b	8b	1.53b

Values in each column followed by a different letter are significant at the  $\alpha = 0.05$  level  
 Average difference of outlet from mean of outlets expressed as a percentage of the mean  
 Maximum difference ratio = maximum outlet weight/minimum outlet weight

**Table 7 : Coefficient of Variation**

Distributor	Flow Rate (kg N/ha)	Rep	Coefficient of Variation (%)	Flow Rate Mean	Overall Distributor Mean	Overall Distributor Mean (-Rep 2 @120 kg N/ha)
HIF	40	1	18			
		2	24			
		3	15	19		
	80	1	10			
		2	21			
		3	12	14		
	120	1	8			
		2	19			
		3	15	14		
160	1	7				
	2	12				
	3	10	10	14	14	
Cont Red	40	1	18			
		2	38			
		3	15	24		
	80	1	36			
		2	22			
		3	28	28		
	120	1	27			
		2	64			
		3	28	40		
160	1	19				
	2	20				
	3	14	18	28	24	

HIF = H.I. Fraser Trangie Rotaflow; Cont Red = Continental A-6006B manifold

Table 8 : Row-To-Row ratio							
Distributor	Flow Rate (kg N/ha)	Rep	RTR Ratio	Flow Rate Mean	Overall Distributor Mean	Overall Distributor Mean (-Rep 2 @120 kg N/ha))	
HIF	40	1	1.64				
		2	1.95				
		3	1.58	1.73			
	80	1	1.36				
		2	1.88				
		3	1.38	1.54			
	120	1	1.27				
		2	1.71				
		3	1.61	1.53			
160	1	1.23					
	2	1.45					
	3	1.30	1.33	1.53	1.53	1.53	
Cont.Red	40	1	1.55				
		2	2.73				
		3	1.73	2.00			
	80	1	4.42				
		2	1.72				
		3	2.23	2.79			
	120	1	1.98				
		2	5.04				
		3	2.08	3.04			
160	1	1.75					
	2	1.77					
	3	1.49	1.67	2.37	2.37	2.13	

HIF = H.I. Fraser *Trangie Rotaflow*; Cont Red = Continental A-6006B manifold

### Conclusions

In terms of distribution efficiency, the *Trangie Rotaflow* has performed significantly better than the Continental A-6006B manifold, when in combination with the Raven system. It is therefore recommended that where Raven Controller Systems are fitted to application equipment that the *Trangie Rotaflow* be used as the standard distribution manifold.

It would be reasonably safe to assume that given the similar operating principles employed by other anhydrous ammonia controller systems, ie the MicroTrak and DICKEY john systems, that the *Trangie Rotaflow* could also be used as the standard distributor for these devices. Overall metering and distribution performance should be improved when these devices are used in combination.

5. Effect of hosetail size on distribution performance of *Trangie Rotaflow* Mark III -  
November 12, 1999

Results and discussion

Greg Rigby of Incitec Fertilizers had indicated the use of 1/16inch orifice size is recommended for use at low flow rates with Continental 4100C meters and RPR manifolds. It was therefore assumed that this would be the case for the *Trangie Rotaflow* when operating at low flow rates. However, following the first run of the experiment using 1/16inch hosetails, the performance of the *Trangie Rotaflow* distributor was not as expected. Indeed variation was extremely high and as a result, the experimental schedule was abandoned and an ad-hoc process to investigate various alternatives was used.

Results from these ad-hoc runs are presented in Table 9 and Figures 10-13, which show the Coefficient of Variation ( $CV = \text{Mean weight} / \text{standard deviation}$ ) and Row-To-Row ratio ( $RTR = \text{Maximum outlet weight} / \text{Minimum outlet weight}$ ) for the various flow rates and lengths of run time.

The effect of flow rate was as expected with distribution variation (both CV and RTR) generally being greater (worse) the lesser the flow rate. CV's were generally less than 10% for the 7.6mm and 3.5mm hosetails whereas they were generally as high as 30% for the 1/16 inch hosetails. RTR's were again very similar at all flow rates for the 7.6 and 3.5mm hosetails (20-35% range), whereas they were substantially higher for the 1/16 inch hosetails (well over 100% for all runs). There were some exceptions to these results but these could be considered abnormal as run-time was substantially less than normal.

The effect of run-time on variation is notable. The longer the run at each flow rate, the less overall variation. For the *Trangie Rotaflow*, this has some interesting consequences. All conclusions from results gleaned from previous experiments have been based on 45-60 sec runs. These runs may have given an indication that variation was actually higher than expected in the field when runs are obviously much greater than our normal laboratory run times. Variation indeed may be at acceptable levels at these low flow rates and indeed some of the results from the runs from this experiment suggest this to be the case.

Figure 14 shows the effect of hosetail size on manifold pressure. The small 1/16inch orifices performed very differently when inserted in the *Trangie Rotaflow*. Whilst they increased manifold pressure as expected, they also have the capacity to stall the rotor as well as produce highly variable output. Manifold pressure does not appear in itself to effect distributor variation.

Conclusions

The experiment, although not going as originally planned, showed some interesting features of the various systems used. The experiment showed run-time was indeed an important issue, with longer runs producing less variation. It is therefore recommended that for future experiments all runs be as long as possible *ie* as long as the drums will allow before over-flowing.

Hosetail size was also important. There appears to be little difference in variation performance between 7.6mm hosetails and 3.5mm hosetails. Given that the large hosetails are already in use and work very well at higher flow rates, it is currently recommended that the large hosetails be used at all times for all flow rates. There may however be some virtue in further investigating sizes between 7.6 and 3.5 mm at a later date.

It is strongly recommended that small orifice sizes (eg 1/16 inch) not be used in the *Trangie Rotaflow* distributor under any circumstances.

High manifold pressure does not appear to be the driving force behind the degree of variation. Indeed acceptable variation was achieved with the *Trangie Rotaflow* at manifold pressures of 2-5 psi. A previous conclusion that manifold pressure for the *Trangie Rotaflow* be maintained above 10 psi is therefore declared unnecessary.

**Table 9 : Pressure and distribution differences for various orifice sizes and flow rates**

Flow rate (lb N /hr)	Orifice size	Run time (sec)	CV (%)	RTR (%)	Tank Pressure (psi)	Manifold pressure (psi)
317	1/16"	15	240	-296	109.91	44.77
750	1/16"	120	30	141	108.79	83.16
952	1/16"	120	28	127	104.57	90.14
952	1/16"	120	336	-144	104.09	88.40
952	1/16"	120	31	153	103.97	88.41
952	1/16"	120	30	130	103.95	88.64
750	3.5 mm	120	7	25	110.06	19.75
1500	3.5 mm	75	6	21	107.31	48.75
2250	3.5 mm	45	7	22	105.57	29.14
3000	3.5 mm	34	16	76	104.81	19.45
317	7.6 mm	15	115	-388	106.97	2.42
317	7.6 mm	30	44	292	107.16	2.66
317	7.6 mm	45	10	35	106.77	2.58
317	7.6 mm	120	7	28	105.46	4.83
317	7.6 mm	120	9	35	106.04	2.16
317	7.6 mm	120	18	97	108.20	1.39
317	7.6 mm	120	7	26	108.34	2.11
750	7.6 mm	240	7	24	108.01	7.48
952	7.6 mm	120	14	66	104.11	9.48
3000	7.6 mm	38	7	30	105.45	7.27

## DESCRIPTION OF PROJECT TECHNOLOGY

### Patents applied for:

Neville Gould and Pat Weldon, "Anhydrous ammonia distributor", United States of America Patent Registration No. 6003534 issued 21 December 1999.

Neville Gould and Pat Weldon, "Anhydrous ammonia distributor", Australian Standard Patent Application No. 12634/97, Serial No 719453 issued 17 March 2000.

Neville Gould and Pat Weldon, "Anhydrous ammonia distributor", Canadian Standard Patent Application No. 2,197,344, Applied for on 9 May 1997.

### Patents granted:

Neville Gould and Pat Weldon, "Anhydrous ammonia distributor", United States of America Patent Registration No. 6003534 issued 21 December 1999.

Neville Gould and Pat Weldon, "Anhydrous ammonia distributor", Australian Standard Patent Application No. 12634/97, Serial No 719453 issued 17 March 2000.

### Licences

A manufacturing licence has been issued by NSW Agriculture to H.I. Fraser Pty Ltd, Unit 6/5 Vuko Place, Warriewood, NSW.

### Commercially significant developments

- **Trangie Rotaflow distributor**

The *Trangie Rotaflow* distributor (see brochure attached) is being manufactured by H.I. Fraser Pty Ltd and distributed by Incitec Fertilizers. Over 100 units have been sold to date in Australia, mainly to cotton growers in NSW and Qld, for use in their cotton, and other summer and winter crop production. Interest has however also been shown by graingrowers.

H.I. Fraser Pty Ltd are currently looking at the potential markets of USA and Canada and have held encouraging talks with potential outlets in the USA. Comparative field research conducted in the USA in August and November 1999 by Dr Mark Hanna from Iowa State University, under varying field and weather conditions, showed that the *Trangie Rotaflow* manifold "generally had application variation across the toolbar lower than the modified forms of the conventional manifold". The year 2000 Iowa crop season will allow the first chance for yield measurements to look at the effect of application uniformity on row crop production.

- **World-class anhydrous ammonia measurement facility**

In addition to this major distributor development has been the development of a world-class anhydrous ammonia measurement facility. This facility has allowed the accurate measurement of both flow and distribution of anhydrous ammonia in a controlled atmosphere environment. It has also allowed a range of operating parameters within the various systems to be rigorously tested. With the closure of the project, this system has now been decommissioned at the Agricultural Research Centre at Trangie.

## TECHNICAL SUMMARY OF ANY OTHER INFORMATION DEVELOPED AS PART OF THE RESEARCH PROJECT

Additional experimentation was conducted as part of the project. The information developed from this experimentation has been provided in the main body of the report.

## RECOMMENDATIONS TO FURTHER DEVELOP OR EXPLOIT THE PROJECT TECHNOLOGY

A number of possibilities have been discussed between NSW Agriculture, H.I. Fraser Pty Ltd and Incitec Fertilizers to further develop or exploit the *Trangie Rotaflow*, namely:

- **Sale of *Trangie Rotaflow* into USA, Canada and Europe**

The future sale price and further development of the *Trangie Rotaflow* is partially contingent on the ability of H.I. Fraser Pty Ltd to increase its market opportunities. Larger markets for anhydrous ammonia equipment already exist in the USA, Canada and elsewhere and as recent USA research shows (see attached journal paper), the *Trangie Rotaflow* is better than most, if not all, technology currently available on the USA market.

- **Continued joint research with Mark Hanna (Iowa State University) and Dr Mark Schrock (Kansas State University)**

Prior to the initiation of the research by NSW Agriculture, very little research was conducted around the world into improving anhydrous ammonia distribution equipment. Recently two major institutions in the USA have undertaken field-based research and development which has led to alternative (untested) technologies as well as very good reports regarding the field use of the *Trangie Rotaflow*. Continued involvement with these organisations may not only assist in the potential acceptance and purchase of the *Trangie Rotaflow* by the USA and Canadian markets but may also lead to other developments.

- **Development of a flow monitor to detect blockages or flow inequalities in the field**

In the event that a problem occurs in the application system such that unequal flow develops, such as with a plumbing problem or a partially kinked or blocked distribution hose, a monitoring system which is able to detect and alert the operator is required. A cheaper, secondary option is a device which could be installed by roving technicians which enabled systems to be checked intermittently in the field.

- **Further investigation of the potential to use unequal hose lengths for lateral distribution of anhydrous ammonia.**

A major set-up cost and operational impediment is the need currently to use equal length distribution hoses to each row. Initial attempts to investigate distribution hoses of unequal length (in combination with other technologies) during this project failed due to problems with the measurement equipment. The opportunity to find and secure a system which allows easier and cheaper plumbing of anhydrous ammonia rigs (especially on broadacre cropping equipment with many more distribution hoses than on row-crop equipment) would be invaluable to the industry.

- **Broadacre application systems**

The current *Trangie Rotaflow* has only 24 outlets and, as such, is more suited to row crop applications. In order for it to be used more widely in a broadacre cropping application role, an alternative arrangement which would enable distribution up to say 50-60 outlets may be required. The options are numerous, including multiple distributors (at the same distribution level), multiple distributors (in a network "tree") or even a more primitive flow splitting arrangement (such as a "T" piece). These alternatives need to be researched and developed in order to assess both practicality and distribution efficiency.

## ATTACHMENTS

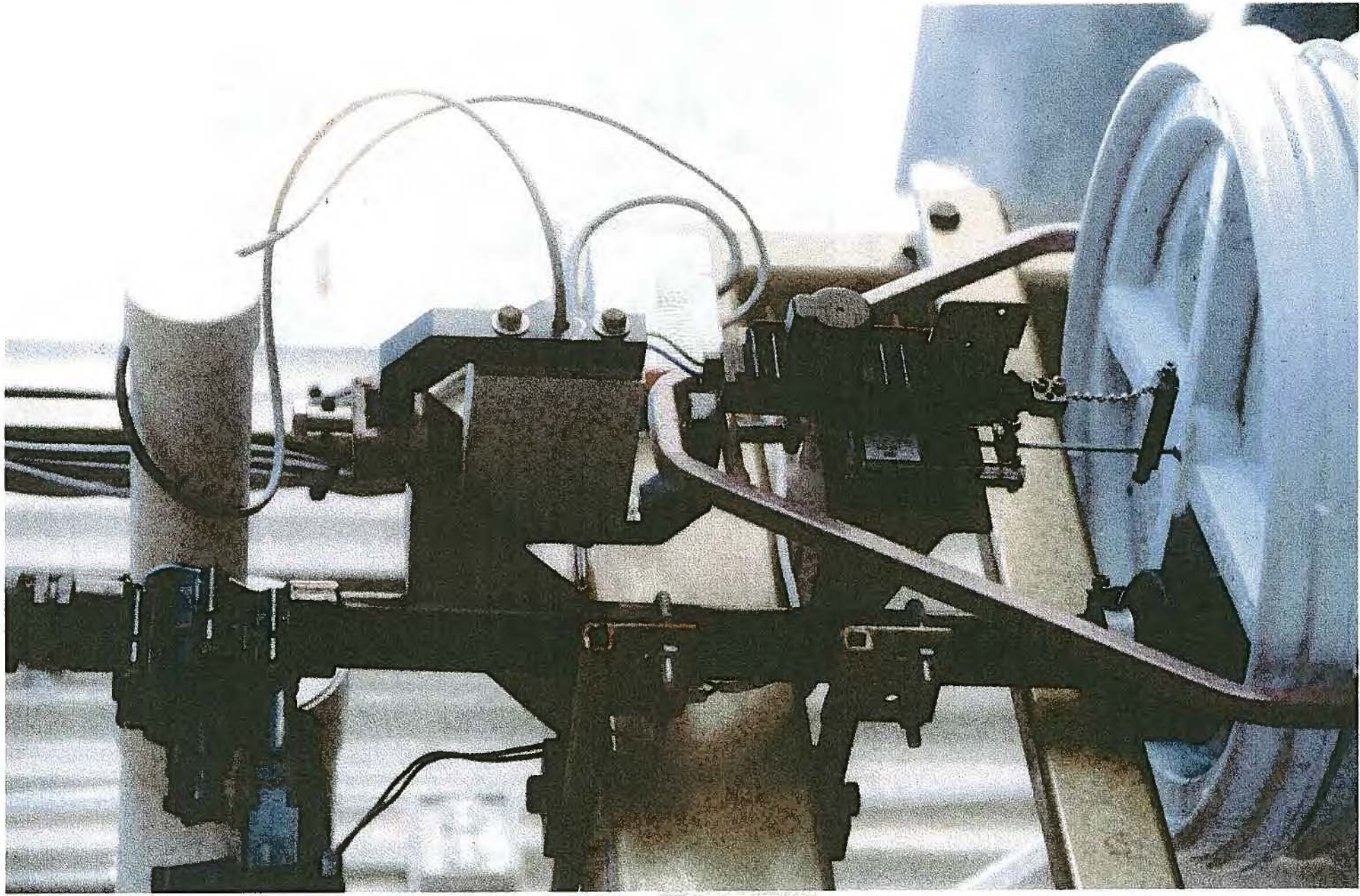
1. Neville Gould and Pat Weldon, **New distributor solves problems in anhydrous application.** *Leading Edge* September-October-November 1998, pp3-4
2. N. Gould, P. Weldon and A. Palmer. **Aussies solve flow rate problems.** *Power Farming* Volume 108 No 5 (1999) pp 22-23.
3. Gould, N.S., Weldon, P.A. and Palmer, A.L.(1998). A new distributor for field application of anhydrous ammonia. 1998 International Conference on Engineering In Agriculture, Perth WA, Paper No SEAg 98/035.
4. Hanna, H. Mark, Colvin, Tom S., White, Michael L. and Baker, James L. (2000). **Reducing anhydrous ammonia application by optimizing distribution - a summary of 1999 experimental results.** Iowa State University Internal Report. January 2000.
5. *Trangie Rotaflow*, sales brochure produced by H.I. Fraser Pty Ltd.



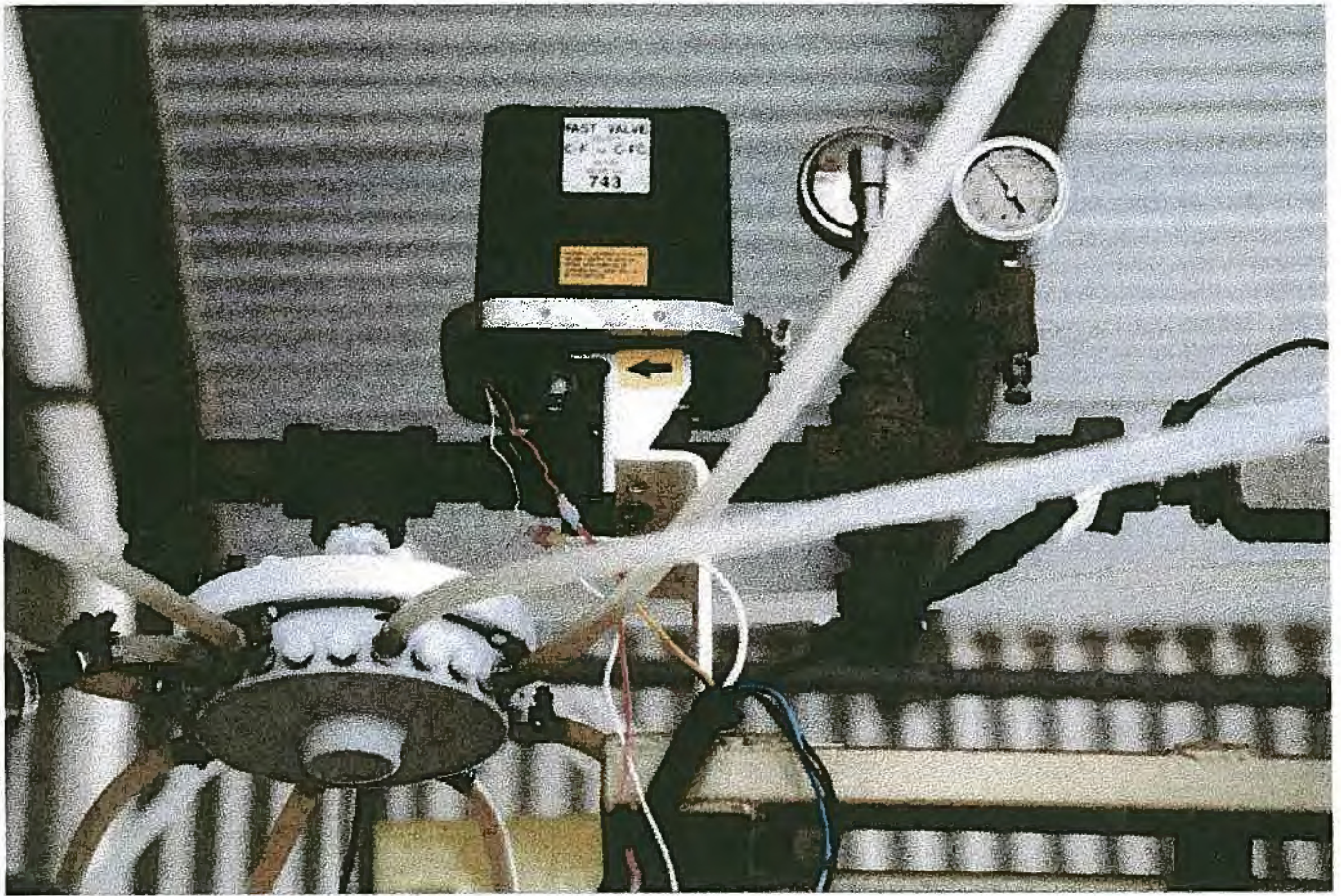
The modified anhydrous ammonia research facility at Trangie Agricultural Research Centre, showing the applicator tank (placed in the cool room to enable tank pressures to be controlled) and the drum collection system.



Drum collection system consisting of 12 30-litre drums mounted on load cells.

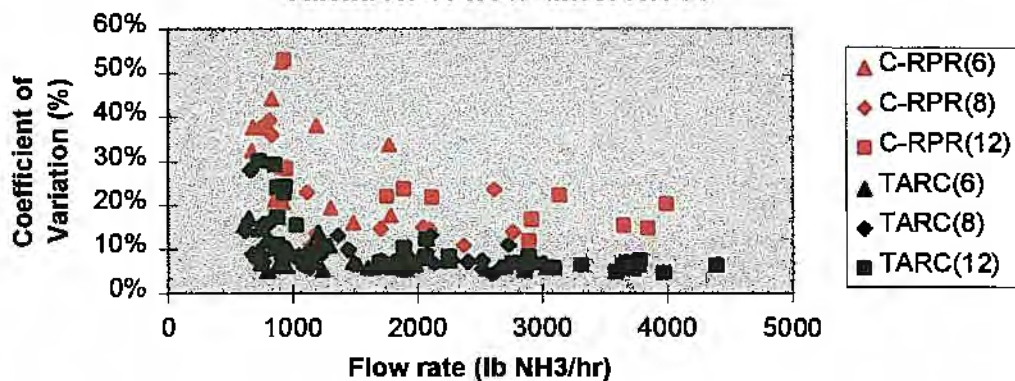


Each drum was instrumented with a load cell.

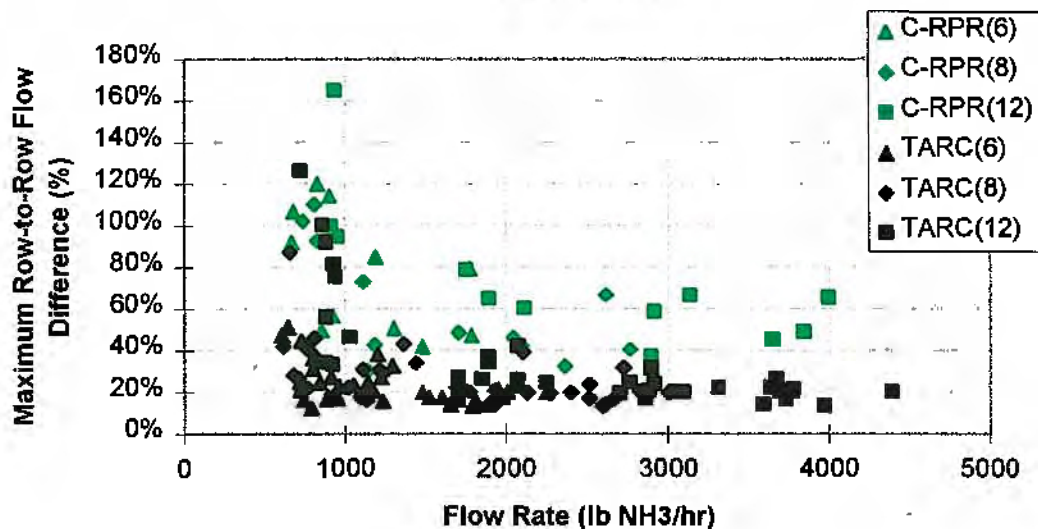


The *Trangle Rotaflow* connected to a Raven Controller System during experimentation at Trangle Agricultural Research Centre.

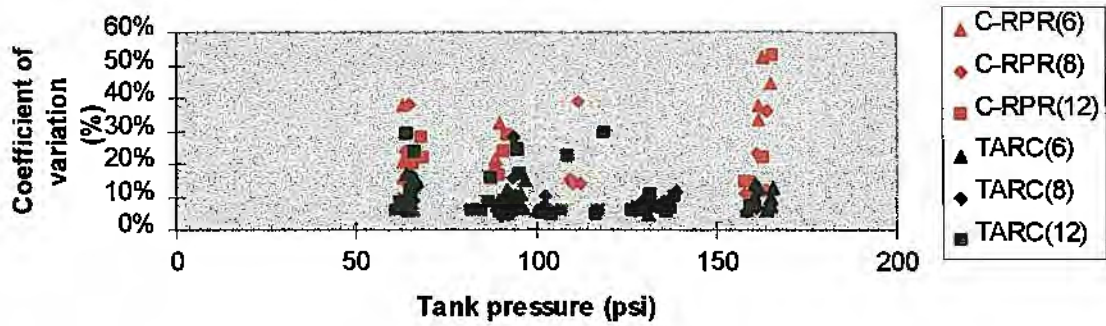
**Figure 1 - Effect of flow rate on coefficient of variation of flow differences**



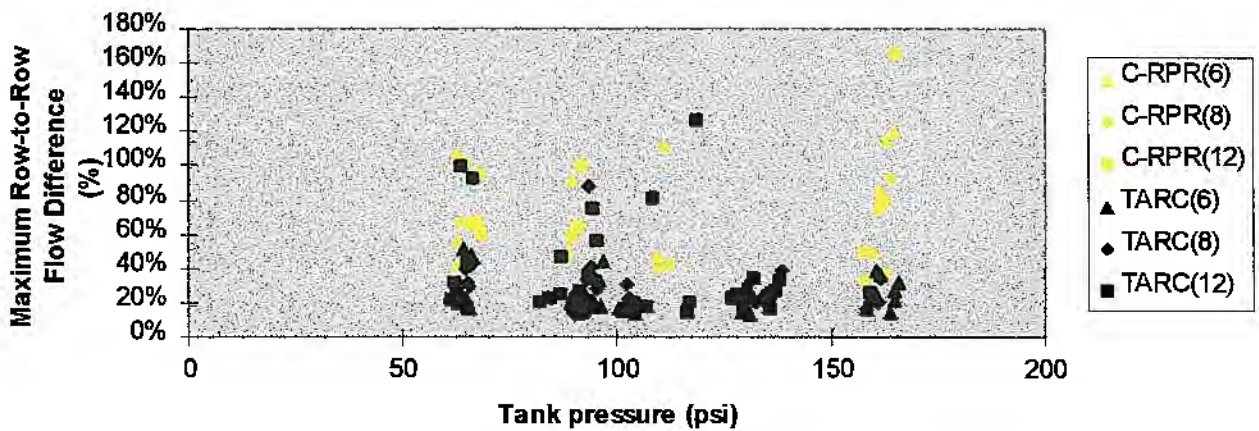
**Figure 2 - Effect of flow rate on maximum row-to-row flow differences**



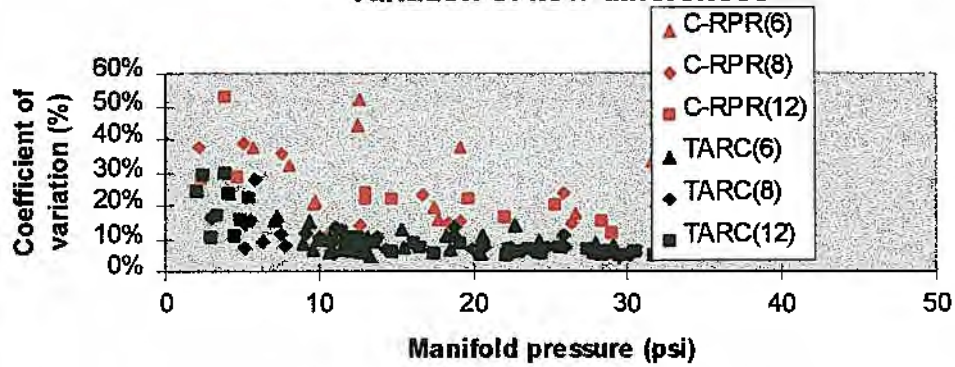
**Figure 3 - Effect of tank pressure on co-efficient of variation of flow differences**



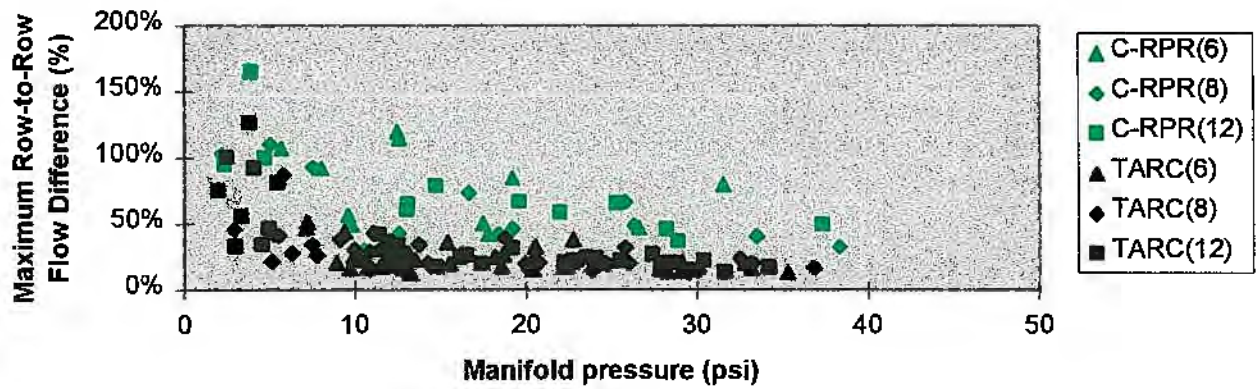
**Figure 4 - Effect of tank pressure on maximum row-to-row flow differences**



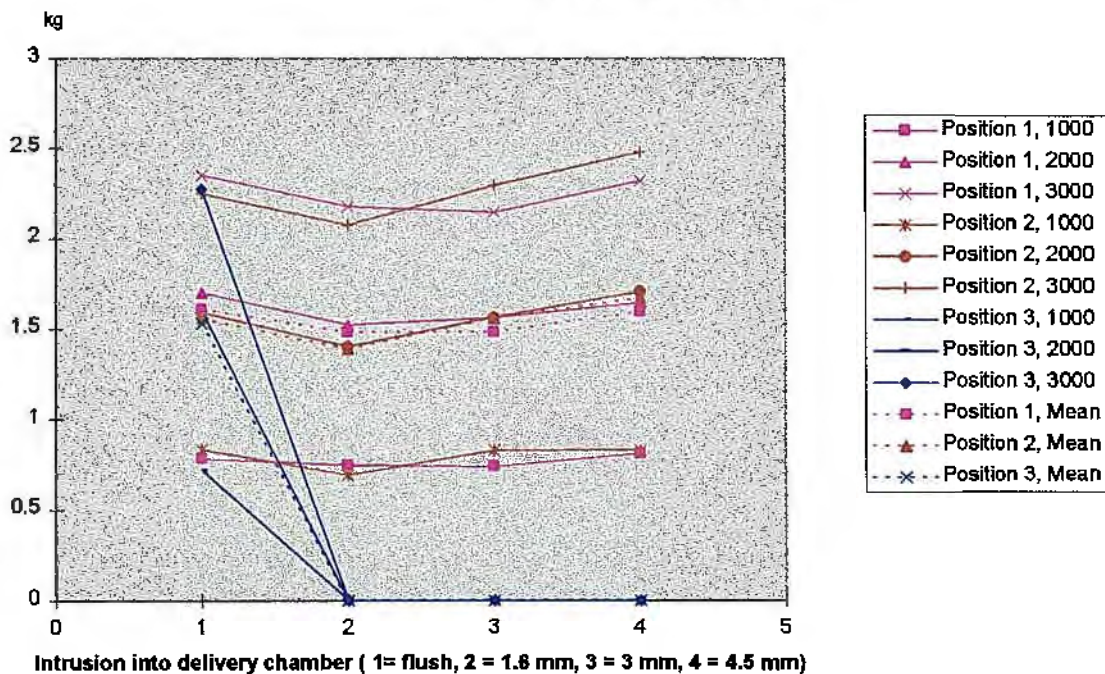
**Figure 5 - Effect of manifold pressure on coefficient of variation of flow differences**



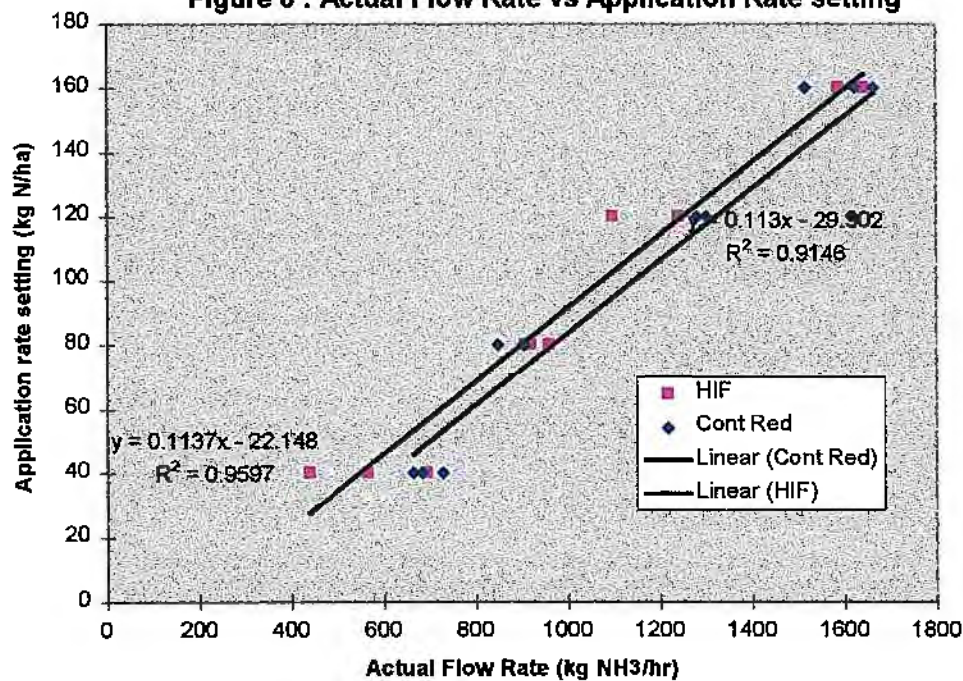
**Figure 6 - Effect of manifold pressure on maximum row-to-row flow differences**



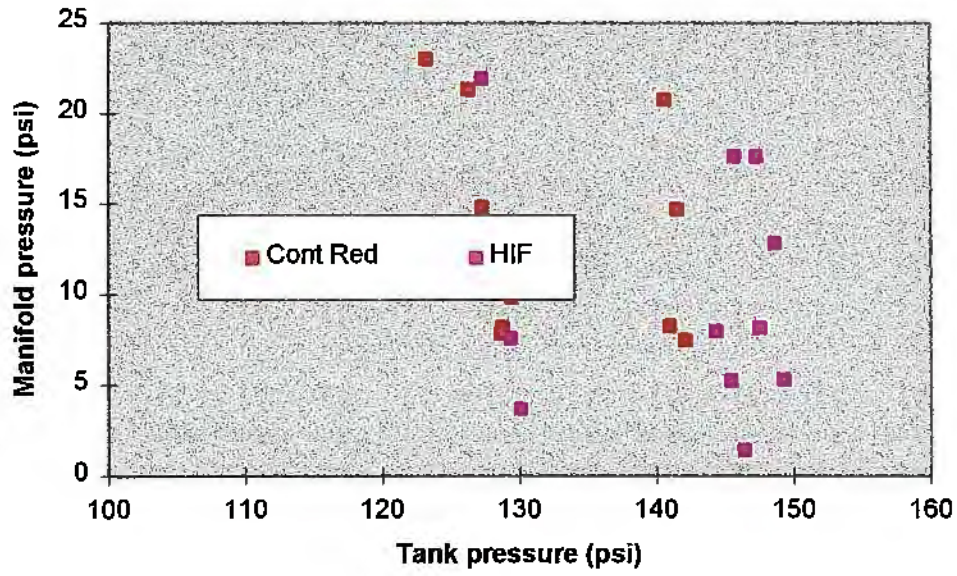
**Figure 7 : Drum weight change (kg) vs depth of hosetail intrusion (mm)**



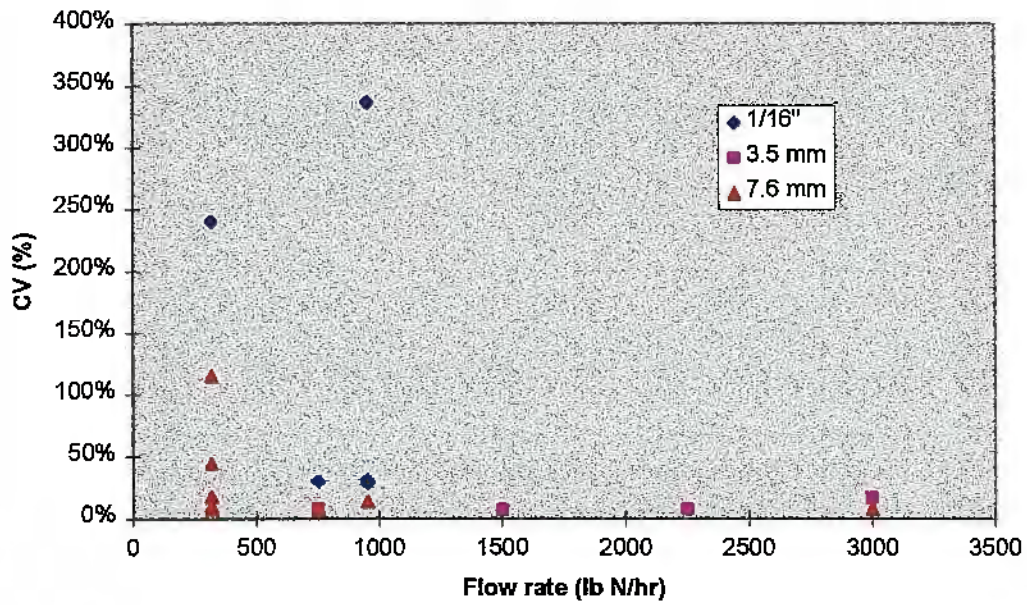
**Figure 8 : Actual Flow Rate vs Application Rate setting**



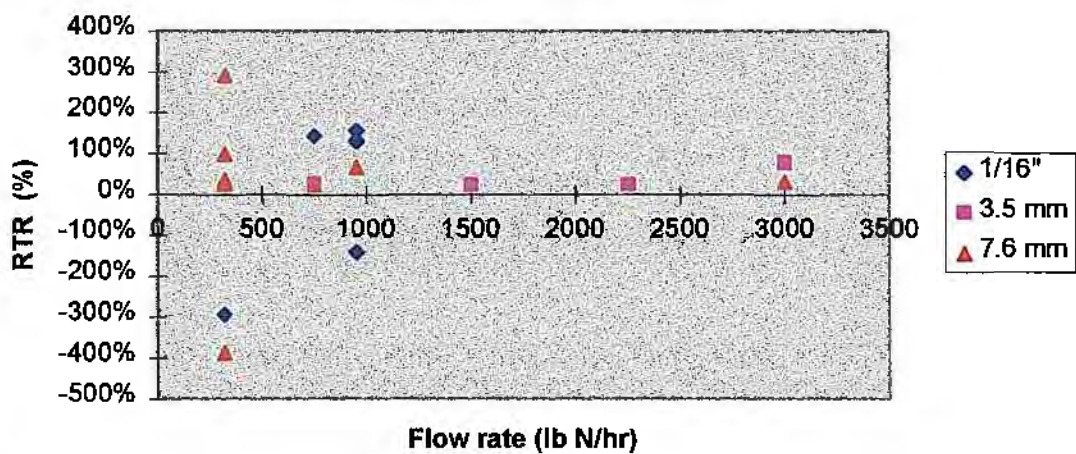
**Figure 9 : Tank Pressure vs Manifold pressure**



**Figure 10: Effect of flow rate and orifice size on distribution variation**



**Figure 11: Effect of flow rate and orifice size on distribution variation**



**Figure 12: Effect of run time on distribution variation**

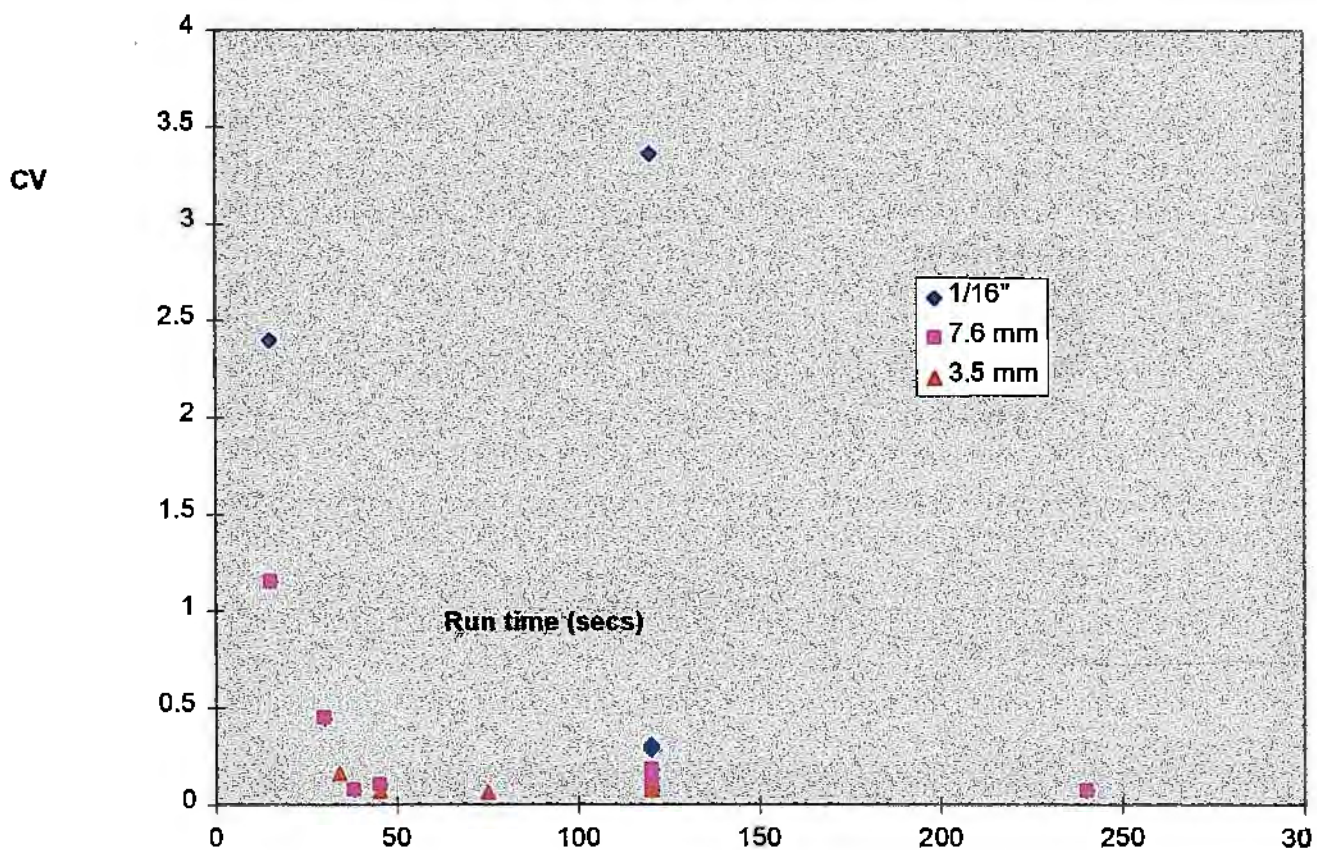


Figure 13: Effect of run time on distribution variation (RTR)

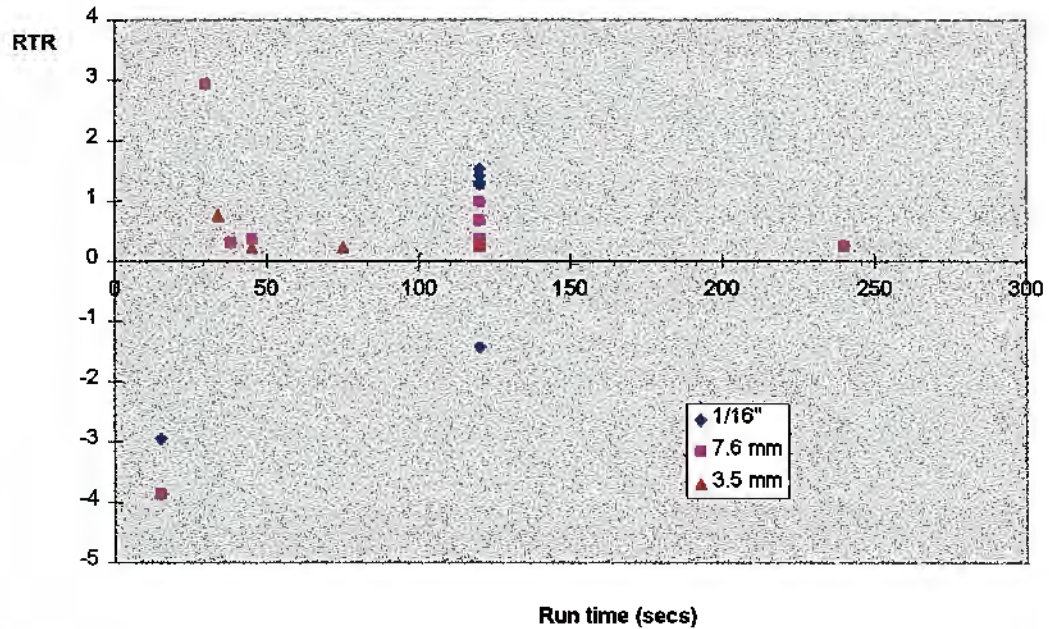
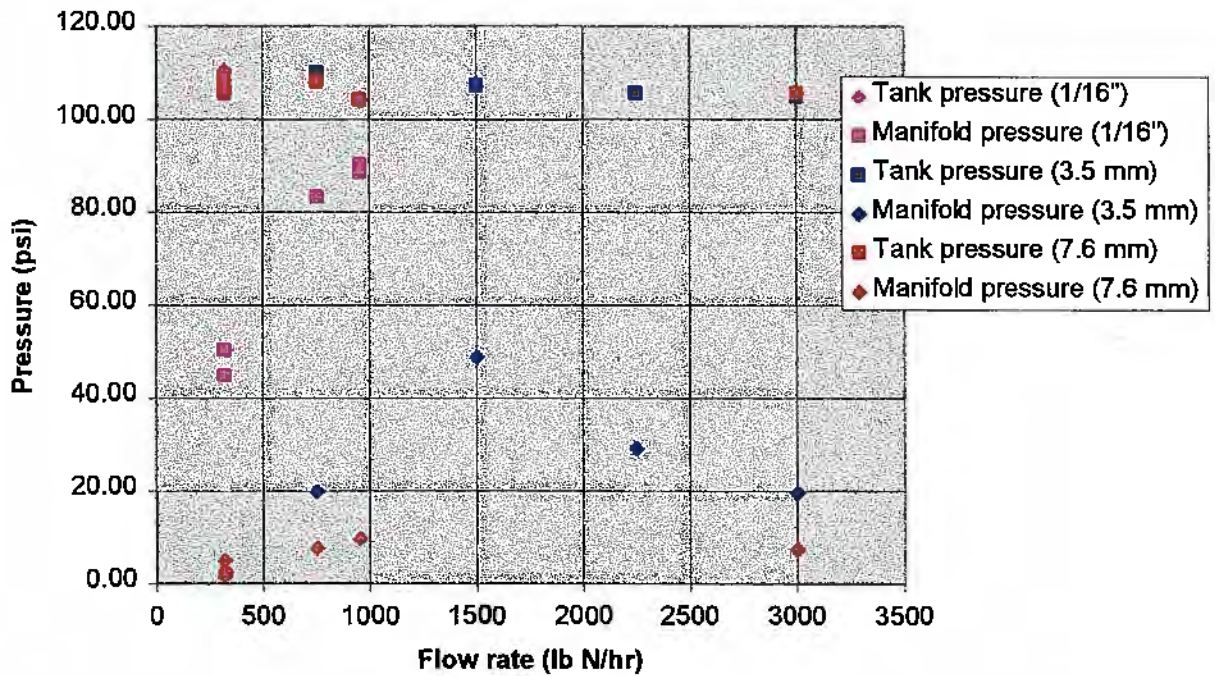


Figure 14: Tank and manifold pressure as a function of orifice size and flow rate



## Part 4 - Final Report Plain English Summary

You must submit a Plain English Summary of your completed research project that is not commercial in confidence, and that can be published by the Cotton Research & Development Corporation in print or on the world wide web. An electronic copy of the Plain English Summary must also be forwarded by E-mail ([angela@crdc.org.au](mailto:angela@crdc.org.au)).

The distribution of anhydrous ammonia across application toolbars onto agricultural crops, particularly cotton, had been highlighted as a major industry problem in recent times, especially in Australia and the USA. Research into other metering and distribution problems related to anhydrous ammonia had taken precedence since it was first applied in 1935. This research project however has allowed the problem of poor and highly variable distribution to be addressed in a practical fashion, resulting in the development of a new anhydrous ammonia distributor, the *Trangie Rotaflow*. The new distributor has reduced lateral variability to more acceptable levels, in most cases less than half that of other commercial manifolds. This has been verified not only in tests performed by NSW Agriculture at Trangie but also in the field by Iowa State USA researchers, where comparisons between conventional technology and the *Trangie Rotaflow* have been performed.

The distributor is now patented in Australia and the USA, with an application still outstanding in Canada. The distributor is being manufactured by H.I. Fraser Pty Ltd in Warriewood, Sydney and being marketed and supported in Australia through Incitec Fertilizers outlets. Marketing opportunities are currently being sought overseas, particularly in the USA. Over 100 distributors have been sold in Australia, with results from the 1999/2000 crop being particularly exciting. No striping has been found on any area where the *Trangie Rotaflow* has been used, whilst many adjacent areas where conventional technology has been used has resulted in "huge" striping differences. Accrued benefits include decreased costs due to reduced N applied and better uniformity leading to easier crop management. Growers using this technology also won local cotton industry awards.

In addition to this major distributor development has been the development of a world-class anhydrous ammonia measurement facility. This facility has allowed the accurate measurement of both flow and distribution of anhydrous ammonia in a controlled atmosphere environment. It has also allowed a range of operating parameters within the various systems to be rigorously tested. With the closure of the project, this system has been decommissioned at the Agricultural Research Centre at Trangie.

# New distributor solves problems in anhydrous application

By Neville Gould and Pat Weldon, NSW Agriculture, Trangie

The cloud of vapour released behind an anhydrous ammonia application rig has for many years hidden a major problem — unequal row-to-row distribution. Overall metering rates per hectare are usually close to the required mark but recent studies have shown that the variability in flow rates from row-to-row can typically be as high as 50-70 per cent and, in some cases, as high as 300 per cent.

Attempts in the US to solve the problem, through the use of 'flow integrators', orifices and the development of new manifold devices such as the vertical dam manifold, have failed. But a new development in Australia is likely to make unequal row-to-row distribution of anhydrous ammonia a thing of the past.

*A new development in Australia is likely to make unequal row-to-row distribution of anhydrous ammonia a thing of the past.*

This new anhydrous ammonia distributor, developed by NSW Agriculture engineers at the Trangie Agricultural Research Centre, has come about in an effort to solve the problem of striping in cotton (see photo above) and has been principally funded by the Cotton Research and Development Corporation.

Anhydrous ammonia is the most con-

centrated form of nitrogen fertiliser, containing 82 per cent by weight of nitrogen and is the most common form of nitrogen fertiliser used by the Australian cotton industry.

## NEW DESIGN

The new distributor encompasses a metal housing in which a high density polyethylene (HDPE) rotor is housed.

It varies greatly from previous anhydrous ammonia distribution devices, in that it uses the energy of the bi-phase (liquid and

4

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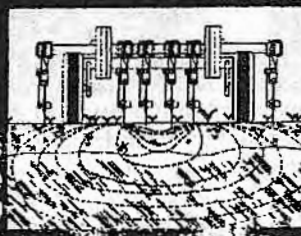
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the cotton industry. The greatest of these potential benefits is decreased anhydrous ammonia cost.

Typically, growers have increased the metering rate of anhydrous ammonia to offset poor distribution from current distributors. US research suggests that metering rates are usually 16 per cent higher than would typically be required if distribution was even across all outlets.

If growers choose to reduce their metering rates by this amount — that is 24–32 units N if 150–200 units N are applied — then they will save around \$20–25 per hectare.

For a typical Australian cotton or grain grower, this saving is substantial and will more than offset the cost of the purchase of the new distributor.

Due to the improved accuracy of distribution there is more even crop growth. This means easier management, particularly in relation to the application of insecticides, growth regulants and desiccants to cotton. With cereals, the pursuit of high protein grain or malting barley may also be easier.

Potentially greater yields will also result due to appropriate  $NH_3$  levels over more of the crop (not too much and not too little).

N losses may also be reduced because



The new distributor is versatile and can be used in both row crop and broadacre cropping situations.

less  $NH_3$  is applied and there is a greater probability of capture and use by a healthier root system. This should also lead to reduced environmental off-site impact due to less leaching into ground water or denitrification into the atmosphere.

The environmental impact aspect of fertilizer application is of international significance — especially in Europe and the US. It is now becoming an issue in Australia as

industries attempt to develop best management practices for crop production.

The new distributor is currently undergoing pre-commercial release testing at Trangie. It is expected that the commercial unit will be officially released by HI Fraser Pty Ltd, Sydney in November or December 1998.

For more information contact Neville Gould on 02 6888 7404.

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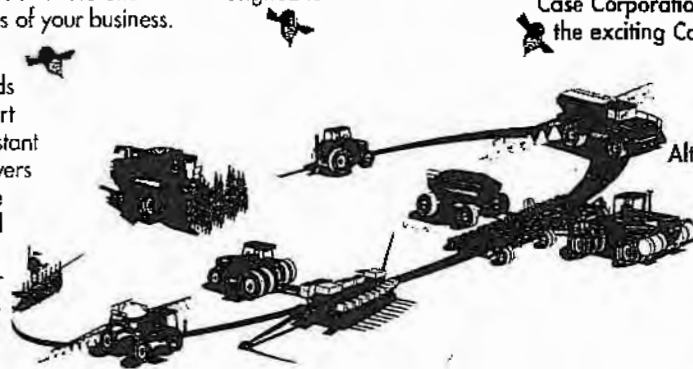
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LEADING EDGE SEPTEMBER–OCTOBER–NOVEMBER 1998

# SPREADING

techniques

**The Americans tried and failed, but an Aussie system seems to have ensured an even flow of nitrogen-rich anhydrous ammonia**



**A** locally developed system for the application of anhydrous ammonia may solve the problems associated with the even distribution of the fertiliser.

Anhydrous ammonia is the most concentrated form of nitrogen fertiliser. It contains 82 per cent by weight of nitrogen, and is the most common form of nitrogen fertiliser used by the Australian cotton industry.

The problem is that flow rates in applying the fertiliser can be very variable.

While many studies have

shown that overall metering rates per hectare of anhydrous ammonia are usually close to the required mark, more recent studies have shown that the variability can typically be as much as 50-70 per cent and, in some cases, as high as 300 per cent.

Attempts in the United States to solve the problem, through the use of 'flow integrators', orifices and the development of new devices such as the Vertical Dam Manifold, have all failed.

But the development in

Australia, however, looks likely to make the problem a thing of the past.

Research into anhydrous ammonia distribution came about to try to solve the problem of stripping in cotton.

The current commercial distribution designs all use fluid flow theory and rely on even resistance to provide even flow.

However, they are not able to handle the liquid-vapour nature of the anhydrous ammonia in the manifold.

The high-velocity vapour (which holds only a small

proportion of the nitrogen mass) becomes a problem because the anhydrous ammonia continues to boil as it loses pressure. This dominates flow behaviour, causing variable flow characteristics.

This new distributor uses a metal housing to contain a high-density polyethylene rotor.

It varies greatly from previous anhydrous ammonia distribution devices in that it uses the energy of the bi-phase (liquid and vapour) fluid to turn the rotor at high speed (up to 3600rpm at low-flow

# A new distributor for field application of anhydrous ammonia

N. S. Gould, P. A. Weldon and A. L. Palmer, NSW Agriculture

## 1. INTRODUCTION

Anhydrous ammonia is the most concentrated form of nitrogen fertiliser, containing 82% by weight of nitrogen and is the most common form of nitrogen fertiliser used by the Australian cotton industry. Whilst many studies, both in Australia and USA, have shown that overall metering rates per hectare of anhydrous ammonia are usually close to the required mark, more recent studies have shown that the variability in flow rates from row-to-row can typically be as high as 50-70% and, in some cases, as high as 300% (Reichenberger, 1993). Attempts in the USA to solve the problem, through the use of "flow integrators", orifices and the development of new manifold devices such as the Vertical Dam Manifold, have all failed. A new development in Australia however is likely to make this problem a thing of the past.

## 2. BACKGROUND

Research into anhydrous ammonia distribution came about in an effort to solve the problem of striping in cotton and has been principally funded by the Cotton Research and Development Corporation.

## CURRENT DESIGNS

The current commercial designs are all designed using fluid flow theory and rely on even resistance to provide even flow. However, they are not able to handle the liquid-vapour nature of the anhydrous ammonia in the manifold. The high velocity vapour (which only contains a small proportion of the nitrogen mass), which increasingly becomes a problem as the anhydrous ammonia continues to boil as it loses pressure, dominates the flow behaviour of the anhydrous ammonia resulting in extremely variable flow characteristics.



Figure 1: A new 8 outlet distributor attached to a Continental Metermatic, the most common form of anhydrous ammonia meter used in Australia.

## 4. NEW DESIGN

The new distributor uses a metal housing to house a high density polyethylene rotor (see Figure 1). It varies greatly from previous anhydrous ammonia distribution devices, in that it uses the energy of the bi-phase (liquid and vapour) fluid to turn the rotor at high speed (up to 3600 rpm at low flow rates has been measured). The rotor, which has a single inlet at its centre and a single horizontal outlet,

evenly distributes the anhydrous ammonia around the inside of the distributor housing irrespective of the metering systems used. Both liquid and vapour phases occur in all metering systems (even the "liquid" systems such as 'Cold-flo®) and are created due to the pressure loss as the anhydrous ammonia flows through the system. The distributor is also fitted with a "rotation" sensor, which is mounted in the top of the distributor. This magnetic sensor picks up rotation of the distributor rotor and is attached to an electronic readout in the tractor which alerts the operator to any malfunction, including either complete or partial stoppage.

## 5. RESULTS AND DISCUSSION

A series of experiments were performed comparing the distribution from the new distributor fitted to a John Blue Nitrolator® with that from the current John Blue or Continental Metermatic® manifolds. Experiments were conducted over a range of typical operating metering rates (1000-4000 lbs N/hr) and pressures (60-140 psi) using a laboratory based anhydrous ammonia cotton application system which simulated a typical 8 row field application system. These experiments showed that this dominating negative impact of the vapour has been used to positive effect in the new distributor, to provide distribution variations typically as low as 6% between rows. Prototypes which have been in the field over the past 2 years, being used in both summer cotton and sorghum production and winter wheat and canola production. They have shown little signs of malfunction or wear. It has been easy to fit to a range of metering systems, easy to operate and very effective in the field (striping has been non-existent in all areas, but still apparent in adjacent areas where the conventional systems has been used).

## 6. CONCLUSION

The new distributor, due to its distribution accuracy, has the opportunity to dramatically reduce striping in cotton and other crops, as well as alter other crop and environmental performance characteristics such as yield, fertiliser application rates and nitrogen leaching, leading to increased returns, lower operating costs and easier crop management.

## 7. REFERENCES

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**Reducing anhydrous ammonia application by optimizing distribution  
A summary of 1999 experimental results**

Investigators:

H. Mark Hanna  
200B Davidson Hall  
Iowa State University  
Ames, IA 50011  
ph: 515-294-0468  
e-mail: hmhanna@iastate.edu  
fax: 515-294-9973

Michael L. White  
202 S 1st St Ste B IA 50849  
Adair Co. Ext. Office  
Greenfield, IA 50849  
ph: 515-743-8412  
e-mail: xlmikew@exnet.iastate.edu  
fax: 515-743-0023

Tom S. Colvin  
234 Soil Tilth Laboratory  
2150 Pammel Drive  
Ames, IA 50011  
ph: 515-294-5724  
e-mail: colvin@nstl.gov  
fax: 515-294-8125

James L. Baker  
219A Davidson Hall  
Iowa State University  
Ames, IA 50011  
ph: 515-294-4025  
e-mail: jlbaker@iastate.edu  
fax: 515-294-2552

Assisted by:

Paul M. Boyd  
105 Davidson Hall  
Iowa State University  
Ames, IA 50011  
Ph: 515-294-5522  
e-mail: pmboyd@iastate.edu

## Project Objectives

1. To determine the ability of a conventional manifold, a Vertical-Dam manifold, and a Cold-flo® device, as well as newly available manifolds and pump systems to uniformly distribute anhydrous ammonia during field application.
2. To test an alternative design such as a high pressure system or modifications to existing manifold cavities to improve anhydrous ammonia distribution.
3. To disseminate project results to applicators and improve application techniques.

## Methods and Materials

Two experiments have been conducted to evaluate manifold distribution uniformity across the width of field application. The experiments were conducted under existing field conditions on property of Iowa State University Boyd Farm near Boone, IA.

### Manifolds Tested

The August 1999 experiment compared conventional, Vertical-Dam, and Cold-flo® manifold designs using both 7- and 11-outlet manifold configurations. The conventional manifold (Continental NH<sub>3</sub> 3497) had spaces for 14 outlets with 12.7-mm (0.5-in.) female pipe thread (FPT) connections. Hose barbs that were 9.5-mm (0.38-in) outside diameter and 7.1-mm (0.28-in) inside diameter were evenly spaced in the outlets and the remaining outlets were plugged. Flow entered the conventional manifold directly from below via a 25.4-mm (1.0-in) diameter 254 mm (10.0-in) long cast iron pipe nipple. The Vertical-Dam manifold (Continental NH<sub>3</sub> Products) used either 7- or 11-outlet distribution rings and manifold housings suggested by the manufacturer for each distribution rate. For the lower application rate a MVD housing was used with a SM:12"=165#N/acre ring. For the higher application rate an SVD-01 housing with an R-152 cotton ring were used. The MVD housing and SM ring were also evaluated at the higher application rate. Although this application method is not recommended by the manufacturer, it was investigated as a method to increase manifold pressure and the amount of ammonia present as liquid. The Cold-flo® system used a Cold-flo® system 16 #20340 canister and separate 16 outlet distribution manifolds for ammonia liquid and ammonia vapor. For the conventional and Cold-flo® manifolds, plugged (unused) outlets were spaced as evenly as possible around manifold. Outlet hoses were connected in order sequentially counterclockwise around each manifold as viewed from above. The outlet for knife one on the left end of the applicator was always at a position of 260° when viewed from above (0° was the direction of travel). In this manner, the location of

would open. Pulling the cable in the opposite direction opened the valve to the knife and closed the valve to the collection container. The operating cable was attached to the valve assemblies of all 11 distribution hoses from the manifold outlets. A lever and cylinder actuated by compressed air allowed an operator to simultaneously redirect flow from all 11 knives to 11 corresponding collection containers. Operating the cylinder in the opposite direction directed flow back to all 11 knives. Figure 2 shows the applicator.

Hose length from the manifold to each valve assembly was 3.66-m (144-in), with all lines being the same length for all manifolds but the Cold-flo®. For the Cold-flo® manifold, hose length to the valve assembly was as short and straight as was practical, in accordance with manufacturer's recommendations. Hose length from the valve assembly to each collection container was 1.02-m (40-in) for all 11 distribution lines. Hoses and hose barbs (7.1-mm or 0.28-in. inside diameter) used in the distribution system downstream from the manifold were 9.5-mm (0.38-in) for the conventional and Vertical-Dam manifolds and 3.2-mm (0.125-in) for the Rotaflow™ manifold.

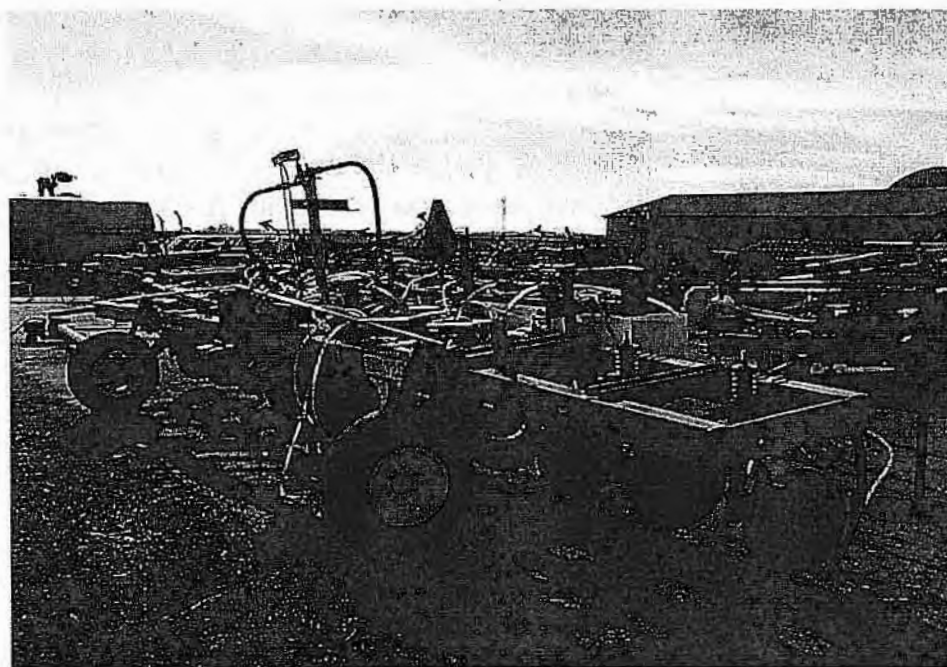


Figure 2. Anhydrous ammonia applicator used for all experiments

In order to reduce back pressure for the Cold-flo® manifold, it is recommended to use 12.7-mm (0.5-in) hose. For this experiment, 12.7-mm (0.5-in) hose and hose barbs were used from the manifold to the valve assembly, but 9.5-mm (0.38-in) hose was used downstream from the valve assembly (12.7-mm or 0.5-in. reducer was used to connect the 9.5-mm or 0.38-in. hose to the liquid inlet on each distribution knife). The smaller hose was used to avoid longer times for changeover between manifolds being tested and re-plumbing of connections into the collection containers. Pressure loss calculations from fluid mechanics indicated that most pressure drop would be at the valve assembly

Application plots were arranged in the field as a randomized complete block with three replications of each treatment. Plots for treatments were randomly located in terrain that ranged from zero to five percent slope. Most plots were zero to three percent slope with the travel direction roughly perpendicular to slope contour.

A standard 3785-liter (1000-gal) field tank towed behind the applicator provided the ammonia. Ammonia flowed via 31.8-mm (1.25-in) hoses from the field tank, through a quick-release coupler and regulator to the distribution manifold (25.4-mm or 1.0-in. hose was used between the regulator and Cold-flo<sup>®</sup> manifold). A single axle utility trailer towed behind the field tank carried the air cylinder for the control valve and a portable generator for the electric solenoid on the pressure switch and provided space for the system operator to ride and control the flow switch. A 9.5-mm (0.38-in) hose connected into a blank outlet on the manifold was connected to a pressure gage on the trailer and used to measure manifold pressure. The operator riding on the trailer recorded tank pressure, manifold pressure, and operated the air cylinder to re-route flow to the collection buckets for a specific time period.

Applicator travel speed was 8 km/hr (5 mi/hr). Plots were 64-m (210-ft) long. Collection times were adjusted based on the application rate to collect an anticipated average of 0.3- to 0.5-kg (0.7- to 1.1-lb) of ammonia. Before each application a manifold was operated for a short period of time to cool it to operating temperature. Manifold temperature was checked immediately prior to testing with an infrared thermometer. This check was done to test the manifold's ability to distribute ammonia at temperatures near those encountered in field operations. Buckets were weighed in the field before and after plot application within 10-min of filling. Actual weight of ammonia delivered from each outlet was determined gravimetricly and was computed as the difference between the final bucket weight after application of ammonia plus water and the initial bucket weight of water only.

Because anhydrous ammonia is a hygroscopic or water-seeking compound that can cause caustic burns, safety equipment was worn by those working anywhere in the vicinity of collection buckets and applicator. This equipment included unvented goggles, long rubber gloves, and long-sleeved clothing and pants. Emergency water dispensers were on the application equipment and a livestock tank full of water was placed near the measuring site for emergency immersion. In addition a respirator with ammonia cartridges was worn at all times by the valve operator and by other workers when conditions warranted. Whenever the applicator moved from a plot to the centralized bucket weighing area, the main tank supply valve to the applicator was closed.

### **Data analysis**

Four measures of variability among outlet distribution were computed. Average outlet difference is the average absolute difference in kg (lb) NH<sub>3</sub> of all outlets from the mean outlet output of all outlets for a particular test plot. The average percentage outlet difference is the average of absolute outlet difference from the mean outlet output

## Results and Discussion

### August 1999

The two experiments run during the second half of 1999 were on August 3<sup>rd</sup> and 4<sup>th</sup>, 1999 (Summer) and November 1<sup>st</sup> and 2<sup>nd</sup>, 1999 (Fall). Each experiment required six people to run all facets of the experiment. Table 1 lists the tank and manifold pressures, for the summer experiment as well as the average measured application rate, and statistical analysis of the experiment results.

As noted, the application rate appears low for the Cold-flo<sup>®</sup> due to not measuring application in the vapor form. Each of the other manifolds were moderately close to the goals of 84 and 168 kg N/ha (75 and 150 lb N/ac). Some error could be expected in the actual application rates due to inexact regulator settings in the field. In general the Vertical-Dam manifolds retained the highest percentage of the tank pressure at the manifold. This was the result of the outlet rings being selected by the research group and the manufacturer to match the application rate. The Vertical-Dam manufacturer (Continental NH<sub>3</sub> Products) does not recommend use of a pressure ratio at the manifold any higher than 65 % of the tank pressure to prevent flow restriction. This high pressure ratio was experimented with to try to have as much ammonia in the liquid phase as possible.

The summary of the four variables used to evaluate the performance of manifolds during the August 1999 experiment provides the best indication of the performance of each manifold tested. In each of the tests the Cold-flo<sup>®</sup> manifold had the widest range of values, with CV values over 20 %. Because of this higher variability of flow to the outlet ports, the Cold-flo<sup>®</sup> was excluded from later tests.

Comparing the two different outlet treatments (7- and 11-outlets), there was little noticeable effect of the number of outlets on the manifold on ammonia output variability. Statistical analysis of the treatments for number of outlets yielded a significant difference at  $\alpha=0.10$  in only one of eight instances (absolute difference in ammonia weight when comparing the data using the large Vertical-Dam at the higher application rate). These results supported the decision to run future experiments at 11 knives only, more nearly matching the increasing size of field applicators being used on midwest grains. The values reported in Table 1 are the average of 7- and 11-outlet measurements.

Statistical analysis separated the manifolds used in the August 1999 experiment into two groups. At the lower application rate, the Cold-flo<sup>®</sup> manifold had a higher coefficient of variation (CV) than the conventional and Vertical-Dam manifolds. The Cold-flo<sup>®</sup> also had a higher average outlet difference than the Vertical-Dam manifold. Increasing the application rate yielded similar results with the CV. The Cold-flo<sup>®</sup> manifold again had a higher CV than all other manifolds tested. At the 168 kg N/ha (150 lb N/ac) application rate, the Vertical Dam (small housing) had a much lower average

**Table 1. Tank and manifold pressure and application rate during treatments with various manifolds (August 1999).**

Treatment	Tank pressure	Manifold pressure	N application rate <sup>*</sup>	Avg. outlet difference, NH <sub>3</sub> <sup>‡</sup>	Avg. % outlet difference <sup>‡</sup>	High/low ratio <sup>§</sup>	Coefficient of variation, %
	psi	psi	lb/a	lb			
84 kg/ha (75 lb/a)							
Conventional	154	24	73	0.116ab	12.4b	1.66	16.1b
Vertical-Dam	142	64	66	0.091b	10.9b	1.47	13.4b
Cold-flo <sup>®</sup>	145	2	56 <sup>†</sup>	0.141a	19.9a	5.18	27.1a
168 kg/ha (150 lb/a)							
Conventional	157	50	154	0.083a	8.2b	1.39	10.4b
Vertical-Dam	141	72	162	0.071a	7.5b	1.51	9.7b
Vertical-Dam (small housing)	141	105	131	0.037b	4.2b	1.21	5.7b
Cold-flo <sup>®</sup>	144	3	103 <sup>†</sup>	0.107a	15.8a	17.59	22.1a

\*Application rate as measured into collection buckets

<sup>†</sup>Measured liquid (without vapor) application rate only for Cold-flo<sup>®</sup>

Values in each column within each rate followed by a different letter are significant at the  $\alpha = 0.05$  level

<sup>‡</sup>Average kg (lb) NH<sub>3</sub> difference of an outlet from mean of outlets

<sup>‡</sup>Average difference of outlet from mean of outlets expressed as a percentage of mean

<sup>§</sup>Maximum difference = maximum outlet weight/minimum outlet weight

**Table 2. Tank and manifold pressure and application rate during treatments with various manifolds (November 1999).**

Treatment	Tank pressure	Manifold pressure	N application rate*	Avg. outlet difference, NH <sub>3</sub> <sup>†</sup>	Avg. % outlet difference <sup>‡</sup>	High/low ratio <sup>§</sup>	Coefficient of variation, %
	psi	psi	lb/a	lb			
<b>84 kg/ha (75 lb/a)</b>							
Elbow-entry	83	20	79	0.212a	21.1a	2.57a	29.6a
Mixer-entry	71	21	90	0.225a	19.6a	2.19b	24.7b
Straight-entry	70	20	92	0.114b	9.7b	1.42c	11.8c
Rotaflow <sup>TM</sup>	65	19	94	0.046c	3.8c	1.18c	4.9d
Vertical-Dam	75	59	87	0.048c	4.3c	1.20c	5.7d
Uneven plugs	88	20	80	0.225a	22.1a	2.25b	28.5a
<b>168 kg/ha (150 lb/a)</b>							
Elbow-entry	81	35	144	0.137a	14.3a	1.75a	17.6a
Mixer-entry	70	35	164	0.129a	11.9ab	1.61a	14.8ab
Straight-entry	78	34	145	0.116a	11.2ab	1.70a	15.6ab
Rotaflow <sup>TM</sup>	65	35	158	0.028c	4.1d	1.23b	5.7c
Vertical-Dam	89	57	150	0.082b	9.7bc	1.47ab	11.7b
Vertical-Dam (small bousing)	85	74	105	0.044c	6.4cd	1.32b	8.3bc
Uneven plugs	68	37	170	0.130a	11.5ab	1.59a	14.1ab

\*Application rate as measured into collection buckets

Values in each column within each rate followed by a different letter are significant at the  $\alpha = 0.05$  level

<sup>†</sup>Average kg (lb) NH<sub>3</sub> difference of an outlet from mean of outlets

<sup>‡</sup>Average difference of outlet from mean of outlets expressed as a percentage of mean

<sup>§</sup>Maximum difference = maximum outlet weight/minimum outlet weight

pressure was seen in the two experiments. Future experiments will help better define this trend.

### **Difficulties Encountered and Refinements in Strategy**

After two experiments and approximately 80 application runs, a number of concerns have been raised and need to be addressed. These include controlling the collected ammonia and regulator control for the correct application rate.

During three runs in the November 1999 experiment, lids popped off the collection buckets from excessive pressure built up as the anhydrous ammonia reacted with the water in the bucket. The mass of water in these buckets was not the originally planned 11-kg but 7- to 8-kg. The originally designed volume was calculated to absorb the ammonia and the heat created in the reaction, the reduction in water mass created excessive temperatures in the buckets. The high pressure created by the boiling of the water was thought to cause the lids to pop off.

The designed application rate is controlled by the pressure regulator in the main supply line. This regulator is set using operating and environmental inputs. Unfortunately this does not compensate for slight pressure or ground speed variations during each run. In addition, the accuracy of the valve on the regulator only creates an estimated 80 to 90 percent confidence that the setting on the display actually corresponds to the internal valve orifice size. Possible solutions to more accurately controlling the incoming ammonia include a mass flow meter on the supply line and then adjusting the regulator to meet the desired application rate. The easiest way to readjust is to do field calculations with the collected ammonia to readjust the regulator. Unfortunately the time that would be taken for these calculations could allow the manifold to warm from operating temperature, making the three replications of each treatment biased.

The water mass in the buckets has been addressed and is not expected to cause future problems. The inaccuracy of the regulator will be diminished as a database of regulator setting and actual application rates is created through its use in future experiments.

After the November 1999 experiment, the addition of the Mixer-entry manifold did not produce results that showed it to be a significantly better approach than some of the other conventional manifolds. While this design refinement did not produce noticeably lower variations at the outlets as was hoped for, it will be used in at least one upcoming experiment to solidify past results.