

CALIBRATION OF ANHYDROUS AMMONIA APPLICATORS

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Precision farming and site specific application of fertilizer has increased the need for well calibrated application equipment. Calibration implies obtaining not just the right rate per acre, but also a uniform application across the width of the applicator. Well-calibrated anhydrous ammonia (NH_3) equipment reduces the chance for inadequate nitrogen rates that reduce crop profits or excessive rates that lead to nitrate contamination of ground and surface water.

SOURCES OF VARIABILITY IN NH_3 APPLICATION

NH_3 Vapor. Formation of vapor in the applicator delivery system is a primary source of variability. Vapor interferes with the flow of liquid ammonia. Regulators are incapable of metering NH_3 accurately if the gas to liquid ratio changes during application. In addition, the vapor form of NH_3 provides very little actual N. An ounce of liquid NH_3 can expand to over 6 gallons of vapor. Vapor volume changes proportionally with pressure. If pressure drops 50%, vapor volume doubles.

Temperature. The main effect of temperature on application rate is on tank pressure. Also, the weight of NH_3 is inversely proportional to temperature. For example, NH_3 weighs 5.3 lb./gal. at 32°F and 4.9 lbs./gal. at 100 °F.

Pressure. The volume of NH_3 delivered changes with pressure. The regulator should be adjusted if tank pressure changes by 10 psi or more. Metering devices can be adjusted manually or with controllers.

Ground speed. The rate of NH_3 applied is directly proportional to the speed of the applicator. Wheel slippage or changes in engine RPM can affect application rate. For example, a drop in engine RPM from 6 to 4 mph increases the application rate by 33%.

CONTROLLING RATE/ACRE VARIABILITY

Flow control monitor/controllers based on radar or ground driven systems minimize the effect of changes in ground speed on application rate. These systems adjust the flow rate of ammonia to compensate for changes in travel speed.

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University of Nebraska Ag engineers recently completed a study of 61 farmer and dealer owned applicators. In this study, N rate/acre was more accurate with applicators equipped with controllers and heat exchangers than with conventional regulators.

Over 80% of the applicators using controllers with regulators were within 10% of the intended rate. But less than 60% of the applicators with only regulators were within 10% (range: 40 to + 50%).

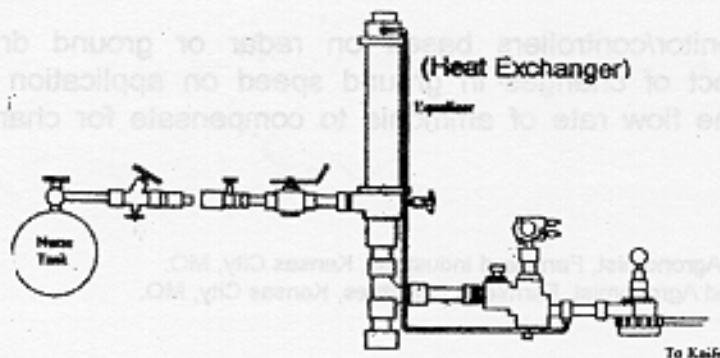
Effect of Controller on Rate Applied/A. Compared to Intended Rate		
	Within 10%	>10%
No Controller	40%	60%
With Controller	80%	20%

Radar-based controllers supplied by Raven, Hiniker, Dickey John, Micro-Trak and others are well suited to grower-owned or custom application units that cover relatively large acreages.

They are less suited to rental units requiring remounting monitors when different tractors are used.

Ground-driven controllers mounted on the applicator are easy to use with different tractors - an advantage for rental units. *Radar-based* controllers may be somewhat more accurate but both systems provide acceptable accuracy.

Heat exchangers are used with controllers to adjust the flow of NH_3 to compensate for changes in air temperature, tank pressure and ground speed. Anhydrous ammonia in the vapor state is converted into liquid as it leaves the heat exchanger. Liquid is metered more accurately than vapor and is less affected by changes in temperature or tank pressure. Any vapor present is removed through bi-pass hoses and is typically delivered to two knives. The total N output of these knives can be higher than from the other knives. Adding a Tee in the vapor lines can divide the vapor among four knives.



Controllers and heat exchangers deliver more accurate rates per acre, but they do not insure knife to knife uniformity. Still, delivery of NH_3 in the liquid form to the manifold has the potential to reduce variability in output from manifold outlets. Note that *N-Serve* can corrode cast aluminum heat exchangers. Flush out the system after every use and at end of the season to minimize corrosion.

Regulators Retrofit used regulators by replacing worn diaphragms, springs, gaskets, etc. Check for plugging from tank rust.

CONTROLLING KNIFE TO KNIFE VARIABILITY

In-the-field calibration tests have shown that many tool bars have excessive knife to knife variability in N rate. Variation in output of individual knives of ± 10 -15% of the average of the set of knives is considered acceptable. However, variability in excess of 100% is not uncommon.

Sources of knife-to-knife application variability include:

Manifold Styles and Setup:

One of the major causes of variability is at the manifold. Recommendations include:

1. Correct plugging of unused outlets.
 - a) Minimize plugging by using a manifold with the *same number of outlets as knives*. Plugging unused outlets increases turbulence in the manifold and reduces the uniformity of flow to the open outlets. Standard manifolds have 14, 16, 18, 20 or 24 outlets. The Continental VD series (vertical dam) manifold can be ordered with 3 to 15 outlets to match knife number.
 - b) If it is necessary to plug outlets, *alternate or space plugs and hoses equally*. DO NOT plug adjacent ports or several ports in a row. This can cause serious outlet to outlet variability in flow rate. An exception may be the meter-manifold units manifolds discussed on the next page.



Correct

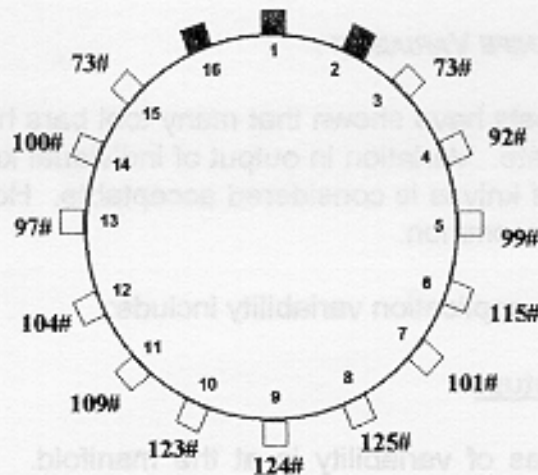


Incorrect

Following are the results of a calibration test on knife to knife variability showing the effect of plugging consecutive outlets vs equal spacing of plugs (16 outlet manifold with 3 plugs and 11 knives).

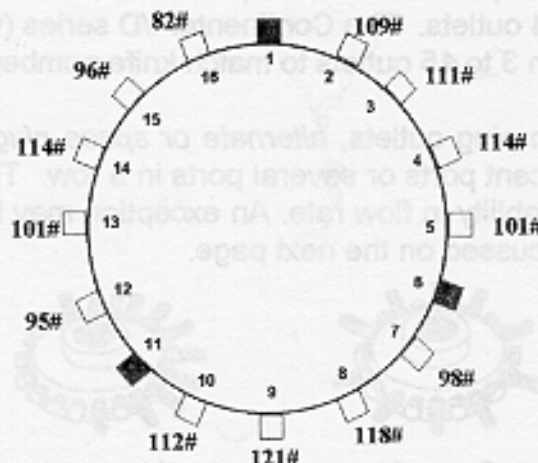
Incorrect Plug spacing

Range 73-125, average 106 lbs. N/acre.
8 of 13 knives are within 15% of set average.



Improved Plug Spacing

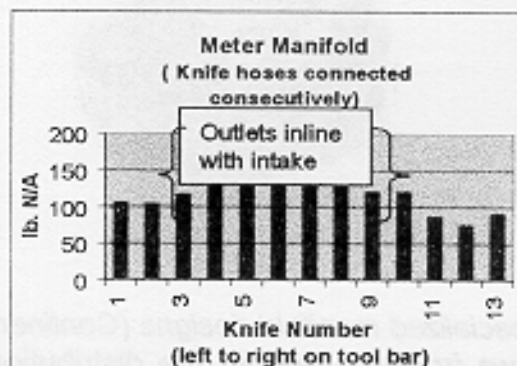
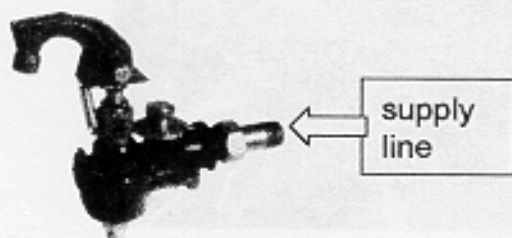
Range: 82-121 lbs. N/acre.
Output of 12 of 13 knives are within 15% of set average.



2. Selection of manifold Style

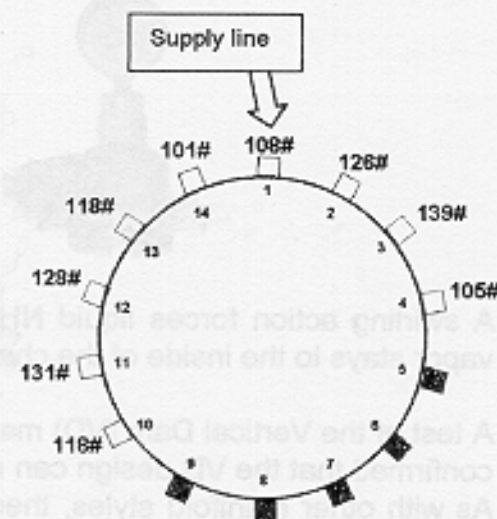
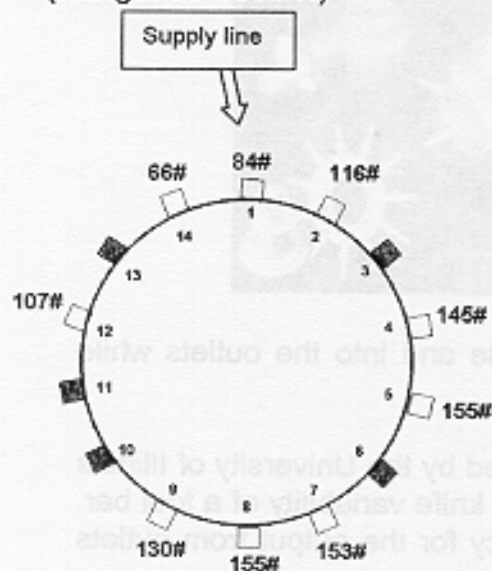
a) Meter-Manifolds Combination Units

With these units, the supply line is mounted horizontally, above or directly into the side of the manifold. Tests show that outlets in line or across from the inlet hose often receive 2-times more ammonia than other outlets. The momentum of the NH_3 appears to force more liquid out of these outlets. Use of meter-manifold combination designs is discouraged.



With this manifold, consecutive plugs across or inline with the flow has reduced outlet variability in some tests. A test on a side-entry manifold shows the effect of:

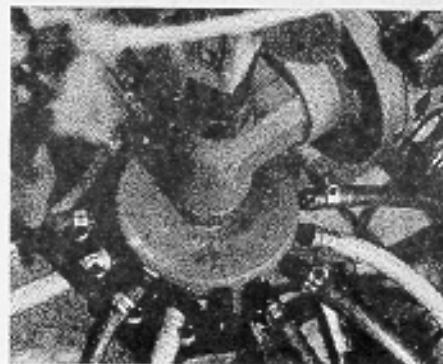
5 random plugs
(Range: 66-155# N)



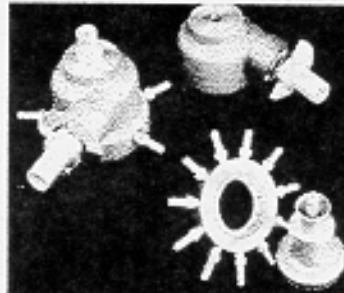
5 plugs opposite the supply hose
(Range: 105-139# N)

Manifold	Knife to knife range in N# compared to the average
Conventional	20 to 40#
Vertical Can	10 to 15#

- b) *Center Inlet Manifolds.* Even when the supply hose is elbowed down through a nipple to the center of the manifold, there is a tendency for the flow to be highest from the nozzles in line with the hose flow as it enters the elbow. Also, a minimum of 3' of hose between the meter and manifold is suggested to minimize the effect of meter turbulence.



- c) *Specialized manifold designs (Continental Vertical Dam).* Anhydrous ammonia flows from the tank to the distribution manifold in both liquid and gaseous forms. This creates uneven pressure in the manifold and forces differing ratios of liquid and gas out each outlet. The vertical dam manifold is designed to separate the liquid and gas as it enters the manifold and distribute each back to the knives proportionally.



A swirling action forces liquid NH_3 to the outside and into the outlets while vapor stays to the inside of the chamber.

A test of the Vertical Dam (VD) manifold conducted by the University of Illinois confirmed that the VD design can reduce knife to knife variability of a tool bar. As with other manifold styles, there is a tendency for the output from outlets inline with the supply line to be slightly higher.

Manifold	Knife to knife range in N, compared to the average
Conventional	-26 to +40%
Vertical Dam	-19 to +14%

Disadvantages of the vertical dam design include higher cost and the need for two or more manifold sizes for different application rates. Two or more manifold sizes may be required if a tool bar is used for wheat and corn N rates for example. The vertical dam design is well suited for low rate application for crops such as wheat or with cold temperatures where knife to knife variability is higher. The larger manifold can be used for lower rates but the accuracy provided by the design is reduced.

3. *Use identical outlet hose barbs.* Different brands or styles are machined with different sized orifices. In general, orificed hose barbs are used with low N rates and with knives that provide little back pressure. With the Vertical Dam manifold, use only hose barbs specifically designed for the VD
4. *Manifold Pressure.* Low manifold pressure is a major factor in producing outlet variation. As pressure decreases, the volume of vapor increases proportionally. For example, if pressure decreases 50%, vapor volume doubles. Low manifold pressure can occur with low application rates of N, cold temperature and/or low tank pressure. Nitrogen rates below 70-80 lb./acre often result in lower manifold pressure and higher knife to knife variation than with application rates over 100 lb./acre.

In one test with a 40 lb./A. N rate and a 3 psi manifold pressure, the knife to knife N rate ranged from 19-93 lbs. Manifold pressure can be increased with orificed hose barbs to create backpressure. In the test above, a 3/32" orifice raised the manifold pressure from 3 psi to 10 psi and reduced the range in N output to 27-71 lbs. Also, large diameter or worn, enlarged knife orifices create less backpressure.

Manifold pressure should be a minimum of 20 psi and preferably 50-75% of the tank pressure for best uniformity in delivery to knives. Flow is restricted if manifold pressure exceeds 80% of the tank pressure. If manifold pressure is <30-40% of tank pressure, orificed hose barbs can be used to increase pressure.

All manifolds should have a pressure gauge to monitor changes in pressure.

5. *Alternate knife hoses around the manifold.*

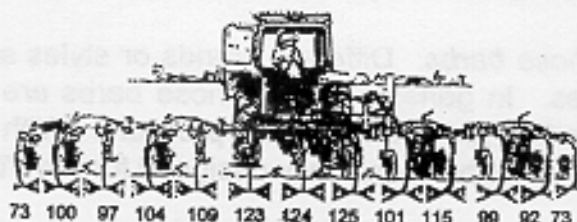
This is probably the best single recommendation for reducing the effect of variability from all manifolds.

There is a tendency for adjoining manifold outlets to have similar outputs due to manifold design, plugs, sloping terrain, etc. Consider randomizing the order of knife hose connections to manifold outlets to reduce the odds of variable

crop response to N. In other words, avoid routing hoses from adjoining manifold outlets to consecutive knives

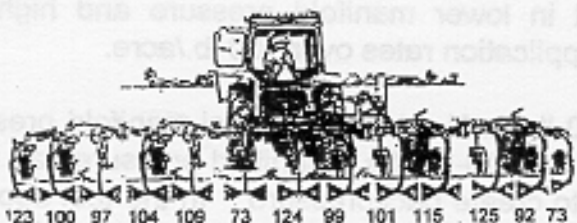
Following is an example of an original setup vs. a setup after hoses were switched to improve distribution.

(ave. = 106 #N/A, knives numbered left to right)



Lbs. N/A distribution from original set up with hoses connected to the manifold consecutively from left to right

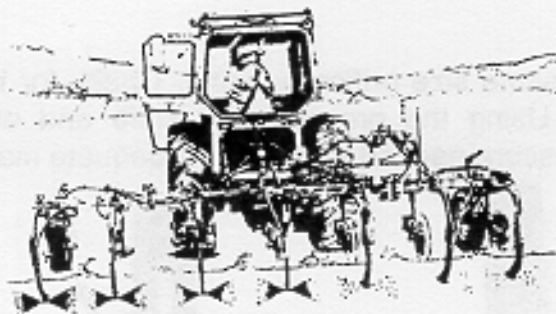
Following is an illustration of the knife to knife application with a randomization of hose connections to the manifold:



Lbs. N/A distribution from an improved set up to alternate low and high output knives. (Switched hoses for knife #1 with #6 and knife #8 with #11)

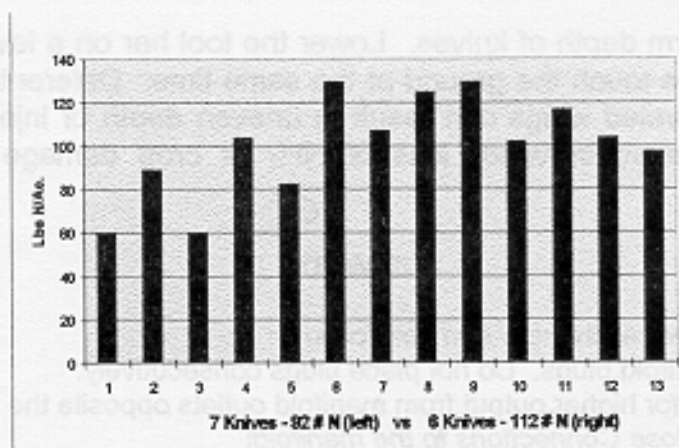
In this case, the tool bar was calibrated and the output was known. However, even without a calibration test, hose randomization should reduce the chance of several knives in a row being significantly high or low. Another reason to alternate outlet position to the knives is the potential effect of slope. Manifold tilt can result in heavier rates on the low side and lighter rates on the high side of the manifold.

6. *Check for rust or other obstructions in the manifold.* Old manifolds should be checked for internal problems such as rust. Use screens to remove rust from tanks before it reaches the manifold.
7. *Level the manifold.* Distribution is affected by slopes (side to side and up and down). Liquid tends to flow faster out down-slope ports. Vapor tends to flow to the up-slope ports. Manifolds with narrower diameters are likely affected less by slope than manifolds with wider diameters.



Effect of side slope on NH_3 distribution

8. **Manifold splitters.** Use a single manifold with less than about 14 knives. It is easier to maintain adequate manifold psi with a single manifold. If a splitter is used with unequal numbers of knives, the side with the most knives can have a lower output per knife. In the following test on a 13-knife bar, the right side with 6 knives averaged 112 #N/knife compared to 92 #N per knife from the left side with 7 knives. With more than 13 knives, the effect of the unequal knives will be less significant. Also be aware that manifolds with more than 14 outlets tend to have higher variability in outlet output.



Hoses

- a) **Equal hose lengths** from manifold to knife. Hose length affects application rate. A Kansas State study found that increasing hose length from 7' to 14', reduced output 13%. Some manufacturers recommend horizontal rather than vertical coils.
- b) **Hose diameter:** Some manifold manufacturers recommend 3/8" hose diameter. Use of 1/2" hose allows for more expansion of NH_3 into vapor that can disrupt the flow of liquid NH_3 .
- c) **Avoid hose kinking or twisting** that can constrict hose diameter.

Knives

- a) Use knives with the same size orifice opening. Check for burrs, obstructions, and orifice wear. Using the proper sized knife and outlet orifice helps maintain the back pressure needed to maintain adequate manifold pressure.



- b) Check for bent tubes, burrs and obstructions. Knives often plug with low NH_3 application rates or when the applicator is backed up with knives in the ground. An increase in manifold pressure may indicate knife obstructions.
- c) Check for uniform depth of knives. Lower the tool bar on a level area and be certain all knives touch the ground at the same time. Different knife or shank styles and unlevelled wings can result in uneven depth of injection. Shallow injection can result in vapor loss of NH_3 or crop damage from preplant applications.

SUMMARY

1. Consider a heat exchanger and controller.
2. Minimize manifold plugs. Do not place plugs consecutively.
3. Compensate for higher output from manifold outlets opposite the supply line.
4. *Randomize Hose Connections to the manifold!*
5. Avoid combination meter-manifold units.
6. Avoid dual manifolds with unequal knives.
7. Use equal knife hose lengths.
8. Use same knife style on the tool bar.