Improving the uniformity of anhydrous ammonia application

Each year Iowa corn growers apply more than a billion pounds of nitrogen as anhydrous ammonia (NH_3) as crop fertilizer. During the application process some of the ammonia vaporizes, changing from liquid to gas, which causes application inefficiencies. This publication reports recommendations to improve the uniformity of anhydrous application that were the result of a series of field experiments using conventional and nonconventional methods.

Anhydrous ammonia begins as a liquid under its own pressure inside the field nurse tank. The pressure in the tank depends on the temperature of the ammonia. In most applicators, ammonia moves by its own pressure downstream through hoses connecting the tank, regulator, distribution manifold, and subsurface injection knives. Ammonia generally begins to boil as pressure decreases in its travel through the system to the knife outlets, which are at zero back pressure.

To understand the change from liquid to gas, consider ammonia being applied on a warm spring day. Figure 1 shows the relationship between temperature and gauge pressure for anhydrous ammonia when it is at the boiling point. The temperature of the ammonia inside the tank may be 70° F. Ammonia at 70° F inside the tank creates a tank pressure of 114 pounds per square inch (psi). When the exit valve is opened, ammonia leaves the tank through the valve, supply hose, and quick-release coupler, with the pressure dropping along the way due to friction. As the pressure of the ammonia drops, some of the ammonia boils, creating ammonia gas. The energy required to change this ammonia from a liquid to a gas is derived mainly from the ammonia itself, which cools the flowing mixture of gas and liquid. The variable orifice used to restrict and meter flow inside the regulator further reduces pressure. In the example above, pressure inside the distribution manifold may fall to 34 psi and the ammonia cool to about 20° F. At this point, about 10 percent of the ammonia mass has changed from a liquid to a gas. But because ammonia gas at this temperature and pressure takes up about 240 times[1] more volume than an equal weight of liquid, most of the volume in the line is gas. This can make uniform division of ammonia flow within the manifold quite difficult, with just a trickle of liquid in the line representing 90 percent of total ammonia, by mass, that is to be equally divided among outlet ports.

Methods to increase flow uniformity from manifold outlet ports

Equipment operators can use several techniques to obtain more uniform ammonia flow from the manifold outlet distribution ports. Equal hose length between the manifold and each knife helps ensure an equal friction loss through each hose to the knife. Experiments at Kansas State University indicate a flow reduction of as much as 10 percent when the length of some outlet hoses is doubled from 7 ft. to 14 ft. In

[1]At atmospheric pressure (i.e., zero gauge pressure) beyond the knife outlet, liquid ammonia expands about 800 times as it transforms to gas.

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general, flow changes about 1 to 2 percent per foot of hose length. The tests further indicate that if manifold pressure is increased by using flow restrictors on outlet hose barbs, differences from hose length are even less. Hoses to knives near the manifold usually must be coiled if equal hose length is used. Keeping coils in a horizontal plane with ties or other supports prevents liquid ammonia from pooling in the lower parts of the hose coils and affecting uniformity.

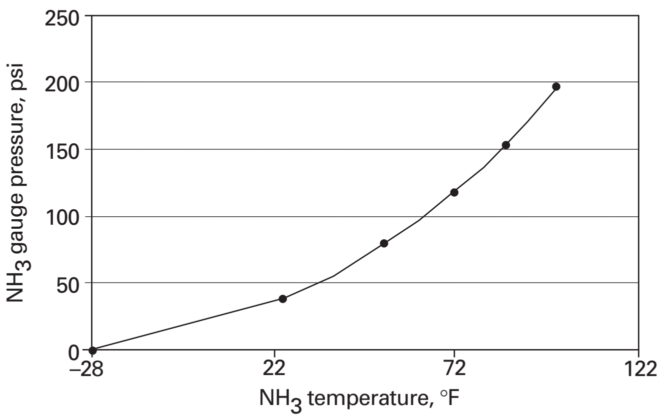

Figure 1. Change in anhydrous ammonia pressure with temperature.

Unused manifold outlets should be plugged evenly around the perimeter so that ammonia leaving the manifold has an equal opportunity to depart. Figure 2 is an example of the ammonia-nitrogen application rates for each of the 11 outlet ports of a manifold. Tests at Iowa State University show that ammonia flow from the port with the greatest output is commonly two to three times greater than that which is flowing from the port with the least output—even with equal hose lengths, horizontal hose coiling, and unused outlets plugged at uniform spacing around the manifold perimeter.

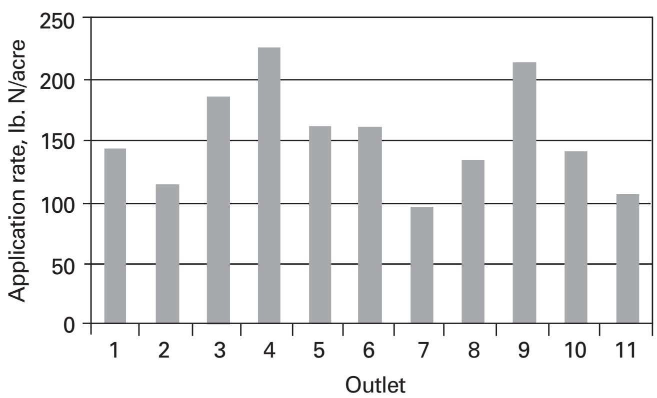

Figure 2. Application rate from individual outlets of conventional manifold.

Tests indicate that outlet ports in different regions of the manifold may have higher or lower flow rates depending on their position relative to incoming ammonia. For example, consider the top-down view of a manifold in figure 3. Imagine a clock face around the manifold and that flow enters a 90°-pipe elbow from the bottom of the picture (at the 6 o'clock position). Although flow is turned 90° into the manifold center, momentum carrying the liquid around the outside of the pipe-elbow curve may be responsible for outlet ports across from the incoming flow (in the 10 o'clock to 2 o'clock positions) receiving greater amounts of ammonia outflow. Ports behind the incoming flow (in the 4 o'clock to 8 o'clock positions) tend to receive intermediate amounts of flow. Ports midway between these regions (from 2 o'clock to 4 o'clock and 8 o'clock to 10 o'clock) receive the least amounts of flow. In an experiment to further test this theory, plugging adjacent manifold outlet ports across from the entry (10 o'clock to 2 o'clock) resulted in a distribution as uniform as plugging ports evenly spaced around the manifold perimeter. Thus, without additional knowledge, evenly spacing plugged outlets around the manifold perimeter is desirable; however, knowing relative flow amounts received by different manifold regions may allow certain unbalanced plugging schemes without detrimental effects.

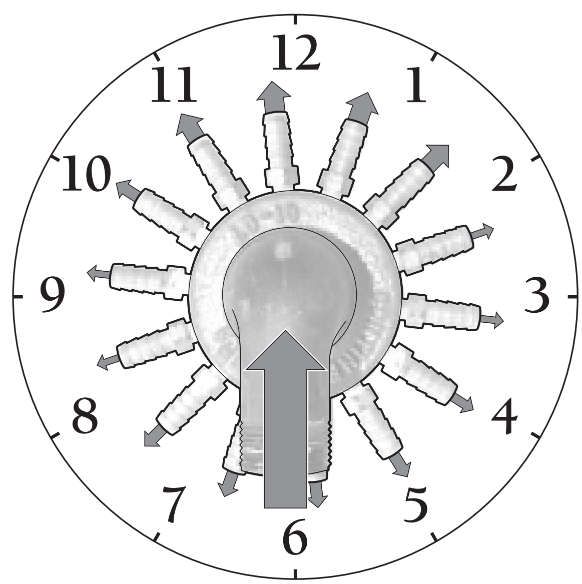

Figure 3. Conventional manifold with incoming flow from 6 o'clock position.

These tests suggest that knives across the back of the application toolbar should not be connected in sequential order to outlet ports around the manifold perimeter. Instead, hoses to adjacent knives should be attached to different regions of the manifold so that two low-output or two high-output ports are not paired.

A heat-exchanger ("cold-flow") flow controller helps obtain the correct overall application rate per acre by measuring total system flow. Although a small portion of total flow is sacrificed to evaporation, incoming flow may be cooled to near 100 percent liquid and total flow accurately measured. Such systems help to accurately control overall application on a per-acre basis; however, gas forms once flow is regulated downstream through a pressure-reducing valve, resulting in a similar distribution problem for the manifold to that of a conventional regulator. In addition, the sacrificed vapor (gas) flow often is indiscriminately applied to one or more knives and may cause further variation across the width of the applicator.

Summary of equipment checkpoints in addition to correcting manifold output variations.

- Manifold should be mounted level on toolbar.
- Manifold outlets should be equal in size and free of obstructions.
- Screens should be clear of any rust particles.
- Hoses should be the same length and diameter.
- Excess hose lengths should be coiled horizontally (not vertically) on the applicator bar.
- Knives should be of same make, in good condition, and free of obstructions.
- Knives should run between 6" and 8" deep for proper sealing.

Other manifold styles

The Vertical Dam manifold (distributed by Continental NH_3 Products, Dallas, Texas) attempts to separate liquid and gaseous ammonia by tangentially inputting flow into the manifold housing. Centrifugal force separates the more dense liquid on a path near the housing's inside wall from the less dense gas toward the center. The action is similar to a cyclone dust collector on a grain mill that separates dust from air. Field distribution tests at ISU indicate that a Vertical Dam manifold sized for low flow rates provides more uniform distribution at lower application rates (50 or 75 lb. N/acre) than does a conventional manifold. At higher application rates (150 lb. N/acre) with a standard configuration for corn (SVD-01 housing; corn: 30" = 75 lb. N min/acre ring), distribution is at least as uniform as with a conventional manifold. Using an R-152 (cotton) ring with the SVD-01 housing (figure 4) typically improves distribution at 150 lb. N/acre compared with the corn ring. Smaller orifices inside

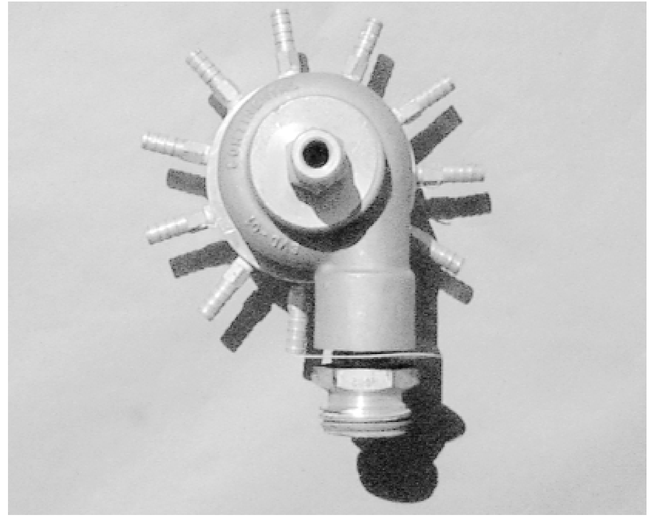

Figure 4. Vertical Dam manifold.

the R-152 distribution ring increase manifold pressure. Applicators should be cautioned, however, that the total application rate can be restricted using this smaller orifice ring if manifold pressure is greater than about 65 percent of tank pressure. Producers who apply no more than 125–150 lb. N/acre may want to try the smaller ring size for improved uniformity if manifold pressure is monitored. Manifold pressure greater than about 65 percent of tank pressure indicates that total application may be restricted and a ring with larger orifices should be used.

Other new manifolds have shown some potential for improved distribution uniformity in field tests at ISU. Distribution from the Rotaflow used in Australian cotton production, and a commercial prototype, FD-1200 (from the John Blue Co., Huntsville, Alabama), are shown in figure 5 along with the conventional and Vertical Dam manifolds.

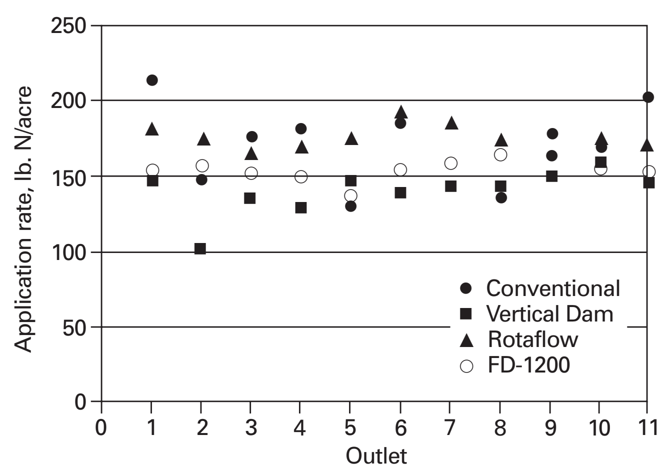

Figure 5. Application rates from individual outlets of four manifolds.

Summary

A small percentage of ammonia vaporizes (becomes a gas) when ammonia moves downstream through an applicator and pressure drops. Although most of the mass of ammonia in the applicator is still liquid, gaseous ammonia becomes a large part of the total volume inside the hoses and valves. After ammonia has passed through a metering valve, more than 90 percent of the space inside the manifold distributor is filled with ammonia gas. This makes it difficult to obtain uniform distribution through manifold outlet ports.

Using equal-length hoses between each manifold outlet port and knife, coiling hoses horizontally to knives adjacent to the manifold, and plugging unused outlet ports at even spaces around the manifold perimeter are helpful, but not a panacea. Tests indicate that doubling the hose length from 7 ft. to 14 ft. results in only a 10 percent decrease in ammonia flow, whereas flow extremes from different outlet ports may vary by 200 to 300 percent.

Because of a tendency for ports in different parts of a manifold to have variable flow rates, it is recommended that ports around the manifold perimeter not be connected sequentially to the knives. That is, adjacent knives on the applicator should not be connected to adjacent outlet ports on the manifold. At application rates of 50–75 lb. N/acre (or for higher application rates with a properly sized outlet ring), a Vertical Dam manifold generally has better distribution than a conventional manifold. Newer, non-conventional manifolds soon may be marketed and some of those tested at ISU may have increased uniformity. Before purchasing a new manifold that advocates greater application accuracy, ask the manufacturer for test data to support the claims.

References

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Kranz, W. C. Shapiro, R. Grisso. 1994. Calibrating anhydrous ammonia applicators. Nebraska Cooperative Extension EC 94-737-D.

Safety checklist

- Always wear gloves intended for ammonia use.
- Always wear unvented goggles for eye protection.
- Do not wear contact eye lenses when working around or with ammonia.
- Always have plenty of clean water on hand in case of an ammonia leak.
- Keep a respirator with appropriate ammonia cartridges nearby in case of an emergency.
- Make sure all ammonia equipment has been properly maintained and is in good working condition.

LEOPOLD CENTER

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