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EC94-737 Calibrating Anhydrous Ammonia Applicators

William L. Kranz
University of Nebraska - Lincoln, wkranz1@unl.edu

Charles A. Shapiro
University of Nebraska-Lincoln, cshapiro1@unl.edu

Robert Grisso
University of Nebraska - Lincoln

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William Kranz, Extension Irrigation Specialist
Charles Shapiro, Soil Scientist — Crop Nutrition
Robert Grisso, Extension Agricultural Engineer

Application of agricultural chemicals has come under increased scrutiny from environmental groups and federal regulatory agencies. Nitrogen fertilizer is used in greater quantities than any other agricultural chemical. It also is the contaminant most often found in Nebraska groundwater. Accurate application of nitrogen is important from an environmental and economic viewpoint.

Approximately 800 million pounds of nitrogen are applied to 12 million acres of Nebraska cropland each year. Nitrogen applied as anhydrous ammonia (NH_3) accounts for around 40 percent of the total nitrogen applied. The purchase price of NH_3 typically ranges from $0.10 to $0.18 per pound of nitrogen. Application cost is approximately $6-$7 per acre, so nitrogen application often represents a significant crop production cost.

Nitrogen applied in excess of what the crop can use efficiently can leach through the root zone and eventually reach the groundwater. Equally important is that nitrogen leached below the root zone has no impact on yields, so it is a crop production cost with zero return.

Properly calibrated and maintained anhydrous ammonia application equipment is required to apply NH_3 accurately and precisely. Applying NH_3 accurately and uniformly has been difficult for many operators. Nebraska research on 44 applicators with variable size orifice regulators indicates that an

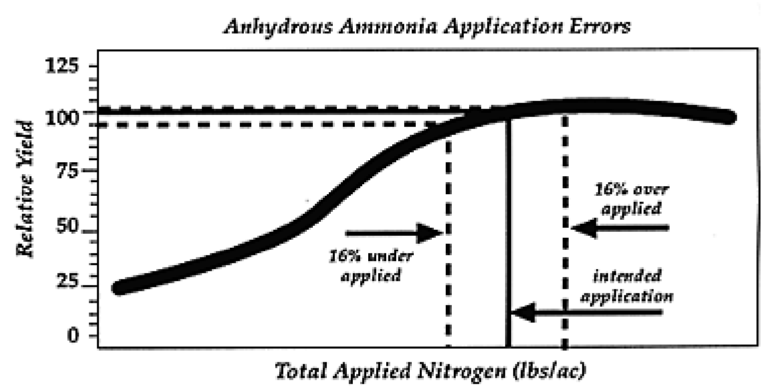

Figure 1a. Potential variation in anhydrous ammonia application rates using regular type application equipment.

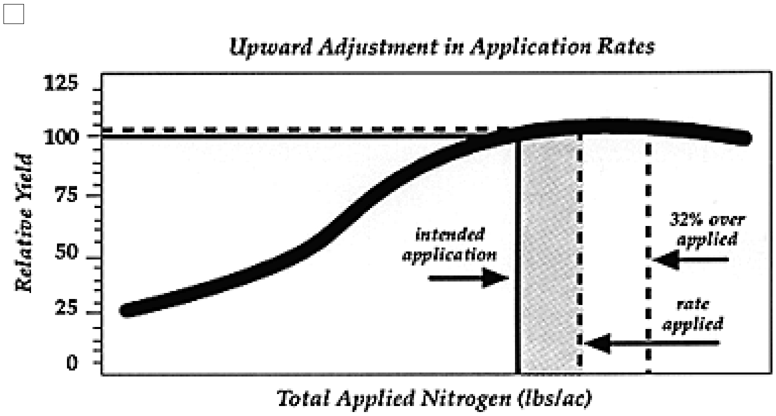

Figure 1b. Potential 20 percent upward adjustment in anhydrous ammonia application rates to ensure the entire field receives the intended AA application rate. The shaded area represents the additional anhydrous applied to ensure that the entire field receives at least the intended rate.

application error of 16 percent is typical. With the majority of current application equipment, these data suggest that some portions of the field could receive up to 16 percent more nitrogen than desired, while other portions could receive 16 percent less *(Figure 1a)*.

To compensate for application accuracy problems, producers often increase their application rates to ensure that all portions of the field receive at least the desired amount of nitrogen *(Figure 1b)*. Should the same application rate error apply (16 percent), some portions of the field could receive 32 percent more than necessary. However, if it were possible to consistently apply NH_3 with a variation of 5 percent or less, much less nitrogen would be applied *(Figure 1c)*.

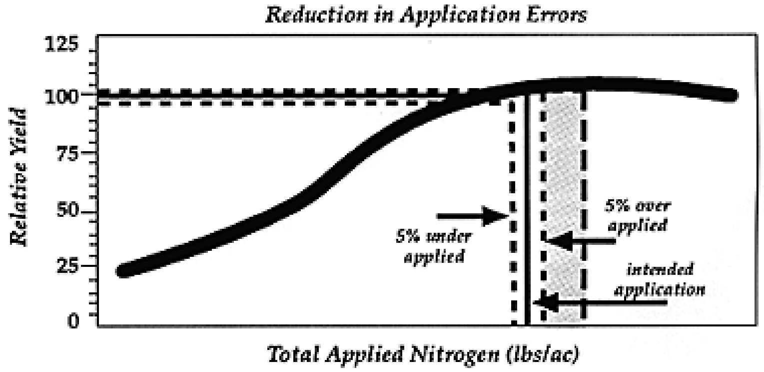

Figure 1c. Potential reduction in anhydrous application rate due to knowledge that variation in the field application rate is 5 percent or less. The shaded portion represents the anhydrous savings due to reduced variation in application rate compared to 16% error.

This circular discusses why NH_3 is so difficult to apply accurately, describes how to identify applicator problems, and presents a method for calibrating anhydrous ammonia application equipment. The text is complemented by a video tape, *Calibrating Anhydrous Ammonia Applicators*, available from IANR Communications and Information Technology. The videotape was developed to highlight procedures for calibrating NH_3 application equipment.

Physical Properties of Anhydrous Ammonia

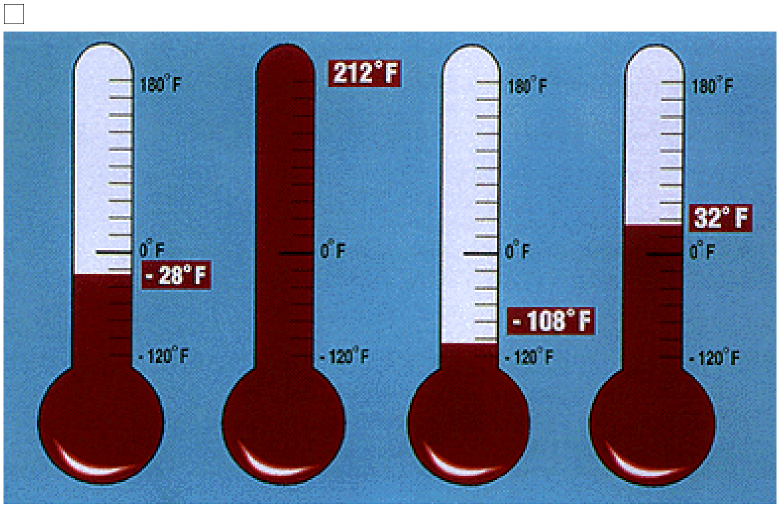

Figure 2. Temperatures at which anhydrous ammonia and water will boil or freeze.

Everyone recognizes the smell of ammonia used for household cleaning purposes. Ammonia used by agriculture is the same chemical. Anhydrous ammonia contains 82 percent nitrogen and 18 percent hydrogen by weight. But unlike the ammonia used for cleaning, NH_3 contains less than 0.5 percent water.

Anhydrous ammonia is stored as a liquid; however, to be stored as a liquid, NH_3 must either be maintained at temperatures below -28^{O}F or kept under pressure. If the temperature of NH_3 increases above -28^{O}F, some of the liquid changes to a gas or NH_3 begins to boil *(Figure 2)*. The boiling point of NH_3 is -28^{O}F. This is an extremely low boiling point, especially when compared to water with a boiling point of 212^{O}F.

The change of NH_3 from a liquid to a gas requires energy. If NH_3 is discharged into the air, energy contained in air is absorbed by NH_3, causing intense cooling of the air. This air cooling produces a visible vapor trail. The vapor trail is not NH_3 but condensed water vapor.

About 590 BTU's of energy are removed from air when a pound of NH_3 vaporizes. To give an idea of the cooling ability of NH_3, each pound of NH_3 that vaporizes is capable of freezing about 4 pounds of water.

NH_3 most often is stored as a liquid under pressure. As a liquid, NH_3 has a density that ranges from 5.7 lbs/gal at -26^{o}F to 4.7 lbs/gal at 125^{o}F *(Figure 3)*. It is important to account for the decrease in density as the temperature of NH_3 in the tank increases. As the density decreases, more gallons of NH_3 must be applied to maintain the same nitrogen application rate.

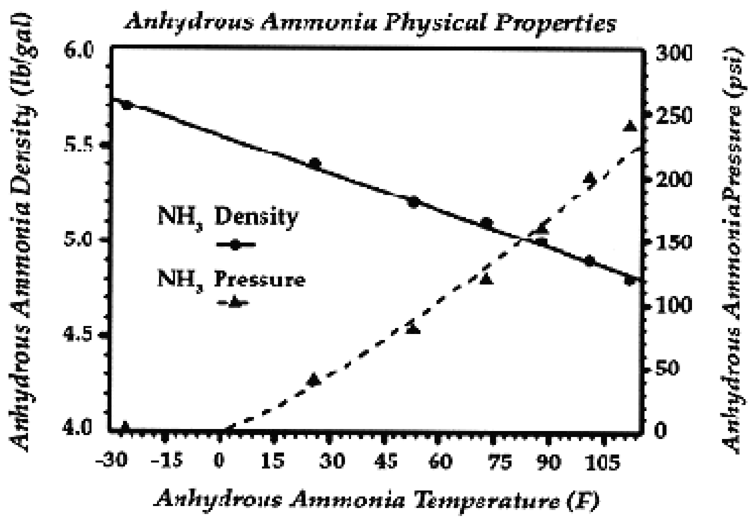

Figure 3. Change in anhydrous ammonia density and pressure with increasing temperature.

Figure 3 also shows that NH_3 pressure increases with rising temperatures. Application equipment typically uses tank pressure to deliver NH_3 to the soil. An increase in NH_3 temperature (and thus pressure) would tend to force more NH_3 through the delivery lines. The number of gallons of NH_3 delivered typically increases with rising temperatures.

The interaction between increasing NH_3 pressure and decreasing density can best be explained with an example. Begin with a nurse tank filled to 80 percent of capacity at a temperature of 53^{o}F and a pressure of 80 pounds per square inch (psi). If the temperature rises to 73^{o}F and 160 psi, the pressure would rise by 50 percent [(120-80)/80], the density would decrease by 1.9 percent [(5.2-5.1)/5.2], and the temperature would increase by 37.7 percent [(73-53)/53] *(Figure 3)*. Since the pressure increase is much greater than the change in density, the net result would be more NH_3 delivered to the field at 73^{o}F than at 53^{o}F.

To compensate for this change in pressure, the meter would need to be adjusted downward using the factor supplied by the manufacturer. For example, one handbook provides a factor of 0.95 for regulators operating at 120 psi and 1.10 for regulators operating at 80 psi. For this example, the factor was reduced from 1.10 to 0.95 due to the increase in pressure from 80 to 120 psi.

If NH_3 is released into the atmosphere, it will expand rapidly to occupy a volume 850 times greater than the original liquid. For example, 2 ounces of liquid will expand to 13 gallons of gas. Anhydrous ammonia readily changes from liquid to gas in the nurse tank and NH_3 distribution system. Consequently, the ratio of NH_3 gas to liquid continually changes as NH_3 passes through the distribution line. Later

Safety Equipment

Rubber gloves, goggles, a respirator, and appropriate clothing are important safety precautions when using NH_3. Skin exposed to liquid NH_3 can become frozen and dehydrated, causing serious injury and frostbite. See Safety Equipment for recommended clothing, equipment, and equipment signage for a safer application.

we will discuss metering problems associated with changing gas-liquid ratios.

NH_3 is highly soluble in water, and has a strong attraction for water. Therefore, NH_3 readily dissolves in water to form aqua ammonia, a material sometimes used as a nitrogen source. Aqua ammonia is an unstable substance, but is less hazardous than pure NH_3.

When calibrating liquid or dry application equipment, non-toxic materials can be substituted for toxic materials. This is not the case with NH_3. There isn't a non-toxic material that can be used during the NH_3 calibration process. **Operators must take special safety precautions when working with NH_3 equipment.**

Application Equipment

Nurse Tank

Anhydrous ammonia is transported to the field in a nurse tank ranging in capacity from 500 to 1,000 gallons. Most tanks have a capacity of approximately 800 gallons of NH_3 when 85 percent full, and have a safe pressure rating of approximately 400 psi *(Table I)*.

Table I. Anhydrous ammonia tank capacities based upon the percent of full.

Percent full	**Tank capacity (gallons)**			
(%)	**150**	**250**	**500**	**1000**
10	15	25	50	100
30	45	75	150	300
50	75	125	250	500
70	105	175	350	700
85*	**128**	**213**	**425**	**850**

*Typical nurse tank maximum fill percentage

Each tank is equipped with two gauges: one shows tank pressure and the other shows the percent of full *(Figure 4)*. Monitoring the tank pressure aids in adjusting the flow regulator; monitoring the percent of full gauge provides information on the accuracy of the application rate and alerts the operator that the tank is nearly empty.

The tank also is equipped with a number of valves for filling, emptying, and pressure relief. Make sure these valves have been lubricated and tested prior to use. While this is particularly true of valves, all NH_3 equipment should be functioning properly prior to each use.

Mainline Hose

Anhydrous ammonia leaves the tank via a dip tube that begins at the inside-bottom of the tank *(Figure 4)*. The dip tube is attached to the tank shutoff valve mounted on the top of the nurse tank. The tank shutoff valve should be ordered with an excess NH_3 flow valve that closes if the flow rate becomes excessive in the event of a mainline hose break.

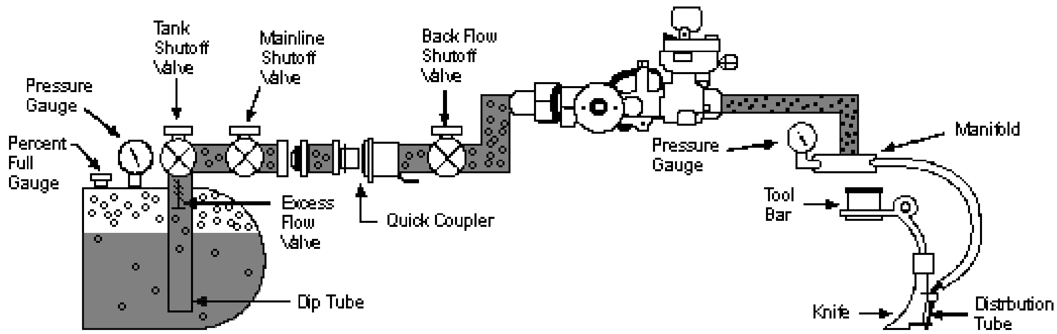

Figure 4. Schematic drawing of components for a typical anhydrous ammonia applicator.

For example, one excess flow valve has a rating of 37 gallons per minute (gpm). If the flow rate is greater than 37 gpm the valve will close preventing NH_3 from being discharged to the atmosphere.

After flowing through the discharge valve, NH_3 passes into the main supply hose to another shutoff valve. Generally, a quick coupler fitting is placed at the outlet of the mainline hose shutoff valve. From there NH_3 passes into a heat exchanger or a flow regulator *(Figure 4)*.

The supply line is typically a flexible hose that is attached to the NH_3 applicator using a special NH_3 quick coupler. The quick coupler allows the tank to be easily hooked and unhooked from the application equipment. It also prevents the hose from being broken in case the NH_3 nurse tank becomes unhooked from the application equipment. All pipeline fittings should be manufactured specifically for NH_3 use and should carry sufficient pressure ratings (greater than 300 psi).

Metering Devices

Anhydrous ammonia application is controlled using one of three metering devices — variable size orifice *(Figure 5a)*, electronic control monitor *(Figure 5b)*, or a metering pump. Each method offers advantages and disadvantages.

NH_3 enters the metering device after passing through a strainer and exits to the manifold for distribution to the individual knives. As we will discuss later, accurate metering of NH_3 requires that the expected application rates are well within the flow range of the regulator. The key is to operate the applicator above 10 percent but less than 90 percent of the manufacturer's rated output. For example, for a regulator with a rated output of 4,100 pounds NH_3 per hour, try to stay away from applications that are below 410 and above 3,690 pounds NH_3 per hour. Excessive friction loss can occur if the output rate is above the 90 percent level. This could cause a large amount of NH_3 to convert to gas. Flow rates below the 10 percent level may not be able to maintain sufficient back pressure in the pipeline. This results in excessive conversion of NH_3 liquid to gas. The cooling effect caused by the NH_3 boiling can freeze up the manifold and increase knife-to-knife variation.

One of the most important characteristics of NH_3 is its response to changes in pressure *(Figure 3)*. Flow of NH_3 through the main pipeline causes friction between NH_3 and the sidewalls of the pipe. Increases in flow rate cause a corresponding increase in friction loss.

Friction loss reduces the main pipeline pressure that allows conversion of some liquid NH_3 into a gas. More friction loss also increases the opportunity for gas to occupy the pipeline. A metering device is incapable of metering NH_3 accurately if the ratio of gas to liquid changes or is unknown. Be sure all parts of the distribution system are sized to deliver the anticipated application rates. Minimizing the number of pipe size changes, elbows, tees, valves and other connectors helps ensure the NH_3 is metered accurately.

Variable Size Orifice

A variable size orifice (or regulator) is the most common means of metering NH_3 An orifice is a small opening in a flat plate that NH_3 must pass through. The orifice is placed in the NH_3 flow path within the regulator. The size of the orifice may be changed by turning the control dial. The dial typically has gradations of pounds per hour (lbs/hr). *Figure 5a* shows an NH_3 applicator equipped with a variable size orifice regulator.

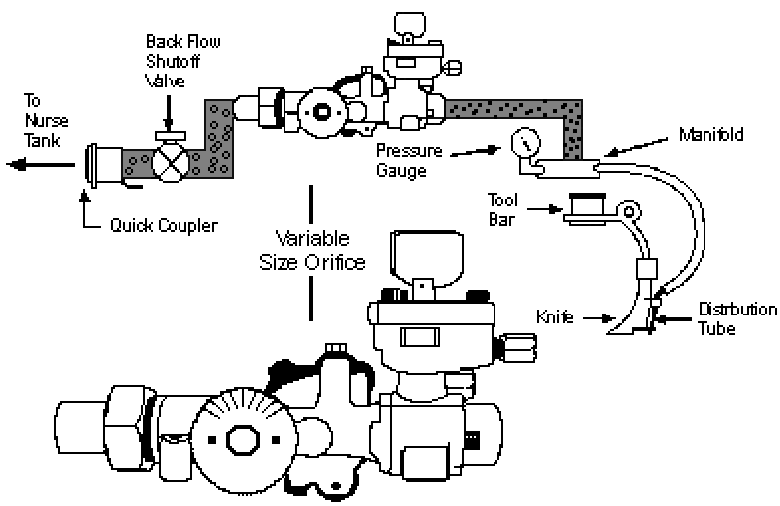

Figure 5a. Components of a variable size orifice metering device including the tank discharge, regulator, manifold, and knife applicator. (Adapted from Continental NH_3 Products Company, Inc.)

Pressure needed to force NH_3 through the pipeline is supplied by the NH_3 contained in the nurse tank. The regulator is designed to maintain a pressure difference between the inlet and outlet of the orifice. By maintaining a set difference in pressure between the inlet and outlet to the manifold the regulator makes it possible to meter NH_3 without using a pump. Increasing the pressure difference increases the flow of NH_3 through the orifice and vice versa.

Charts provided by the manufacturer are used to select the orifice setting necessary to deliver the desired amount of NH_3 per acre. Applicator swath widths and estimated travel speeds are included in each table. Delivery charts are based upon calibrating the regulator using equipment designed to simulate that used by farmers and fertilizer dealerships. These charts should only be used as a starting point. Each applicator should be carefully calibrated to ensure the desired rate of NH_3 is being delivered. A change in application rate requires a calibration check.

Application amount is controlled by the applicator speed of travel and the orifice size determined by the regulator setting. Applicators operating on rolling terrain will experience changes in travel speed when going uphill, compared to downhill. Accurate application rates require that the operator manually maintain the travel speed. Failure to maintain travel speed will result in excess applications going uphill and insufficient applications going downhill.

Changes in travel speed could result from two factors: 1) changes in wheel slippage; and 2) changes in horsepower requirements due to the force of gravity and potentially the depth of knife penetration. Applying NH_3 to tilled field surfaces tends to increase the magnitude of wheel slippage.

When going uphill, the influence of gravity tends to increase the horsepower required to pull the applicator. The opposite is true when going downhill. Driving through changes in slope direction (downhill to uphill), may cause the depth of knife penetration to change slightly. The horsepower required changes in direct relation to the depth of knife penetration.

Variable size orifices can provide acceptable application accuracy if: a) a constant pressure difference is maintained between the orifice inlet and outlet; b) the tank pressure is monitored and the regulator adjusted when the tank pressure changes by 10 psi or more; and c) the applicator travel speed is nearly constant.

Flow Control Monitor

A flow control monitor uses a slightly different approach to metering NH_3 *(Figure 5b)*. Manufacturers have used different approaches to ensuring accurate metering of the gas-liquid mixture. Application accuracy is improved by the metering of a single phase fluid (liquid).

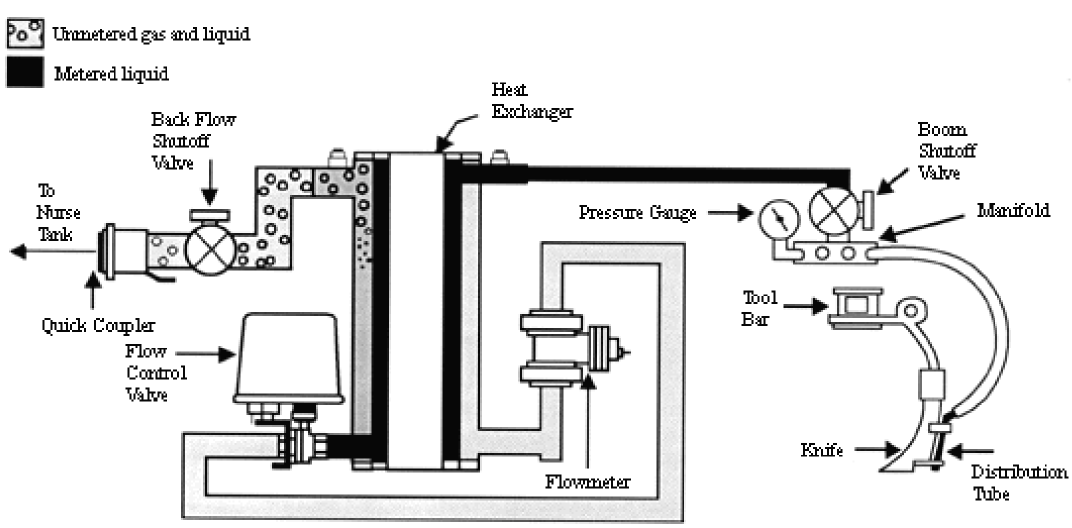

Figure 5b. Components of a flow control monitor metering device including the tank, thermal transfer unit, control valve, and flow meter. (Adapted from drawing by Dickey John Corporation)

All systems use the cooling properties of NH_3 to convert gas back into a liquid inside a heat exchanger.

A mixture of gas and liquid enters the heat exchanger after passing through a backflow shutoff valve. Once in the heat exchanger, the cooling properties of NH_3 are used to convert incoming NH_3 gas into a liquid. This results due to the enlarged plumbing and reduced pressure within the heat exchanger *(Figure 5b)*. Liquid NH_3 flows out of the heat exchanger into the flow meter (lower right). The metered NH_3 flows through the flow control valve to the manifold for distribution to individual knives.

The main difference among manufacturers is how the heat exchanger is plumbed into the system and the sophistication of the electronic controls. One manufacturer strips gas out of the flow, before it is metered, so that only liquid passes through the flow meter. NH_3 condensed inside the heat exchanger is discharged into the main pipeline prior to the meter. Any remaining gas is discharged through an extra tube attached to two or more knives.

In a second approach, all NH_3 is passed through the heat exchanger prior to entering the metering device. Manufacturers report that NH_3 leaving the heat exchanger is nearly 100 percent liquid, so metering NH_3 should be quite accurate and dependable.

One manufacturer is marketing a type of controller that uses a servo valve, attached to a conventional flow regulator, to adjust the flow for changes in travel speed. This allows the flow rate to be adjusted on-the-go from the tractor cab. These systems have readout devices similar to those used by liquid spray applicators. However, since the major factor inhibiting accurate NH_3 metering is gas-liquid ratio changes, this type of regulator has the same inherent problems as the variable size orifice regulator.

With all flow control monitors, flow rates are controlled by a throttling valve electronically linked to a speed sensor mounted on the tractor. The flow rate is controlled so that as navel speed increases, the flow is increased to ensure a consistent application rate. Likewise, the flow rate is decreased when travel speed decreases. Anhydrous ammonia delivery rates are continuously adjusted to account for changes in travel speed.

A flow control monitor requires the addition of electronic monitoring devices to the tractor and application equipment. When installed, this equipment allows the operator to make adjustments for changing NH_3 nurse tank pressure, and alter the nitrogen application rate from the tractor cab.

In addition to the speed sensor and the throttling valve, a readout monitor is installed inside the tractor cab. The monitor keeps track of how much NH_3 has been applied, the acres treated, the application rate, tank pressure, and speed of travel. The addition of these devices can improve the application accuracy substantially, but their operation depends upon proper calibration and monitor programming. Proper care and maintenance is critical.

Metering Pumps

Flow of NH_3 also may be controlled by using a variable stroke piston pump. Though available, these units are not commonly used in the Midwest. Anhydrous ammonia output is controlled by adjusting the stroke length or pulse frequency. Power for driving the pump is provided by non-drive wheels on the NH_3 tank or by a fifth wheel (ground driven). The fifth wheel is most likely to experience slip. This wheel slip is not associated with the tractor, so it can be addressed by properly configuring the pump drive wheel.

Fifth wheel slippage will decrease the application rate. In addition, extremely rough soil surfaces increase the number of wheel revolutions by the fifth wheel in relation to the horizontal distance traversed. To accurately apply NH_3, these applicators should be calibrated for different soil surface conditions.

Like all piston pumps, the piston is in direct contact with NH_3. This could alter the calibration over time and reduce the life of the pump. Accurate metering is possible only if liquid NH_3 enters the pump. To accommodate this, most systems have a heat exchanger that is used to convert NH_3 gas to a liquid. These pumps are expensive to maintain and are used almost exclusively in areas with extreme field elevation changes.

Manifold

From the metering device, NH_3 enters a manifold that distributes NH_3 to the individual knives *(Figure 6)*. The manifold is a crucial part of the distribution system. NH_3 entering the manifold is distributed to each knife in relation to the pressure at the manifold outlet and the position of the outlet relative to horizontal.

For best results, the manifold should have the same number of outlets as applicator knives; the outlets should be equally spaced around the manifold; the manifold should be mounted level on the applicator; and a pressure gauge should be mounted on the manifold so that it is visible from the tractor.

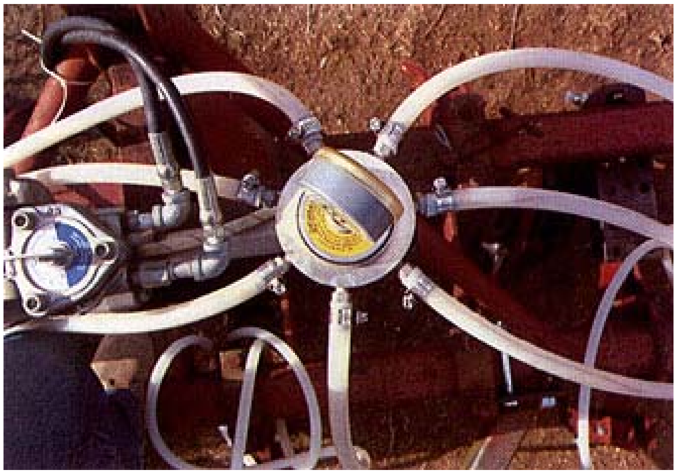

Figure 6. Anhydrous ammonia distribution manifold with outlets equally spaced around the manifold.

Metering accuracy to individual knives is improved by minimizing the amount of NH_3 gas in the manifold. When NH_3 gas occupies a portion of the manifold chamber, liquid NH_3 flows toward the low side of the manifold while gas moves toward the high side of the manifold. Due to the difference in density between NH_3 gas and NH_3 liquid, more nitrogen is applied to the side with the greater proportion of liquid.

Extra manifold outlets increase the turbulence within the manifold, causing more gas to be distributed to the knives with orifices on the high side of the manifold. Concentration of outlets to one side of the manifold causes turbulence to be more prominent in the manifold chamber. Again, some knives will have a greater percentage of gas, and others, more liquid.

Maintaining the manifold in a horizontal position will ensure that nearly equal amounts of liquid and gas are distributed to each knife *(Figure 7a)*. If the manifold is not horizontal, the upslope outlets will receive a greater percentage of gas than downslope outlets *(Figure 7b)*, so each individual knife could distribute a different amount of NH_3.

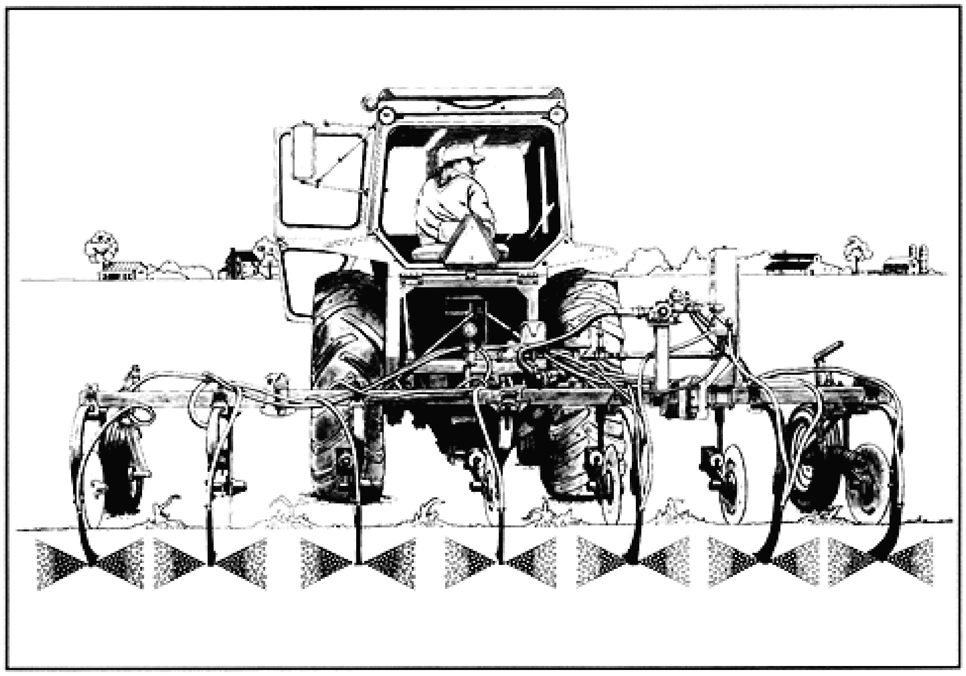

Figure 7a. Conceptual drawing of uniform application due to manifold being level.

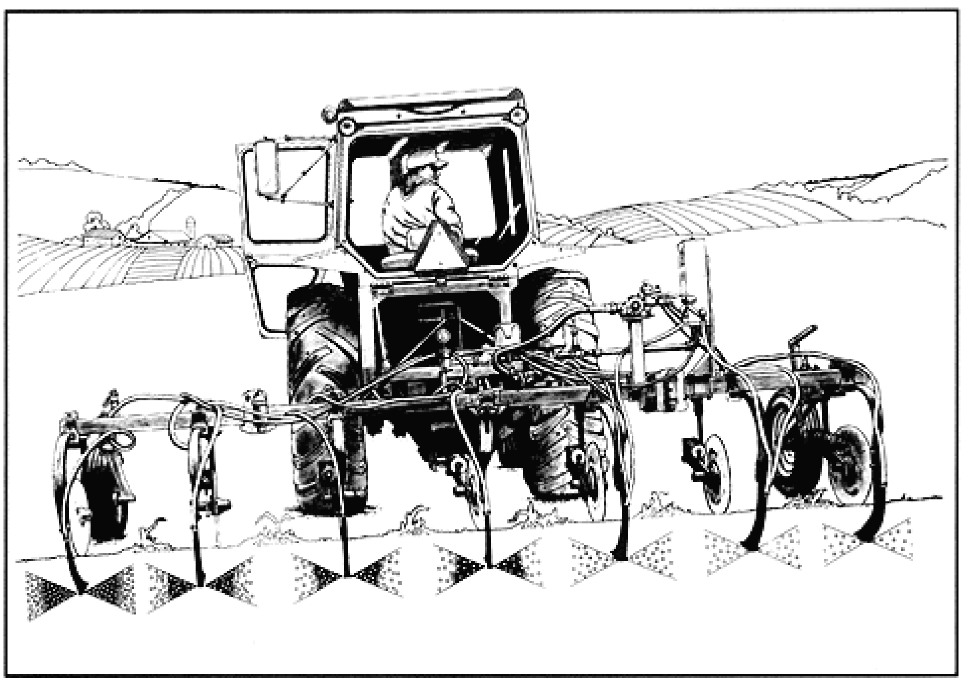

Figure 7b. Conceptual drawing of the variation in applicator knife output due to manifold being tilted.

One way to improve distribution of NH_3 to the knives is to use orifice size control rings designed to create more back pressure at the manifold. For example, if the application rate you desire is on the low end of the delivery chart, NH_3 delivery to individual knives can vary greatly. Reducing the size of the manifold outlets will create more back pressure at the manifold outlet. This will ensure that distribution will be more uniform to individual knives.

In a similar manner, if the intended delivery rate is toward the high side of the chart, some of the rings should be removed so that back pressure is maintained at the desired level. Check with your supplier to see if rings are available for your manifold.

Distribution Fittings and Hoses

All pipeline fittings should be made of steel rather than copper alloys (such as brass) to prevent corrosion. Plastic fittings also should not be used. Anhydrous ammonia readily degrades copper-based metals, so brass, zinc, or copper-type fittings should not be used in NH_3 distribution systems. Only fittings designed for propane and NH_3 should be used. The pipelines should be sized to limit friction losses.

For example, applicators equipped with regulators designed to apply greater than 3,000 lbs.-NH_3 per hour should use 1.0 inch mainline hose and 1.25 inch quick couplers. The 1.25 inch quick coupler is needed to match flow characteristics of the 1.0 inch mainline hose. Increasing the hose size would be beneficial. However, the limiting factors are the standard tank inlet tube and the manifold inlet sizes. These fittings are typically 1.0 inch inside diameter. Larger sizes can be special ordered. For systems with flow rates greater than 5,000 lbs NH_3 per hour, a second tank should be used.

The main hose used to deliver NH_3 from the nurse tank to the regulator should be specifically made for NH_3 use. This heavy-duty hose is typically black rubber with a wire mesh support rated at 200 psi or greater. Hose labeling should clearly identify it as anhydrous ammonia hose, the maximum working pressure, and the year of manufacture. If this information is not clearly visible on the hose, do not use it for NH_3 application. The manufacturer's name and trademark also should be included.

Flexible polyethylene hoses 3/8" inside diameter are typically used to carry NH_3 from the manifold to the knives. All hoses should be the same diameter, length, and have appropriate pressure ratings. Hose length is set by the distance to the furthest knife. All other hoses should be the same length.

Hoses that feed knives toward the middle of the applicator should not be bent or crimped. Wrap the excess hose in a horizontal coil (say 1.5 feet in diameter) and attach it to the applicator.

Applicator Knives

The final consideration is the type of knives and tubes to use. When using a knife applicator, tubes release NH_3 horizontally out both sides of a tube attached to the rear of the straight knife shank *(Figures 7 and 8a)*. Directing NH_3 to the side of the knife opening places NH_3 in contact with a larger volume of soil.

Another common knife design is the vibrating shank (Figure 8b). This configuration reduces the potential for breaking a knife on rocks, tree roots or other obstructions in the soil. By vibrating, the shank reduces the opportunity for dragging crop residues in front of the knives shanks.

Figure 8a. Anhydrous ammonia applicator equipped with straight shank knifes.

Some operators use a cultivator or field cultivator to apply NH_3. When a cultivator is used, tubes are attached to the rear of cultivator sweeps *(Figure 8c)*. This allows the field to be cultivated and fertilized in one pass.

Figure 8b. Anhydrous ammonia applicator equipped with vibrating shank knifes.

Plugged knives are a common problem for NH_3 applicators. Typically the knife becomes plugged if these three conditions are met:

a) the flow valve is shut off, allowing no NH_3 to flow toward the knives,
b) the knife remains in the soil, and
c) the applicator direction is reversed (operator backs up).

Figure 8c. Anhydrous ammonia applicator equipped with behind cultivator sweep knives.

If the knives are removed from the soil as the unit is shut off and raised out of the soil, the knives rarely become plugged. However, if the operator stops at the end of the row, the applicator will tend to recoil backward, potentially plugging a knife outlet. An increase in manifold pressure of 5-10 psi should alert the operator that a line is plugged.

Calibrating NH_3 Applicators

When applying NH_3 application errors can result from either setting the application equipment incorrectly, or due to differences in application from one knife to another. Incorrect setting of the metering device will cause an error in the gross amount of NH_3 applied per acre. The calibration procedure discussed in the adjacent box will allow you to determine the gross application rate using a small amount of NH_3. You also can identify errors in gross application by carefully monitoring the number of acres treated per tank of NH_3.

The difficult error to quantify is the variation in application rate among knives. Remember that improper positioning of the manifold can affect the mixture of gas and liquid distributed to each knife. Other factors include steepness of side slopes, friction loss or back pressure in distribution lines, and the size of opening or orifice at the knife. The only way to accurately determine the distribution uniformity among knives is to do a water-can test.

Preliminary Data

The first step in calibrating an NH_3 applicator is to determine the amount of nitrogen needed per acre. This can be done using the procedure described in the NebGuide Guidelines for Soil Sampling, G91-1000 and the NebGuide Fertilizer Suggestions for Corn (revised in 1994), G74-174. These publications describe how to determine how much nitrogen fertilizer you should apply.

Tank Pressure

Determining Nitrogen Application Rates

Follow the seven steps outlined to determine the nitrogen application rate for your field and then determine the travel speed necessary for accurate application. If the speed is too high or too low, the right amount of nitrogen will not be applied. See Determining Nitrogen Application.

The second factor needed during the calibration process is nurse tank pressure. Nurse tank pressure is used to adjust regulator settings reported at a standard pressure of 100 psi. As was discussed earlier, increases in nurse tank pressure result in greater NH_3 application and vice versa. If the tank pressure is greater than 100 psi, the table value must be multiplied by a factor less than 1.0. If the tank pressure is less than 100 psi, the table value is multiplied by a factor greater than 1.0.

Tank pressures rise due to increases in NH_3 temperature caused by absorption of heat from the sun. As application begins early in the morning, the sun has little impact on nurse tank temperature. However, in the afternoon, the sun can raise the temperature of NH_3 enough to cause the NH_3 pressure to rise.

The pressure gauge mounted on the tank should be used to monitor changes in pressure due to temperature. The pressure gauge should have gradations in 10 psi intervals or less. It is desirable to obtain an estimate of tank pressure to the nearest 5 psi. If the tank pressure is different from 100 psi, apply the correct adjustment factor provided by the equipment manufacturer.

One way to monitor the change tank pressure is to mount a pressure gauge on the manifold. Since the regulator is designed to maintain a set pressure at the orifice, manifold pressure is an direct indicator of nurse tank pressure. If the gauge is mounted so it is visible from the tractor, the operator can monitor the manifold pressure during the day. The regulator should be adjusted if the manifold or tank pressure changes more than 10 psi.

While it is tempting to mount the manifold pressure gauge in the tractor cab because it is easier to monitor there, NH_3 could be discharged into the tractor cab should the pipeline or pressure gauge fail. **For safety, always mount the gauge on the manifold and outside the tractor cab**.

Anhydrous ammonia is a caustic and corrosive chemical. Purchase a pressure gauge with a pressure range of 0-150 psi when mounted on the manifold and 0-400 psi if mounted on the tank. NH_3 gauges are typically made of stainless steel and should be liquid filled to withstand equipment vibrations and short pulses in pressure caused by movement of NH_3 in the nurse tank. A pulse dampener can reduce the chance of gauge failure due to these problems. Gauges should be examined regularly to ensure accurate operation and to check for corrosion. Replace gauges when necessary.

Applicator Width

Applicator swath width is the third piece of information required to adjust the regulator. When combined with travel speed, swath width determines the area treated per unit time.

Swath width depends on the number of knives and the spacing between the knives. Other factors include whether the outside knives are overlapped, or if an extra space is left between two passes with the applicator *(Figure 9a and 9b)*.

For example, if a preplant application is conducted without overlapping the two outside knives, the swath width is equal to the number of knives multiplied by the spacing between knives *(Figure 9a)*. If 8 knives are mounted on a tool bar 30 inches apart, the swath width would be 240 inches (20 feet).

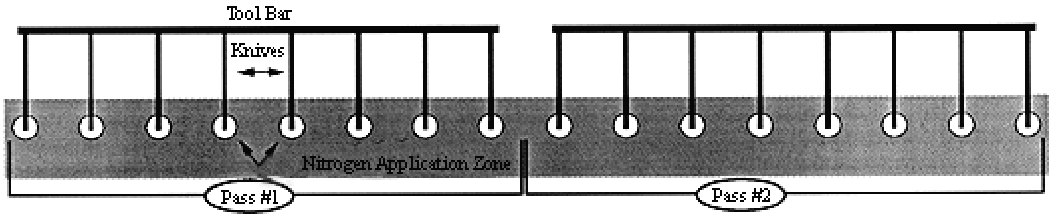

Figure 9a. Two passes of an 8-knife applicator without overlap of outside knives suitable for preplant applications.

If you overlap the two outside knives *(Figure 9b)*, the swath width would be the number of knives minus 1, multiplied by the knife spacing. Seven knives mounted on a tool bar 30 inches apart result in a swath width of 180 inches (15 feet) [(7- 1) x 30" = 180 inches].

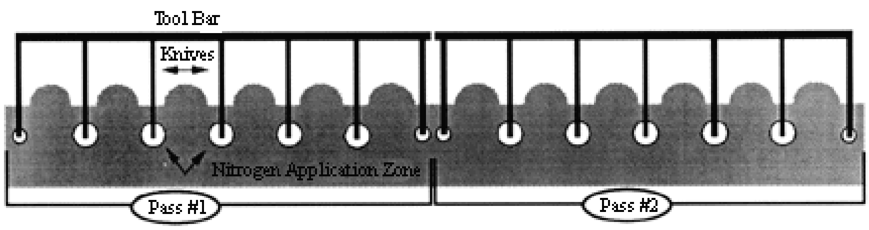

Figure 9b. Two passes of a 7-knife applicator in a field planted with a six-row planter showing overlap of two outside rows.

When the two outside knives are overlapped, flow delivered to the two outside knives must be half that supplied to the other knives because the area is covered twice. If the flow rate were equal for all knives, the application would be doubled where the knives were overlapped.

A typical way to divide flow in half is to install one manifold outlet for both outside knives. Then place a "T" in the line and run a single delivery hose to each outside knife.

Check the spacing between each pair of knives. The impact of knife spacing isn't very significant when spacings differ by an inch or two, but the equipment is designed to have equal spacings. If the spacings differ, adjust the knife spacings so all are equal. Record the applicator swath width in your field book so it's available for future use.

Adjusting the Applicator

The next step depends on which type of application equipment is being used. An applicator equipped with a variable size orifice should come with a set of tables for adjusting the flow rate through the regulator. Locate the table developed for the swath width of your applicator (let's use 30 feet).

The table will commonly have speed of travel in the first column on the far left *(Table II)*. Desired nitrogen application rates are listed across the top of the table. Locate the measured speed of travel in the first column and move horizontally to the column that is labeled closest to the desired application rate.

Table II. Regulator settings for a 30' applicator operating at a tank pressure of 100 psi.								
Travel Speed	**Desired nitrogen application rate (pounds nitrogen per acre)**							
(mph)	75	80	100	120	140	150	160	180
4.0	1,091	1,164	1,454	1,745	2,036	2,182	2,327	2,618
4.5	1,227	1,309	1,636	1,963	2,291	2,454	2,618	2,945
5.0	1,364	1,454	1,818	2,182	2,545	2,717	2,909	3,272
5.5	1,500	1,600	2,000	2,400	2,800	3,000	3,200	3,600
6.0	1,636	1,745	2,182	2,618	3,054	3,272	3,491	3,927
6.5	1,773	1,891	2,363	2,836	3,309	3,545	3,781	4,254
Remember: This table is specifically for application equipment with a 30' swath width adapted from a Continental Products Catalog. Multiplication factors are provided to convert the regulator setting should the nurse tank pressure be different than 100 psi.								

Knife-to-Knife Variation

The only way to evaluate knife-to-knife variation is through a water-can test. Not all applicators need to be tested in this manner. It may be easier to replace outlet tubes and distribution hoses on an annual basis. However, if you are interested in knowing how variable the distribution is, the procedure is summarized here.

Calculating Regulator Dial Setting

To get the most accurate nitrogen application possible, it's important to correctly calculate and set the regulator dial. Sometimes that may require interpolating between two settings. See Calculating Regulator Dial Setting for more information.

A water-can test should be conducted with all knives having identical components (i.e., hose length, knife opening, type of knife, and manifold outlets). knives with different components usually will result in different application rates. Be certain that all knives have the same components and that the components are in good operating condition. **Prevent accidents —** replace components regularly. If you rent an applicator, request that the applicator have the same components on each row.

The test should be conducted with the applicator positioned so that all knives are as level as possible. This ensures that elevation differences do not contribute to variation among the knives. Differences in knife distribution would therefore be due to the application system and not other factors.

Unfortunately, the errors due to the impact of side slopes cannot be corrected without regulating NH_3 flow to individual knives. Though individual control is possible, it is not economical.

Monitoring Application

With the regulator set and the knife-to-knife output fine tuned, your job will be easier, but not over. Changes in tank pressure can alter the application rate, so the pressure gauge should be monitored closely. Adjust the regulator if the pressure changes by more than 10 psi. Try to keep the application rate within 5 percent of your intended rate.

Double check your application rate by monitoring the acres covered with each tank. If possible, measure row lengths in several portions of the field and record them in your field record book. Keep track of the number of passes made with the tank and estimate the total acres treated.

When you return the tank or have it refilled, ask for the amount of NH_3 used and divide the amount used by the number of acres treated. Finally, multiple the NH_3 application rate by 0.82 to get pounds of nitrogen delivered. Record this number for the appropriate field area in your field record book. Recording these data could help you explain differences in crop appearance and yield later in the season. If the pounds of NH_3 delivered remains relatively constant, you can be assured that you are doing your best to apply NH_3 uniformly.

Equipment Maintenance

Anhydrous ammonia is a very corrosive substance. Even the most well-desired components used with it require regular maintenance and replacement. Each type hose has an expected lifetime set by the manufacturer. The main delivery pipeline is a multi-layered rubber hose with rayon, nylon/kevlar, or stainless steel braiding woven between two of the layers. Anhydrous ammonia will cause the hose to deteriorate over time.

The operator should inspect the hose prior to each use. If any cuts, cracks, bulges or unusual wear spots are noted, the hose should be replaced. Likewise, if the end couplers are loose, or if the fittings have been flattened, the hose should be replaced regardless of age. As a general rule, the hose should be replaced at least once every 2 to 3 years, depending on whether the type of braid material is rayon or stainless steel.

System leaks often can be traced to loose fittings around the delivery tubes, split hoses, or a partially plugged control valve. Loose fittings maybe a sign of a bad or failed clamp that may require little disturbance to allow the delivery hose to easily become disconnected, spraying NH_3 in a hazardous manner. If leaks are detected, be sure to allow ample time for all of the NH_3 to vent into the atmosphere. Complete venting requires that all portions of the line be open to the atmosphere and no liquid NH_3 is present. Remember that liquid NH_3 has enough cooling power to prevent the transition of liquid NH_3 to a gas.

If the regulator becomes frosted over, the location of frost can be indicative of the problem. For instance, the Continental Products Company's maintenance information indicates that frost occurring on the upper body of the regulator excluding the union nut can result due to three problems:

a) the strainer could be plugged,
b) the diaphragm could be ruptured, or
c) there is a restriction in the meter-barrel.

In each case, instructions are provided to make the appropriate repairs.

Knife distribution tubes *(Figure 4)* may become worn or bent, causing them to discharge more or less than the desired NH_3 application rate. The discharge orifices also may become worn, increasing the outlet diameter. Larger orifice diameters result in reduced back pressure and increased application rates. A properly sized drill bit can be used to check the orifice diameters. If the orifice size has increased, replace the tube.

One of the most common problems encountered by NH_3 distribution systems is rust or metal flakes from the nurse tank becoming lodged in valves, strainers, flow controllers and manifolds. A properly installed and maintained strainer should limit most of these problems. Occasionally flakes large enough to limit valve operation pass though the strainer. Therefore, for safety, never assume that valve closure eliminates NH_3 flow. Some NH_3 may leak past a partially fouled valve.

Metal flakes may come from the supplier or from inside the NH_3 nurse tank. Should metal flakes enter the delivery line, some components may require cleaning on a more regular basis. For example, check the strainer every couple days.

Extreme caution should be used whenever disassembling NH_3 equipment. Be sure the main valve on the tank has been securely closed and that all the NH_3 contained in the distribution system has been vented to the atmosphere before disassembling any of the components. Remember that some portions of the delivery system may be isolated from the rest of the line by control valves. Treat each portion of the system like it contains high pressure NH_3.

To ensure that leaks do not result from maintenance practices, the same care should be used when putting the parts back together. Use a gasket or joint sealant material specifically made for use with NH_3 systems. Other forms of joint sealant cannot withstand the chemical degradation caused by anhydrous ammonia.

When the equipment has been cleaned and reassembled, the regulator should be flushed with water and stored in a warm, dry place during the off-season. Take care to protect the regulator from dust and moisture. Components left outside should be protected to make sure dust cannot enter any open pipelines.

Moving parts of all valves and couplers should be lubricated with a small amount of oil to make sure they remain in safe operating condition. This is particularly important when preparing the equipment for off-season storage.

Similar care should be given to the electronic control box if one is installed. Record the controller settings before unhooking the battery. Store this information so that it is readily available for the next season. Store the control box in a warm, dry area during the off-season.

Summary

To apply NH_3 accurately and uniformly, the operator must take steps to ensure that application equipment has the proper components and to monitor the output under different atmospheric conditions. Successful applicators:

a) determine the amount of NH_3 to apply using good nitrogen management practices;
b) record some preliminary field data such as travel speed and row lengths;
c) begin with a system equipped with identical components for each row;
d) set the regulator or controller based upon the swath width and travel speed;
e) check the application rate to verify that it is within 5-10 percent of the intended rate;
f) install a pressure gauge to monitor manifold pressure from the tractor cab,
g) check the NH_3 application rate for each nurse tank used;
h) perform regular maintenance to maintain all components in good operating condition; and,
i) practice good safety habits when working with NH_3 equipment.

Operators who exhibit care when setting the equipment properly and diligence when monitoring the equipment ensure that the application rate is near the intended rate, reduce the potential for environmental problems, and minimize crop production costs while ensuring economical yields.

More information on recommended nitrogen management practices can be found in the following publications. contact your Extension Office for more information:

G91-1000	*Guidelines for Soil Sampling*
G74-174	*Fertilizer Suggestions for Corn (1994 revision)*
EC 91-735	*The Impact of Nitrogen and Irrigation Management and Vadose Zone Conditions on Groundwater Contamination by Nitrate-Nitrogen*
EC 90-2502	*Perspectives on Nitrates*
Video	Copies of the video tape *Calibrating Anhydrous Ammonia Applicators* are available for $29.95 plus $2 shipping and handling from IANR Communications and Information Technology, 207 Agricultural Communications Bldg., P.O. Box 830918, University of Nebraska-Lincoln, Lincoln, NE 68583-0918.

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