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Ammonia as a source of nitrogen

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AMMONIA
AS A SOURCE OF NITROGEN

Applying anhydrous ammonia before planting cotton.

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AGRICULTURAL EXPERIMENT STATION
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Anhydrous ammonia is the cheapest source of nitrogen available. The pressure which anhydrous ammonia exerts varies with the temperature and reaches 197 pounds per square inch at 100° F. This high pressure is not dangerous provided the equipment contains the necessary safety devices.

Anhydrous ammonia may be diluted with water to form a 25 to 30 percent solution of ammonia which exerts little or no pressure except with high summer temperatures, and then only a low pressure is obtained. Anhydrous ammonia and solutions of ammonia have equal value for crop production.

In experimental work anhydrous ammonia and solutions of ammonia (aqua ammonia) have been found to have crop producing value equal to or superior to ammonium nitrate for row crops. Where the application of nitrogen at depths of 4 to 6 inches is superior to shallower applications, ammonia may be applied at these depths more easily than can solid sources of nitrogen.

For small grains ammonia is a good source of nitrogen; however, there are problems connected with its application in the spring to fall-planted small grains which may limit its use. When applied in February anhydrous ammonia has usually been superior to ammonium nitrate.

Ammonia will kill germinating seed if it comes in contact with them. In a few known cases farmers have applied ammonia in the zone where the seed were later placed and poor stands of cotton resulted. However, where ammonia has been placed 4 to 6 inches below the planting depth of the seed no injuries to the germinating seed have been obtained in our tests.

The data on crop response to ammonia and information on the equipment for applying it were made available on March 7, 1947. In Mississippi alone, anhydrous ammonia was applied to over 200,000 acres in 1947, and to more than 500,000 acres in 1948. Its use has moved into Alabama, Arkansas, Louisiana, and Tennessee. Aqua ammonia is used to a small extent in Mississippi and Florida.

With the equipment which is now in use for applying anhydrous ammonia and solid sources of nitrogen, farmers apply anhydrous ammonia with one man and a tractor to a considerably larger acreage than they fertilize with two men and a tractor, using solids. The acreage covered per day with anhydrous ammonia usually varies from 25 to 40 acres; however, many farmers report fertilizing larger acreages with anhydrous ammonia.

Both anhydrous ammonia and aqua ammonia are suited for pre-planting or side-dressing applications. Anhydrous ammonia has been applied in the following operations by farmers in the Mississippi Delta:

(1) Before planting on level land. (2) Before planting on bedded land. (3) Before planting and bedding simultaneously with listers. (4) As a side dressing.

Nitrogen as anhydrous ammonia moves very little when applied to the soil, before it is converted into nitrates, which takes about six weeks in the spring. It is therefore necessary for it to be applied in the root zone, or where the roots will reach it within a short time if plants are to respond to it immediately. For this reason the distance from the plants at which anhydrous ammonia should be placed varies with the age of the plants. Young cotton grows very slowly as compared to young corn, and placing anhydrous ammonia close to the young plants is more essential for cotton than for corn.

This bulletin is a revision of Bulletin 448 published by the Mississippi Agricultural Experiment Station in June, 1947.

Ammonia as a Source of Nitrogen

By W. B. ANDREWS, F. E. EDWARDS, and J. G. HAMMONS[1]

During the past 100 years nitrogenous fertilizers have come into general use; prior to this time nitrogen was derived from animal manures, green manure crops, and legumes grown in rotation.

The first source of commercial nitrogen was Chilean nitrate of soda, after which by-product nitrogen was obtained from coking of coal, and since the early part of this centrury nitrogen has been obtained synthetically from the air.

There are three synthetic nitrogen processes in which nitrogen from the air is used in making nitrogenous fertilizers. They are: (1) the cyanamid process in which nitrogen is made to react with calcium carbide, (2) the nitrate process in which nitrogen and oxygen are united in an electric arc, and (3) the synthetic ammonia process in which nitrogen and hydrogen are combined under high pressure. All of the new synthetic nitrogen plants use the ammonia process because it is much cheaper than the other processes.

In the most recent synthetic ammonia plants, hydrogen is derived from natural gas and steam, and the nitrogen is obtained from the air. The final mixture of three volumes of hydrogen and one of nitrogen is compressed under a pressure of about 5,000 pounds per square inch in the presence of iron rust, which speeds up the formation of ammonia from these two gases.

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P. H. Grissom, John Pitner, William E. Meek of the Delta Branch Experiment Station, S. P. Crockett of the North Mississippi Branch Experiment Station, and J. Clyde Edwards of the Central Station, cooperated in collecting crop data included in this report.

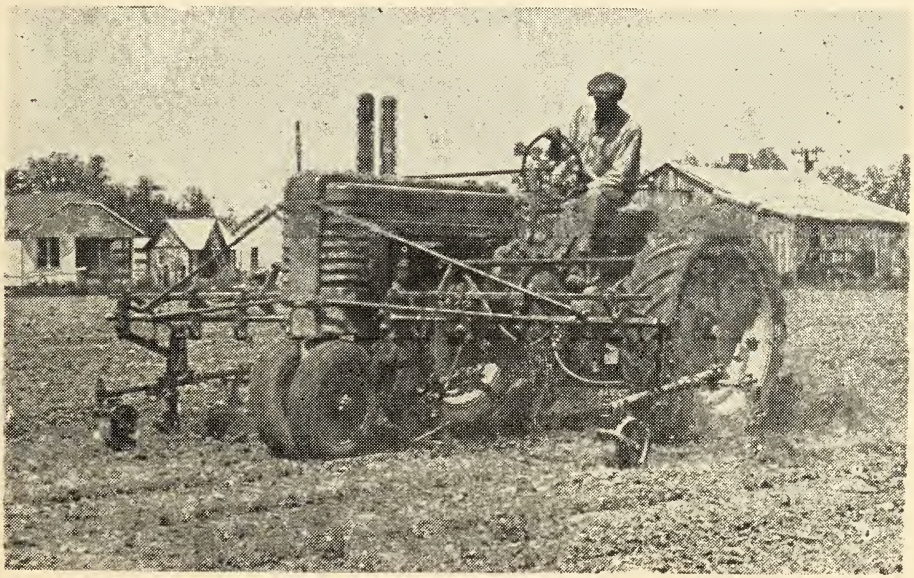

Figure 1. Side dressing cotton with anhydrous ammonia. Note relation of sweep to applicator.

At the present time most synthetic ammonia is converted into ammonium nitrate before it is used for fertilizer. In making ammonium nitrate about one half of the ammonia is burned over a platinum gauze and combined with water to make nitric acid. The nitric acid is combined with ammonia to make ammonium nitrate, which is dried, grained, treated with a mixture of rosin, paraffin, and paraffin oil, coated with clay, and packed in moisture-proof bags. In the process of making ammonium nitrate from ammonia, about 7 percent of the nitrogen is lost.

With a relatively cheap price on natural gas, the cost of producing a ton of anhydrous ammonia containing 1640 pounds of nitrogen is about the same as the cost of producing a ton of ammonium nitrate containing 650 pounds of nitrogen.

The retail price of nitrogen in the different sources in 1948 was approximately as follows:

Source	Cost of one pound of nitrogen
Nitrate of soda	16 cents
Cyanamid	15 cents
Ammonium nitrate	9.5 to 10 cents
Anhydrous ammonia	6 to 7.3 cents

Since the cost of nitrogen as ammonia is much less than its cost in the materials usually used to supply nitrogen, work was started by the Mississippi Agricultural Experiment Station in 1943 to determine its value as a source of nitrogen, and to develop equipment for applying it to the soil. The research program has been supported jointly by the Mississippi Agricultural Experiment Station and the Tennessee Valley Authority.

Four years were spent in research on the use of anhydrous and aqua ammonia before the information was released to farmers. During this period anhydrous and aqua ammonia were compared to ammonium nitrate in a large number of tests in which the response of corn, cotton, and oats to ammonia compared favorably to that obtained with ammonium nitrate.

During the period that the tests were being conducted on the crop producing value of anhydrous and aqua ammonia, the equipment for their application was being developed, improved, and adapted for use by farmers.

In March of 1947 after sufficient information had been obtained to prove that anhydrous and aqua ammonia are good sources of nitrogen, and after good equipment had been developed for their application on the farm, information concerning their value and on equipment for handling and applying them to the soil was released to the farmers of Mississippi.

During the 1947 crop year, Mississippi farmers fertilized over 200,000 acres with anhydrous ammonia and a few thousand acres with aqua ammonia. Its use also moved to Arkansas and Louisiana in 1947. In 1948, the farmers of Mississippi applied anhydrous ammonia to approximately 500,000 acres of crop land. Its use is increasing in Arkansas and Louisiana. Other states which will use anhydrous ammonia in 1948 are Alabama, Tennessee, and Illinois. As a result of our work the use of anhydrous ammonia is also moving into other countries.

The acceptance of anhydrous ammonia by the farmers of Mississippi is shown by the fact that the present storage capacity is 282 carloads, which is expected to increase to at least 363 cars by June and 403 cars by August. One carload contains enough nitrogen for 1,000 acres when applied at the rate of 43 pounds of nitrogen per acre. The 403 carload storage capacity is sufficient for 403,000 acres for each filling.

Properties of Anhydrous Ammonia

Anhydrous ammonia contains 82 percent nitrogen. It weighs 5 pounds per gallon and contains 4.1 pounds of nitrogen per gallon.

AMMONIA AND FUELS FORM DEADLY POISON

Recent experiments at State College show that when a mixture of anhydrous ammonia and butane or propane is burned, hydrocyanic acid, which is very poisonous, is formed. Propane or butane, which is to be used for household purposes, should not be put into tanks which have been previously used for anhydrous ammonia unless the ammonia is completely removed.

Ammonia may be completely removed from tanks by first draining the liquid ammonia and then blowing the fumes out or filling the tanks with water, which will absorb the ammonia, and draining. No odor of ammonia should remain in tanks which are to receive household butane or propane.

—Marvin Gieger, Chemist.

Anhydrous ammonia is a gas at at-nospheric pressure and normal tempera-ures. At 28 degrees below zero Fahren-ieit and lower, it exists as a liquid at ıtmospheric pressure. At 50° F. anhy-lrous ammonia has a pressure of 75 ›ounds per square inch, and the pressure ncreases to 197 pounds per square inch at .00° F.

In commerce, anhydrous ammonia is ıandled as a liquid under pressure. The :ontainers for handling anhydrous am-nonia require the necessary strength to ıold the high pressures.

Propane and butane tanks are customarily fitted with brass fittings. Pure anhydrous ammonia attacks brass very little, but where a little moisture is present, the brass is corroded rapidly. The fittings for anhydrous ammonia equipment should always be iron or steel, which would make it necessary to change the brass fittings to iron or steel before using propane tanks for anhydrous ammonia.

Ammonia is not considered inflammable, but it is possible to get a mixture of ammonia and air which will ignite at high temperatures. Welding should not

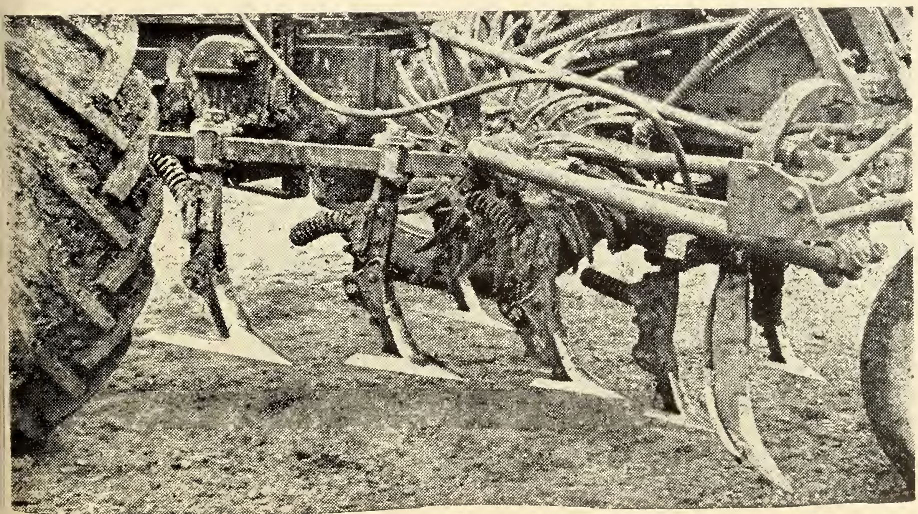

Figure 2. Anhydrous ammonia equipment mount, in addition to two-row cultivating equipment. Note ammonia applicator, and rotary hoe for preventing the covering of small plants.

be done on tanks which contain ammonia, due to the possibility of getting an explosion.

In low concentrations ammonia is very irritating to the nose, eyes, mouth, throat, and lungs. It will blister the skin. Water should always be available for washing off any ammonia which comes in contact with the body. Gas masks, tight fitting goggles, and rubber gloves should be available where the danger warrants them. The safety equipment needed with different types of ammonia is listed on page 18. The tight fitting goggles should be worn at all times while working with ammonia.

Purity of Anhydrous Ammonia

Anhydrous ammonia should be over 99 percent pure ammonia. A general idea concerning the purity of ammonia may be obtained by collecting a quart jar full of the ammonia and permitting it to evaporate. Evaporation can be speeded up by surrounding the open jar with water. Care should be taken to avoid water getting into the ammonia because it will cause the ammonia to splatter.

When the ammonia stops bubbling off, water containing 25 to 30 percent ammonia should be present only in the depressions of the bottom. If the bottom should be covered, water is indicated and the state fertilizer inspector should be contacted.

Properties of Aqua Ammonia

At ordinary temperatures anhydrous ammonia may be diluted[2] with water to make solutions containing up to about 30 percent ammonia. In the fertilizer trade these solutions usually contain 27 to 31 percent ammonia, which is equivalent to 22 to 25 percent nitrogen. These solutions are usually sold on the basis of analysis without being standardized to a definite percentage of ammonia.

Aqua ammonia containing 30 percent ammonia exerts no pressure below 70° F.. At 110° F. a pressure of 10 pounds per square inch is exerted. A 30 percent solution of ammonia contains 24.6 percent nitrogen. One gallon weighs 7.4 pounds and contains 1.85 pounds of nitrogen.

Aqua ammonia attacks brass and copper readily, and all fitting and equipment should be made of iron, steel, and ammonia-resistant hose.

The same precautions about personal contact and first aid treatment are necessary with aqua ammonia as with anhydrous ammonia.

Crop Response to Ammonia And Ammonium Nitrate

When anhydrous or aqua ammonia is applied to the soil, the ammonia goes into solution in the soil water. The ammonia is absorbed almost immediately from the soil water by the clay and organic matter. When ammonia is absorbed by clay and organic matter, the products formed are ammonium clay and ammonium organic matter. These ammonium products are solids, just as ammonium nitrate and sulphate of ammonia are solids.

When ammonia is applied to soils, it readily goes on the clay particles in place of hydrogen. When applied well below the surface it is held by the clay and organic matter even though free lime is present. The authors have encountered no sandy soils with too little clay to absorb the ammonia applied at the rate of 32 pounds of nitrogen per acre and at a depth of four inches with the applicators spaced 38 to 42 inches apart. Where very high rates of nitrogen as ammonia are to be applied to extremely sandy soils, it may be desirable to increase the depth of application to 8 or 10 inches or to increase the number and thereby decrease the spacing of ammonia applicators.

Ammonia is a gas at ordinary temperatures and atmospheric pressure. In order that it not be lost, it is necessary that either anhydrous ammonia or aqua ammonia be applied 4 inches or more deep and covered simultaneously. Am-

[2]Requires special equipment.

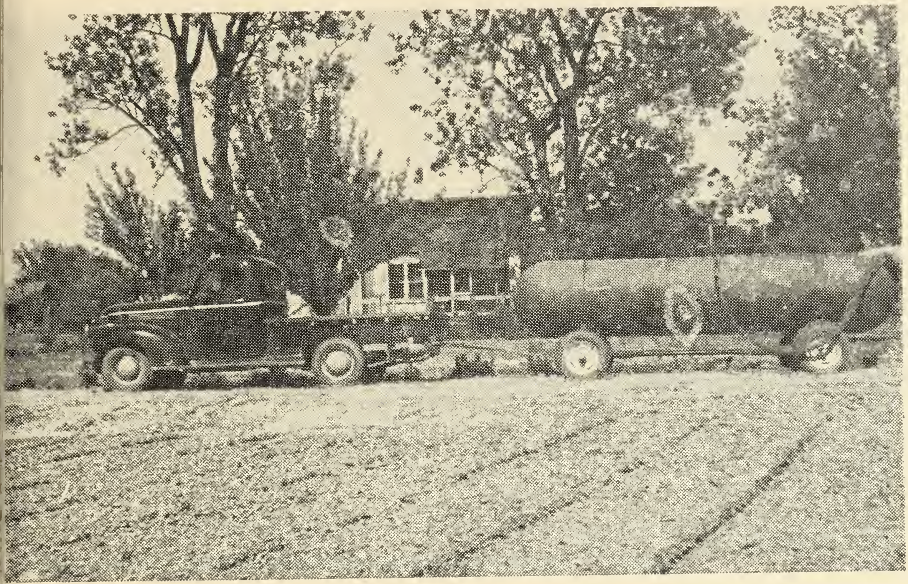

Figure 3. Moving 4,100 pounds of nitrogen as anhydrous ammonia with a pick-up truck.

nonia cannot be applied to the surface f the soil nor in sprinkling irrigation ystems without excessive loss of ammonia.

Ammonia which is in ammonium clay nd ammonium organic matter does not each out of the soil; however, it is ufficiently soluble to supply crops with itrogen.

During warm weather most of the mmonium nitrogen is converted into itrate nitrogen within 4 to 6 weeks in oils which have a good supply of lime nd which are well aerated. With colder veather, with wet soils which are poorly erated, and in soils low in lime, the ate of nitrification is much slower.

Young corn and cotton plants prefer mmonium nitrogen to nitrate nitrogen, nd they grow off more rapidly when mmonium nitrogen is available than when the source of nitrogen is nitrate itrogen. Since young corn grows off much more rapidly than young cotton, the preference for ammonium nitrogen is much more noticeable with corn than with cotton. Even though the preference of young cotton for the ammonium form of nitrogen is much less marked than the preference of young corn, it has been definitely established that the preference is real.

In general, older plants prefer nitrate nitrogen to the ammonium form. However, in our side-dressing experiments anhydrous ammonia has been slightly superior to ammonium nitrate for corn, and essentially equal to it for cotton. It should be pointed out that cotton was usually side-dressed by the time of the second plowing, and corn by the time it was knee high. When only nitrogen is considered, a pre-planting application of ammonia, which supplies young plants with this form of nitrogen and the unused part of which is changed in the soil to the nitrate form for older plants, appears ideal.

Where the preference of young plants for the ammonium form of nitrogen is to be taken advantage of to give young plants a quick start, it is necessary that it be applied immediately before planting or before the plants have made much growth. If ammonia is applied several weeks in advance of planting on fertile soils, it is converted into the nitrate form before the young plants use it.

When crops are exposed to the fumes of ammonia the leaves are killed; however, the buds are usually not injured and growth continues. Young cotton plants may be completely killed by ammonia fumes. In side-dressing with either anhydrous or aqua ammonia, it is necessary that it be applied and covered in such a manner that plants are not exposed to the fumes. It is therefore doubly desirable that ammonia be properly applied, for noticeable fumes mean also that nitrogen is being lost.

It is desirable for either anhydrous or aqua ammonia to be applied where it is to stay; however, farmers may sometimes find it desirable to replow land to which ammonia has been applied. After ammonia has been in the soil for four days, no loss of nitrogen should occur on plowing it up. If ammonia is applied 5 to 6 inches deep in side-dressing, it will not be disturbed by ordinary cultivation.

Tests with Corn and Cotton

Data are reported on 19 tests with cotton in which anhydrous ammonia and ammonium nitrate were compared for pre-planting and side-dressing cotton, using different depths of application. There were six replications of each treatment. In addition, data are reported for seven side-dressing tests with only three treatments conducted on a dry year. Data for four tests in which the fertilizers were applied before planting are also reported. There were four replications of each treatment in the last two sets of tests.

Anhydrous ammonia and ammonium nitrate were compared with depth of application as a variable in 13 side-dressing tests, and in five tests where the treatments were applied both before planting and as a side-dressing. There were six replications of each treatment in these tests. In addition, there were eight side-dressing tests with only three treatments and four replications conducted on a dry year.

Data are reported for a total of 30 tests with cotton and 26 tests with corn.

Tests with Oats

Anhydrous ammonia and ammonium nitrate were compared for the production of oats for grain and for forage. Ten tests were conducted on oats for grain in 1945-1946, and six tests for grain were conducted in 1946-1947. Three tests were conducted on oats for forage in which grain yields were obtained in 1946-1947. Where oats were planted for grain the ammonia applicators were spaced 15 inches apart; where they were planted for forage the applicators were spaced 12 inches apart.

There were four replications of each treatment. The oats planted for forage were clipped with a small power mower during the first week in December, and the third week in February. The grain was harvested with a combine.

THE RESPONSE OF COTTON TO ANHYDROUS AMMONIA AND AMMONIUM NITRATE

During 1945, 1946, and 1947 nineteen tests were conducted with cotton in which anhydrous ammonia and ammonium nitrate were applied before planting, using two depths of application of anhydrous ammonia. The data are reported in table 1. The data for eighteen of the tests were averaged. In these eighteen tests the following data were obtained for anhydrous ammonia and ammonium nitrate applied before planting at the rate of 32 pounds of nitrogen per acre:

Source of nitrogen	Depth of application	Increase in yield, pounds seed cotton per acre
Ammonium nitrate	4″	277
Anhydrous ammonia	4″	354
Anhydrous ammonia	6″	392

At the 4-inch depth of application before planting, anhydrous ammonia produced an average increase in yield of 354 pounds of seed cotton per acre as compared to 277 pounds for ammonium nitrate. The superiority of anhydrous ammonia is attributed to less leaching of nitrogen during the first eight weeks after application.

The 6-inch depth of application of anhydrous ammonia produced an average of 48 pounds more seed cotton than the 4-inch depth of application in the 18 tests. The superiority of the 6-inch depth of application of anhydrous ammonia is attributed to this depth of application being more favorable for cot-

Table 1. The response of cotton to anhydrous ammonia and ammonium nitrate at several locations in 1945, 1946 and 1947.

Location	Source of nitrogen, pounds per acre, depth of application in inches, and time of application								
	Ammonium nitrate 32 lbs. 4″ preplant	Anhydrous ammonia 32 lbs. 4″ preplant	Anhydrous ammonia 32 lbs. 6″ preplant	Anhydrous ammonia 32 lbs. 4″ side dress	Ammonium nitrate 32 lbs. 4″ side dress	Ammonium nitrate 32 lbs. surface side dress	Check no nitrogen	Anhydrous ammonia 64 lbs. 4″ preplant	Anhydrous ammonia 64 lbs. 6″ preplant
	Yield in pounds of seed cotton per acre								
Greenwood[1]	1310	1175	1432	1338	1433	1410	1013	1240	1303
Lambert	2160	2130	2443	2375	2370	2297	2013	2660	2607
Columbus	953	1150	1072	1100	1177	1143	703	1343	1180
Holly Springs	1907	1942	1923	1860	1875	2002	1433	2237	2240
Tomnolen	1485	1710	1720	1350	1470	1510	1130	1440	1380
Columbus	1263	1352	1507	1458	1302	1423	1120	1320	1453
Indianola	1593	1723	1707	1563	1503	1583	1523	1633	1663
Indianola	1785	1710	1690	1630	1725	1720	1205	1945	1860
Holly Springs	1270	1274	1412	1308	1264	1258	756	1362	1520
Lambert	2127	2353	2183	2190	2177	2073	1983	2313	2290
Starkville	1473	1568	1487	1487	1565	1472	1148	1455	1373
Tomnolen	1215	1265	1408	1228	1353	1188	755	1310	1323
Aberdeen	430	453	527	407	417	503	217	563	643
Clarksdale	2750	2888	2944	2514	2824	2620	2402	3024	3094
Roundaway	1426	1396	1572	1542	1264	1274	1216	1462	1538
Lambert	1130	1094	1102	1124	1068	1090	998	1144	1100
Morgan City	1352	1404	1478	1402	1460	1356	1100	1672	1718
Holly Springs	1023	1122	1080	947	1014	1048	863	1048	1076
Columbus	890	1080	1036	1082	1048	996	682	1052	944
Average 18 tests	1457	1534	1572	1476	1493	1475	1180	1610	1611
Average increase	277	354	392	296	313	295	.	430	431

[1]Omitted from average due to loss of ammonia in application at the 4-inch depth of application.

Table 2. The response of cotton to sources of nitrogen.

Source of nitrogen	Stoneville	Yazoo City	Money	Onward	Average	Increase
	Yield in pounds seed cotton per acre					
Anhydrous ammonia	2197	2206	1953	1528	1971	517
Ammonium nitrate	2262	2171	1989	1474	1974	520
Cyanamid	2102	2176	1962	1390	1908	454
Sulphate of ammonia	2133	2169	1950	1448	1925	471
Nitrate of soda	2291	2246	1917	1475	1982	528
No nitrogen	1727	1788	1464	838	1454	..

Average of 30, 45, and 60 pounds of nitrogen per acre.

Table 3. The response of cotton to side dressing with anhydrous ammonia and ammonium nitrate on a dry year.

Location	Source of nitrogen: Anhydrous ammonia 5 inches deep	Source of nitrogen: Ammonium nitrate surface
	Increase in yield, pounds seed cotton per acre	
Eupora	193	175
Marks	242 (305)[1]	92 (180)[1]
Shuqualak	258	104
Heathman	98	48
Stoneville	305	159
Stoneville	105	125
Yazoo City	207	225
Valley Hill	263	215
Holly Springs[2]	205[3]	201

[1]The first figures are for the first picking. The second picking was lost. The figures in parenthesis are based upon the first picking and boll counts.

[2]Preplanting application.

[3]Aqua ammonia.

ton, or possibly to a slower rate of nitrification which would result in less leaching of nitrogen.

Where anhydrous ammonia was applied at the rate of 64 pounds of nitrogen per acre, the depth of application did not affect the yield. In some tests 64 pounds of nitrogen produced considerably more seed cotton than 32 pounds; in others, it had little effect on the yield of cotton.

In the Greenwood test the soil was in such poor physical condition that the anhydrous ammonia was not completely sealed at the 4-inch depth of application, and it was inferior to ammonium nitrate; however, the 6-inch depth of application of anhydrous ammonia was superior to ammonium nitrate at the 4-inch depth.

In four tests in cooperation with the Delta Branch Experiment Station, Stoneville, anhydrous ammonia and ammonium nitrate made the same average increases in yield of seed cotton (table 2). Data are also reported in table 2 for sulphate of ammonia, cyanamid and nitrate of soda.

The data in table 1 show a comparison for anhydrous ammonia and ammonium nitrate applied to cotton as a side-dressing. The average for 18 tests with 98 side-by-side comparisons are as follows:

Source of nitrogen	Depth of application	Increase in yield, pounds seed cotton per-acre
Anhydrous ammonia	4″	296
Ammonium nitrate	4″	313
Ammonium nitrate	Surface	295

The side-dressing applications were usually made soon after the cotton was worked out the first time.

These tests were conducted in 1945, 1946, and 1947. The first two years were wet; the last year was wet until June 1, after which it was dry. The side-dressing applications were made while the cotton was still small. In these tests anhydrous ammonia made practically the same increase in yield as ammonium nitrate when both were applied 4 inches deep. The surface application of ammonium nitrate was also practically as good as the 4-inch depth of application.

In 1944 nine side-dressing tests were conducted with cotton in which anhydrous ammonia and ammonium nitrate were compared. The tests were usually put out during the first part of June after the cotton had made considerable growth. At several of the locations dry weather prevailed for several weeks after the fertilizers were applied. The anhydrous ammonia was applied about 5 inches deep, while the ammonium nitrate was applied on the surface and mixed with the surface soil by cultivation. The data reported in table 3 show that anhydrous ammonia applied 5 inches deep was much superior to surface-applied ammonium nitrate in several of the tests. The surface-applied ammonium nitrate was inferior because it did not get into the root zone.

Observations suggest that deep application of nitrogen applied as side-dressing is more important on heavy soils and where it is applied late.

THE RESPONSE OF CORN TO ANHYDROUS AMMONIA AND AMMONIUM NITRATE

Anhydrous ammonia and ammonium nitrate were compared in five tests in 1945 in which pre-planting and side-dressing applications were made. In 1945, 1946, and 1947 thirteen side-dressing tests were conducted. In these tests the depth of application was variable. In addition, eight other side-dressing tests have been conducted.

In the five tests where both pre-planting and side-dressing applications were made (table 4), there was little difference in the yield of corn for pre-planting and side-dressing applications. Pre-planting applications of nitrogen have an advantage in that corn grows off more rapidly and fewer cultivations are required.

In 18 side-dressing tests where anhydrous ammonia was compared to ammonium nitrate for corn production in 108 side-by-side comparisons (tables 4 and 5), the following data were obtained:

Source of nitrogen	Depth of application	Increase in yield, bushels of corn per acre
Anhydrous ammonia	4"	16.2
Ammonium nitrate	4"	14.3
Ammonium nitrate	Surface	13.1

The average of the 18 tests shows that anhydrous ammonia produced 1.9 bushels more corn than ammonium nitrate when applied 4 inches deep. The surface application of ammonium nitrate produced 1.2 bushels of corn less than the 4-inch depth of application. In a few cases surface-applied ammonium nitrate produced several bushels of corn less than that applied 4 inches deep, but on the average the difference was not large.

In one test conducted at Stoneville, anhydrous ammonia, ammonium nitrate, and nitrate of soda made practically the same increase in yield of corn.

In 1944 seven side-dressing tests were conducted with corn in which anhydrous ammonia applied 5 inches deep was compared to ammonium nitrate applied on the surface of the soil (table 6). The weather following the application of the fertilizer was very dry. As was the case with cotton, in most of these tests anhydrous ammonia was superior to ammonium nitrate. On one heavy soil, a heavy rain after the fertilizer was applied was not sufficient to carry the ammonium nitrate into the soil.

During this dry year there was sufficient difference in favor of a 5-inch placement of fertilizer as compared to surface application to warrant deep application at all times. Deep application of nitrogen used as a side-dressing becomes increasingly important as summer approaches when prolonged dry periods are frequent, and as side-dressing is delayed until crops are larger. Where crops are planted early and side-dressed early, depth of application is probably of little importance. However, ammonia must be applied 4 to 6 inches deep in order to cover it well enough to prevent loss.

Where depth of application of nitrogenous fertilizers is a factor in crop production, and with the equipment available for applying both liquid and solid sources of nitrogen, anhydrous and aqua ammonia may be applied at the deeper depths more easily than solid sources of nitrogen.

Table 4. The response of corn to anhydrous ammonia and ammonium nitrate, 1945 and 1946.

Location	Ammonium nitrate 32 lbs. 4" preplant	Anhydrous ammonia 32 lbs. 4" preplant	Anhydrous ammonia 32 lbs. 6" preplant	Anhydrous ammonia 32 lbs. 4" side dress	Ammonium nitrate 32 lbs. 4" side dress	Ammonium nitrate 32 lbs. surface side dress	Check no nitrogen	Anhydrous ammonia 64 lbs. 4" preplant	Anhydrous ammonia 64 lbs. 6" preplant
	Yield in bushels of corn per acre								
Columbus	24.2	28.3	27.8	27.4	27.8	28.5	12.1	38.9	37.7
Starkville	21.8	26.0	29.1	34.6	28.7	26.2	12.4	38.4	40.2
Tomnolen	55.3	56.1	55.9	57.8	55.3	54.6	42.8	60.6	61.8
Holly Springs	82.8	84.6	82.5	79.1	79.5	80.6	69.9	84.8	77.8
Holly Springs	66.3	60.5	66.7	69.5	62.3	63.7	56.0	72.8	69.8
Average	50.1	51.1	52.4	53.7	50.7	50.7	38.6	59.1	57.5

Table 5. The response of corn to anhydrous ammonia and ammonium nitrate applied as a side dressing: 1945, 1946, and 1947.

Location	Check no nitrogen	Anhydrous ammonia 32 lbs. 6" deep	Anhydrous ammonia 32 lbs. 4" deep	Ammonium nitrate 32 lbs. 4" deep	Ammonium nitrate 32 lbs. surface	Anhydrous ammonia 64 lbs. 4" deep	Anhydrous ammonia 64 lbs. 6" deep
	Yield in bushels per acre						
West Point	54.1	59.2	60.3	58.2	59.6	68.3	65.4
State College	61.8	75.9	73.2	73.8	68.6	79.8	84.8
State College	33.8	41.4	37.3	40.8	35.2	43.5	47.2
Starkville	11.7	34.6	33.8	28.1	27.4	39.4	40.1
Columbus	13.6	37.1	36.1	34.2	35.1	46.2	49.9
Aberdeen	19.3	44.1	42.3	40.6	35.2	54.0	51.4
Columbus	5.6	34.3	34.7	33.0	33.9	48.4	47.6
Starkville	40.3	46.2	47.0	48.8	50.9	56.3	57.4
Columbus	22.2	42.9	44.4	46.3	39.3	50.5	53.9
Sessums	37.0	47.7	46.5	40.5	43.1	60.7	58.1
New Hope	31.2	51.6	52.3	50.2	46.9	54.7	59.0
Columbus	18.6	46.7	45.6	43.7	44.1	56.9	57.9
Columbus	11.0	22.7	22.8	17.7	16.6	19.4	19.8
Average 13 tests	27.7	45.0	44.3	42.8	41.2	52.2	53.3
Average increase		17.3	16.6	15.1	13.5	24.5	25.6

Table 6. The response of corn to side dressing with anhydrous ammonia and ammonium nitrate on a dry year.

Location	Anhydrous ammonia 5 inches deep	Ammonium nitrate surface
	Increase in yield, bushels corn per acre	
Eupora	10.8	8.2
Marks	5.6	2.2
State College	12.5	8.6
State College	13.8	4.5
Tomnolen	13.4	13.0
Shuqualak	6.2	3.4
Valley Hill	10.0	7.2
Holly Springs[1]	6.8[2]	7.4

[1] Preplanting application.

[2] Aqua ammonia.

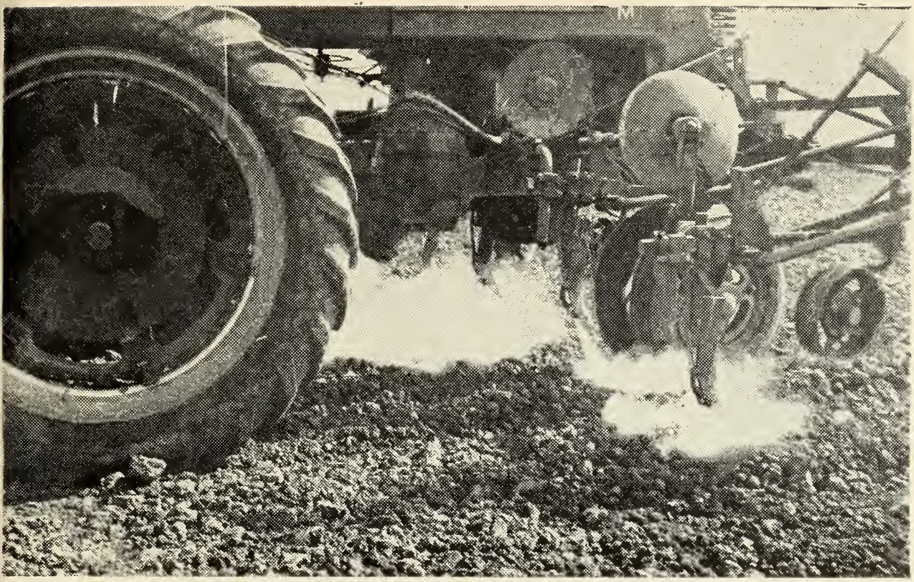

Figure 4. Checking applicators to see that all of them are applying anhydrous ammonia. Note the fog of ammonia, which is not present when the applicators are moving in the soil.

THE RESPONSE OF OATS TO ANHYDROUS AMMONIA AND AMMONIUM NITRATE

A total of 16 tests have been conducted with oats in which anhydrous ammonia and ammonium nitrate have been compared for grain production. Three tests have been conducted in which forage yields have been obtained, two of which were used to obtain grain yields.

Fall planted oats apparently use nitrate and ammonia nitrogen equally well in the fall. However, nitrogen applied as ammonia in the spring must be changed into nitrate nitrogen before it is used by oats.

1945-46 Experiments

The acidity of the soil as measured by pH is closely associated with rate of nitrification. Nitrification was found to be slow in soils with a pH of 5.1 or less, and more rapid in soils with a pH of 5.5 or higher. The following data were obtained for anhydrous ammonia as compared to ammonium nitrate:

Acidity of soil	pH 5.1 or lower	pH 5.5 or higher
Number of tests	5	5
Rate of nitrification	Slow	Fast
Source of nitrogen	Increase in yield—bushels oats per acre	
Anhydrous ammonia applied in fall	28.0	14.0
Ammonium nitrate applied in spring	23.6	23.5

In soils of pH 5.1 or lower the rate of nitrification was slow, and fall-applied anhydrous ammonia was retained by the soil through the winter and gave larger yields of oats than spring-applied ammonium nitrate. In soils with a pH of 5.5 or higher the rate of nitrification was rapid so that part of the fall-applied anhydrous ammonia was changed to nitrate nitrogen and was leached out of the soil before spring, which accounts for the lower

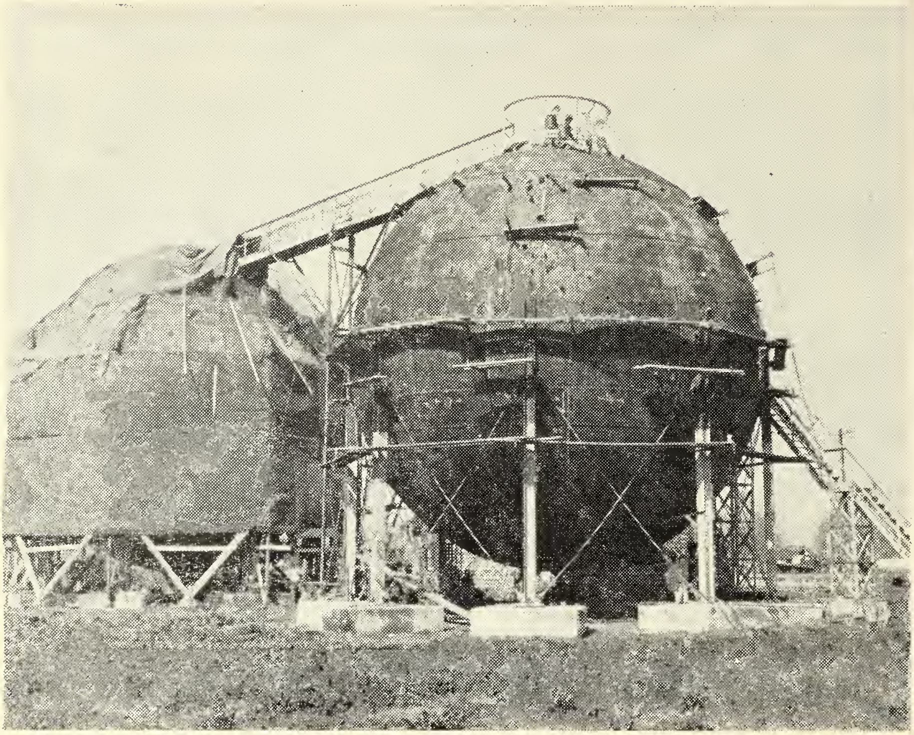

Figure 5. Two Horton spheres under construction. Each sphere has a capacity of 210,000 gallons. The pressure in Horton spheres is usually maintained at 60 pounds per square inch or less by means of refrigeration.

yields produced from anhydrous ammonia applied in the fall than from spring-applied ammonium nitrate.

On one soil with a pH of 4.95 the following data on oats were obtained:

Source of nitrogen	Time of application	Increase in yield, bushels oats per acre
Anhydrous ammonia	October	28.9
Aqua ammonia	January	30.2
Ammonium nitrate	March	26.8

On this soil October and January were satisfactory dates for applying ammonia.

On one soil with a pH of 5.1 the following data on oats were obtained:

Source of nitrogen	Time of application	Increase in yield, bushels oats per acre
Anhydrous ammonia	October	18.5
Ammonium nitrate	March	19.6
Anhydrous ammonia	March	10.4

The March application of anhydrous ammonia on this soil was too late for the ammonia to be changed over to nitrates in time for oats to make maximum use of the nitrogen.

On one soil with a pH of 7.8 the following data on oats were obtained:

Source of nitrogen	Time of application	Increase in yield, bushels oats per acre
Anhydrous ammonia	October	8.5
Anhydrous ammonia	March	25.1
Ammonium nitrate	March	23.9

The ammonia was changed to nitrate nitrogen rapidly in this soil and March application was satisfactory. The fall application of anhydrous ammonia was unsatisfactory.

In most tests ammonium nitrate applied in the fall was only about one-half as efficient as anhydrous ammonia. The superiority of anhydrous ammonia over ammonium nitrate for fall application to oats for grain production is attributed to less leaching of nitrogen where anhydrous ammonia was applied.

Ammonia was superior to ammonium nitrate for fall application to oats planted for grain production in all except one of the ten tests conducted (table 7).

Table 7. The response of oats to fall applied anhydrous ammonia and ammonium nitrate

Test No.	Source of nitrogen: Anhydrous ammonia	Source of nitrogen: Ammonium nitrate
	Increase in yield, bushel oats per acre	
1	30	16
2	32	15
3	30	16
4	29	20
5	19	10
6	25	15
7	12	8
8	15	8
9	14	10
10	4	4
Average	21	12

Where oats are planted in October for grain production little growth is normally made before spring, and it is necessary for most of the nitrogen to be retained by the soil if it is to increase the yield of oats.

1946-47 Experiments

The data reported in table 8 on the response of oats to anhydrous ammonia differ somewhat from those reported above. Anhydrous ammonia applied the last of October was not equal to ammonium nitrate applied in the spring in any of the four tests in which fall applications were made. Fall application of the two sources of nitrogen was not made on strongly acid soil in 1946 except in one test at Holly Springs. In this test, fall application of anhydrous ammonia did not perform as well as it did in a nearby test in 1945-46.

In most tests the spring application of anhydrous ammonia and ammonium nitrate was made during the last two weeks in February. The weather was unusually good during this period and most farmers top dressed their oats during this period in 1947. In general, the response to nitrogen was low for this year.

In the six tests where anhydrous ammonia and ammonium nitrate were applied in February, anhydrous ammonia was superior to ammonium nitrate with both the 32- and 64-pound rates of nitrogen application. The superiority of anhydrous ammonia to ammonium nitrate when applied in February is attributed to less nitrogen being lost by leaching from anhydrous ammonia than from ammonium nitrate.

In the two tests at Columbus where the fertilizers were applied during the first week in March, ammonium nitrate was slightly superior to anhydrous ammonia. It is suggested that the rate of nitrification of ammonia was too slow for the oats to make maximum use of the nitrogen when applied to these soils on this date.

The test at Shelby was conducted on a heavy clay soil which had been broken deep before the oats were planted. The tractor cut into the soil and apparently injured the oats considerably; however, the apparent injury was not reflected in reduced yields.

In general, little or no damage is obtained from the applicator cutting through the oats when ammonia is applied as a top-dressing. With the present equipment, ammonia applied to oats is sealed only by the soil opening, closing up behind the applicator. If soils are in fair physical condition sealing is satisfactory; if they are excessively wet the ammonia is not sealed as well as it should be. It is

Table 8. The response of oats to anhydrous ammonia and ammonium nitrate, 1946-1947.

Nitrogen treatment		Date of	Location and yield in bushels oats per acre.							
Source	Lbs. per acre	application	Lambert	Greenwood	Columbus	Shelby	Clarksdale	Columbus	Columbus	Holly Springs
None			36.9	50.0	34.9	25.8	23.1	26.3	14.6	5.0
Anhydrous ammonia	32	Oct.	45.1	53.9	39.7	....		....	....	16.5
Anhydrous ammonia	64	Oct.	41.9	58.0	50.6	....		....		24.9
Ammonium nitrate	32	Feb.	58.7	62.2	51.7	30.0	42.5	45.5*	40.4*	18.0
Anhydrous ammonia	32	Feb.	59.1	67.1	58.9	35.2	52.3	41.3*	35.9*	21.8
Anhydrous ammonia	64	Feb.	65.6	74.7	65.2	58.8	70.0	....		34.5
Ammonium nitrate	64	Feb.	69.8	62.7		43.3	58.2	....	....	30.0
Anhydrous ammonia	32	Nov.	55.2	53.0	50.8					

*Applied the first week in March.

Table 9. The response of fall-planted oats to anhydrous ammonia and ammonium nitrate as measured by forage and grain yields.

Nitrogen treatment			Yield per acre test number				
	Time and rate		Oven-dry forage[1]			Grain	
Source	Fall	Spring	Test 1	Test 2	Test 3[2]	Test 1	Test 2
	lb. N	lb. N	lb.	lb.	lb.	bu.	bu.
Anhydrous ammonia	32	....	922	619	759	25.2	19.0
Ammonium nitrate	32	....	759	381	707	24.2	17.1
Ammonium nitrate	64	....	1627	703	1147	22.6	21.3
Anhydrous ammouia	64	....	1582	1076	1162	23.6	17.1
Anhydrous ammonia	32	32	944	605	681	43.2	39.6
Ammonium nitrate	32	32	820	305	652	45.8	43.8
Ammonium nitrate	....	32	63	13	81	45.1	41.0
Anhydrous ammonia	....	32	52	14	....	39.3	35.7
Anhydrous ammonia	....	32	....	....	....	44.0	36.1
Ammonium nitrate	....	32	....	....	....	50.0	40.7
No nitrogen	....	....	....	....	....	26.3	14.6

[1]The oven-dry forage yields may be converted into hay yields of 12 percent moisture by adding 14 percent to the yields reported.
[2]First week in December clipping only.

anticipated that more satisfactory equipment will be developed.

Forage and Grain Yields

The response of fall planted oats to anhydrous ammonia and ammonium nitrate as measured by forage and grain yields is shown by data reported in table 9. The oats were planted the last week in September. The anhydrous ammonia was applied before planting; the ammonium nitrate was applied two weeks later. The second application of both sources of nitrogen was made the first week in March.

The data show that less than 100 pounds of air-dry forage was produced without nitrogen. The yields produced with 32 pounds of nitrogen as anhydrous ammonia were 922, 619, and 759 pounds per acre for three tests; the corresponding yields for 64 pounds of nitrogen as anhydrous ammonia were 1582, 1076, and 1162 pounds per acre. The data suggest, if oats are to be planted for forage, that no less than 64 pounds of nitrogen per acre should be applied on poor soil since the yield was dependent upon the amount of nitrogen applied.

Ammonium nitrate produced somewhat less forage than did anhydrous ammonia in two tests at the low nitrogen rate, which was probably due to the fact that it was applied two weeks after planting, and the rainfall was insufficient to carry it into the soil, while the anhydrous ammonia was applied in the root zone; at the high nitrogen rate, there was little difference in the yield for the two sources of nitrogen.

The forage yields were obtained by clipping with a power mower about the 5th of December and the 14th of February. The data for the two clippings with 64 pounds of nitrogen as anhydrous ammonia in two tests are as follows:

Test No.	Pounds of forage per acre	
	Dec. 5	Feb. 14
1	1243	239
2	863	213

The data show that most of the forage was produced prior to the first of December, and that little growth was made during the winter months. These data suggest that forage for winter grazing is produced in the fall months rather than during the winter months.

Data have been reported by other investigators which show that grazing oats and other small grain reduced the yield of grain, when planted on fertile soil or when nitrogen was applied in the fall without spring fertilization with nitrogen. Based upon the data presented in this paper, moderate grazing of small grain should not reduce the yield provided they are fertilized in the spring to supply the nitrogen removed in the forage consumed by the animals.

SPECIFICATIONS FOR STORAGE EQUIPMENT FOR ANHYDROUS AMMONIA

The working pressures referred to in this bulletin are based on the A.S.M.E. Code. The corresponding pressures under the A.P.I.-A.S.M.E. Code are 25 percent higher.

The minimum designed working pressure of containers used in the storage, handling, and distribution of anhydrous ammonia should be as follows:

1. Unprotected above-ground storage tanks, 250 pounds per square inch.

2. Above-ground storage tanks provided with an approved sprinkling system or protecting shed, 200 pounds per square inch.

3. Underground storage tanks with a working pressure of 150 pounds per square inch were formerly thought to be acceptable for anhydrous ammonia. However, if underground tanks of this type are properly treated to prevent corrosion and insure long life, the total cost will be about the same as for 200-pound working pressure tanks. The use of underground tanks for storage of anhydrous ammonia is therefore not recommended at the present time.

It has also been found that insulated low pressure tanks which are to be refrigerated cost about as much as 200-pound working pressure tanks. Taking into consideration the cost of maintaining the insulation as well as the cost of refrigeration, low pressure tanks which are refrigerated and insulated are not recommended, with the exception of Horton Spheres.

4. Above-ground storage tanks with a designed working pressure of less than 200 pounds per square inch should be refrigerated to maintain the pressure below the pop-off pressure. Refrigeration requires the following equipment:

(a) One electric motor operated, automatically controlled, compressor and cooling coil.

(b) One gas, gasoline, oil, or other fuel-propelled engine operated compressor and coil, maintained in standby condition. Where electricity is not available there should be two such sets of equipment available for use.

5. Where underground storage tanks are installed, unless underground drain-

Figure 6. A bulk storage plant consisting of four 30,000-gallon high pressure tanks. The compressor for loading and unloading is located in the small house.

age is such that there is no accumulation of water which could lift the tank out of the ground, tile should be placed under each side of the tank, and connected to a main tile at the end which (a) empties into a satisfactory outlet, or (b) empties into a catch basin which is provided with an automatically operated power driven pump to keep the water away from the tanks. A hand-operated pump should be maintained in standby condition. If tanks are buried two-thirds underground, with one-third above the ground and properly covered with dirt, provision for underground drainage is not necessary.

6. Transport, delivery, tractor, skid tanks, etc., should have a minimum working pressure of 200 pounds per square inch.

7. All high-pressure fittings on tractor tanks should be firmly attached to the tank.

8. On tractor tanks, high-pressure ammonia should be conducted in iron or steel only. Hoses are dangerous and should not be used except where they are located in such a position that failure would not endanger the tractor driver.

9. Every bulk storage plant should have a minimum of the following equipment:

(a) One approved ammonia gas mask with refill charges.
(b) One pair of tight-fitting goggles.
(c) One pair of rubber gloves.
(d) Acceptable first-aid kit.
(e) One easily accessible shower bath.

Every over-the-road transport truck, trailer, or field transport trailer should have the same safety equipment as set out above except, in lieu of the shower bath, they should carry five gallons of water.

10. Bulk storage plants should not be installed within the corporate limits of

any town or city. They should not be erected within 200 feet of any regularly inhabited building. The pop-off valves should be provided with a vent which discharges at least 15 feet above the ground, the upper end of which is turned down to prevent rain from getting to the pop-off valve.

11. All transfer hoses on bulk storage tanks, transport trucks, and trailers should have a ¼-inch pop-off valve set on 200 pounds pressure per square inch. For hoses on Horton Spheres the setting may be less.

12. All transfer hoses should be connected to a down pipe at the top of tanks, rather than to an outlet at the bottom, to facilitate the removal of liquid from the hose.

13. The recommended percentage fill of the tank varies with the temperature as follows:[3]

Temperature of liquid ammonia in tank	Maximum volume filled with liquid
Degrees F.	Percent
30	86
40	88
50	89
60	90
70	91
80	92
90	93
100	95

Safety Relief Devices, Valves, Hoses, Pipings, Fittings, etc.

All piping, fittings, valves, and hoses should be ammonia resistant. Copper and brass must not be used. They should be made for a working pressure of 250 pounds per square inch.

The area and setting of the pop-off valves should be in accordance with the current published regulations of the National Board of Fire Underwriters. At the present time pop-off valves may be set to be fully open at a pressure not to exceed the working pressure of the tank plus 25 percent, based upon the A.S.M.E. code.

The fittings required for anhydrous ammonia tanks are as follows:

1. 300-pound ammonia pressure gauge.
2. A ¼- to ½-inch gas outlet valve with short pipe extending into the tank which should not permit filling to over 90 percent capacity. This valve may also be used for gas escape in filling by bleeding.
3. A ¾- to 1-inch vapor return valve for filling with a pump or compressor.
4. Safety or pop-off valves. Size, tractor tank, ¾- to 1-inch; setting, 250 pounds per square inch.
5. A ¾- to 1-inch liquid inlet filling valve.
6. Liquid outlet feed valve connected to a down pipe equipped with a 1/64-inch mesh strainer. Size: storage tank ¾- to 1-inch; tractor ½- to ¼-inch.
7. A liquid level float gauge.

Specifications of Storage Equipment for Aqua Ammonia

In order to avoid the loss of ammonia from aqua ammonia it should be maintained in a closed system at all times. Where tanks are not closed some ammonia will be lost constantly, and the

[3] These recommendations were made by E. I. Du Pont de Nemours.

Table 10. Number of applicators and sizes of orifices for different types of operations.

Type of operation	Number of applicators	Number of orifices: Full size	Number of orifices: Half size
1. Before planting on level land	Same as number of rows	All	----
2. Before planting on bedded land	Same as number of rows	All	----
3. Lister application	5	3	2
4. Planting operation	Same as number of rows	All	----
5. 3-row middle buster	6	----	6
6. Split row, two bottom middle buster	4	----	4
7. Two bottom middle busters	3	1	2

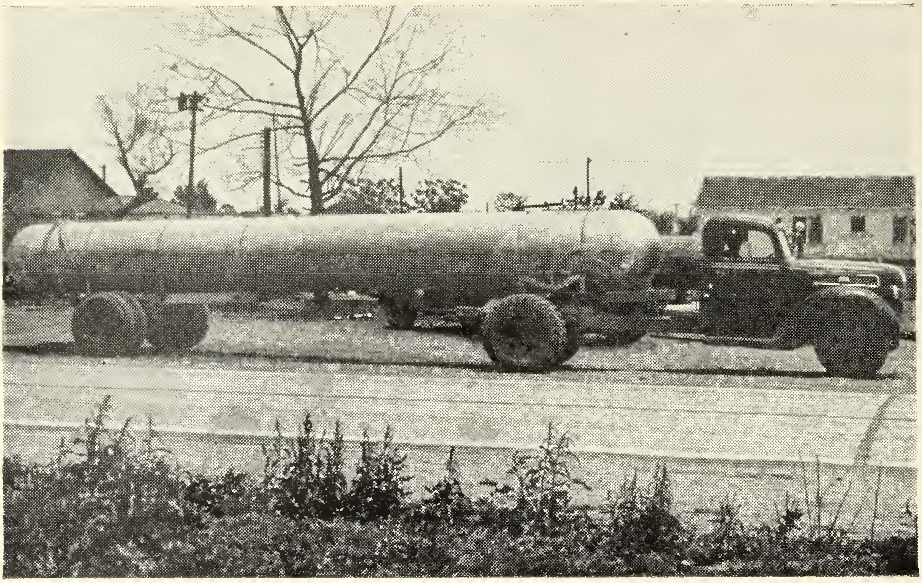

Figure 7. Anhydrous ammonia transport truck. Capacity 3,000 gallons.

total loss over a period of a few weeks will be considerable, especially during hot weather.

The highest anticipated gauge pressure of a 30 percent solution of ammonia is 10 pounds per square inch. With this pressure it is necessary that the heads of the tanks be convex. Therefore, all tanks in which aqua ammonia is to be handled should be built to withstand this pressure. Even though the pressure of aqua ammonia should not exceed 10 pounds per square inch, the thickness and strength of the tank probably should be such that it has a working pressure of not less than 20 pounds per square inch. With the thicker tanks an allowance is made for loss in strength due to rusting, and increased durability is provided.

All tanks for handling aqua ammonia should have the following fittings:

1. Filling valve.
2. Pop-off valve set on 10 pounds pressure.
3. Bleeding valve.
4. Air inlet check valve.
5. Outlet valve and hose.
6. A liquid level gauge which indicates the amount of ammonia in the tank.

Table 11. Possible loss of anhydrous ammonia that may be obtained when filling by bleeding off of a 360-pound capacity tank.

Temperature of tractor tank	Gauge pressure at beginning	Pressure differential	End temperature of tank	Gauge pressure reading at end	Ammonia loss	
Degrees F.	Pounds	Pounds	Degrees F.	Pounds	Pounds	Percent*
110	232	232	—28	0	133	36
110	232	40	99	192	11	3
110	232	20	105	212	6	1.8
110	232	10	107	222	3	.9

*These calculations include the cooling of the tractor tank, weight of which is 400 pounds.

EQUIPMENT FOR APPLYING ANHYDROUS AMMONIA

The development of a machine to apply anhydrous ammonia was started at the Mississippi Agricultural Experiment Station in 1944. The first equipment used for applying anhydrous ammonia was a 1-row machine. It consisted of a side-mounted standard 100-pound anhydrous ammonia cylinder, Atlantic seamless steel high pressure hose feed line, rotameter (recommended for experimental work) and mounting, control valve, distribution line, and applicator shank. This equipment was mounted on a tractor equipped with a 2-row cultivator.

Later, 2-row and 4-row equipment was developed. The tank mounting was changed to the rear of the tractor to facilitate loading of 150-pound capacity anhydrous ammonia cylinders. A report on this machine, which was designed for research, was published in the September, 1947, issue of the Journal of the American Society of Agricultural Engineers.

The present equipment for applying anhydrous ammonia on the farm was developed as a result of the experience obtained with the research machine described above. In changing the research machine over to a more practical type farm machine, the following changes were made: (1) an 80- to 110-gallon tank was mounted on the back of the tractor instead of the standard 150-pound capacity anhydrous ammonia cylinder, (2) a differential pressure regulating valve and gauge, or needle valve and gauge, was used to replace the rotameter for metering, and (3) the number and size of orifices in the manifold was changed.

Setting Up Field Equipment

All fittings should have a working pressure of 250 pounds per square inch. Field storage and tractor tanks should have a working pressure of 200 pounds per square inch (A.S.M.E. Code). Spec-

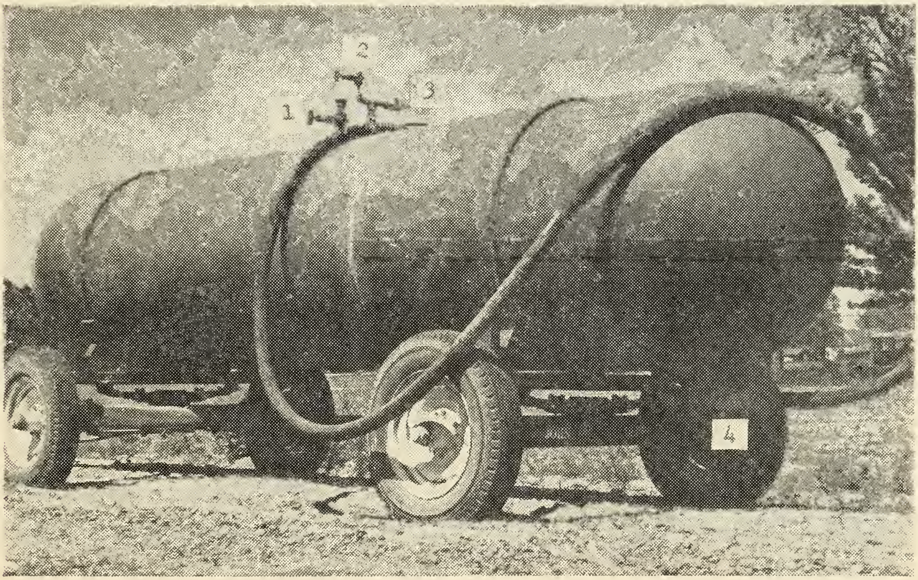

Figure 8. Field transport tank for anhydrous ammonia. Capacity 1,000 gallons containing 4,100 pounds of nitrogen—102 acres at 40 pounds per acre. (1) Filling valve. (2) Bleed-off valve with stationary fill depth pipe in tank. (3) Pop-off valve. (4) Liquid outlet and valve.

Table 12. The pounds of ammonia per hour required for different rates of nitrogen with different row width and tractor speeds.

Rate in pounds nitrogen per acre (speed of tractor feet per second)	Four row equipment — Row width 36″	Row width 38″	Row width 40″	Row width 42″
	Pounds of anhydrous ammonia per hour for 40 pounds of nitrogen per acre			
2.0 miles per hr. x 1.47 = 2.94 ft./sec.	140	150	160	170
2.5 miles per hr. x 1.47 = 3.9 ft./sec	175	188	200	213
3.0 miles per hr. x 1.47 = 4.41 ft./sec.	210	225	240	255
3.5 miles per hr. x 1.47 = 5.15 ft./sec.	240	262	280	300
4.0 miles per hr. x 1.47 = 5.88 ft./sec.	280	300	320	340
4.5 miles per hr. x 1.47 = 6.68 ft./sec.	315	340	360	380
5.0 miles per hr. x 1.47 = 7.35 ft./sec.	350	375	400	425
	Pounds of anhydrous ammonia per hour for 30 pounds of nitrogen per acre			
2.0 miles per hr. x 1.47 = 2.94 ft./sec.	105	113	120	128
2.5 miles per hr. x 1.47 = 3.9 ft./sec	130	140	150	160
3.0 miles per hr. x 1.47 = 4.41 ft./sec.	160	170	180	190
3.5 miles per hr. x 1.47 = 5.15 ft./sec.	180	195	210	220
4.0 miles per hr. x 1.47 = 5.88 ft./sec.	210	225	240	255
4.5 miles per hr. x 1.47 = 6.68 ft./sec.	240	255	270	285
5.0 miles per hr. x 1.47 = 7.35 ft./sec.	260	280	300	320

ifications for over-the-road tanks come under the jurisdiction of the Interstate Commerce Commission at the present time. The same type fittings are used on farm transport and tractor tanks. At present, anhydrous ammonia is transported in 1000-gallon tanks mounted on trailers.

The fittings for tractor tanks and transport tanks are as follows:

1. 300-pound ammonia pressure gauge.

2. A ¼- to ½-inch gas outlet valve with short pipe extending into the tank which should not permit filling to over 90 percent of capacity. This valve is used for gas escape in filling or bleeding. The valve is used to indicate when the tank is 90 percent filled when a pump or a compressor is used in filling.

3. A ¾- to 1-inch vapor return valve for filling with a pump or compressor.

4. Safety or pop-off valves. Size: Farm transport tank, 1½ inch; tractor tank, ¾- to 1-inch; maximum setting, 250 pounds per square inch.

5. A ¾- to 1-inch liquid filling valve.

6. Liquid feed valve connected to a down pipe equipped with a 1/64-inch mesh strainer. Size: Farm transport tank ¾- to 1-inch; tractor ½- to ¾-inch.

7. A liquid level float gauge, which indicates the amount of ammonia in the tank.

Controlling the Rate of Application Of Anhydrous Ammonia

The amount of ammonia applied is controlled by two types of regulating valves and pressure gauges:

1. Differential pressure valve with an attached pressure gauge.

2. Needle valve and pressure gauge.

On the basis of the experience of farmers in 1947, the needle valve and pressure gauge are more rugged and operated with less interference than the differential pressure valve and associated pressure gauge. However, manufacturers of valves are working on differential pressure valves and associated pressure gauges which may prove to be very satisfactory.

An advantage of the differential pressure valve and associated pressure gauge is that it can be made in a compact unit which has the manifold built in. Valuable developments on this part of the equipment are anticipated in the near future.

A short nipple connects the tank feed line valve to a quarter-turn cut-off valve which is connected to the regulator valve. The manifold connects to the low pressure side of the regulator valve. The regulator valve should be built to withstand 250 pounds pressure per square inch on the tank side and 200 pounds per square inch on the manifold side. The manifold is made of ¼- x 2-inch nipples, tees, elbows, and anhydrous ammonia flange unions into which the orifices are fitted.

The manifold described is compact, and has given uniform distribution to the different rows. Much longer manifolds have been used, and some irregularity of application has been attributed to them. Even though a long manifold is not recommended, there is no proof that the irregularity was due to the type of manifold; it may have been due to trash in the orifices, rough orifices, size of orifices not being uniform, outlet in applicators not being of uniform size or to improper setting of applicator or covers.

All manifolds should be so constructed that they may be taken apart easily for the removal of trash, which sometimes gets into the orifices. Manufacturers are making a compact manifold. The orifices and lines are attached to a central pipe where the ammonia enters. This type of manifold should give a uniform rate of flow and it is easily taken apart which facilitates cleaning the orifices.

The feed lines from the manifold to the applicator are made from 150-pound working pressure ¼-inch rubber air hose, or other ammonia resisting hose with a 150-pound working pressure.

Figure 9. Fittings for anhydrous ammonia tractor tank. (1) Vapor line return valve for filling with pump or compressor. (2) Pop-off valve with stand pipe. (3) Bleed-off and stationary fill gauge valve and stand pipe. (4) Tank pressure gauge. (5) Filling valve. (6) Feed line valve. (7) Quick cut-off valve. (8) Regulating needle valve. (9) Low pressure gauge. (10) Manifold.

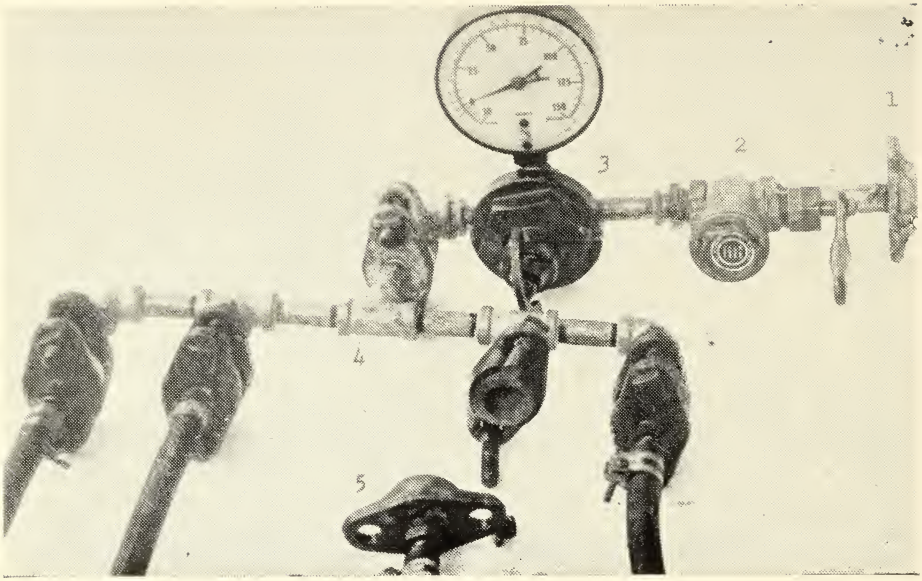

Figure 10. Mechanism for regulating the flow of anhydrous ammonia. (1) Connection to tractor tank. (2) Quick cut-off valve. (3) Regulating valve with gauge. (4) Manifold for 4 rows—over-all length 14 inches. (5) Flange containing 3/32-inch orifice.

The manifold described above was calibrated, after the machine was assembled for operation, by the use of a rotameter and the data reported in table 13 were obtained.

When a metering pump has been developed to operate under high pressure ammonia, and suitable for mounting on a tractor, anhydrous ammonia may be applied in a manner similar to that described below for aqua ammonia.

The orifices used were 3/32 of an inch in size. Larger orifices may be desirable where very high rates of application are used. Constrictions in the feed lines, the size of the outlets on applicators, and the type of manifold, all affect the rate of delivery of ammonia. It is, therefore, apparent that each manufacturer should calibrate its equipment with a rotameter and supply the tables of data to the purchaser of the equipment.

When one applicator is used per row the size of the orifices are 3/32 of an inch. When the application is made with middle busters or listers or other equipment where two applicators are used on some rows and one-applicator is used on other rows being fertilized, the orifices feeding the applicators which go twice to one row should have one-half of the area (not one-half of the diameter) of 3/32-inch orifices. The diameter of the one-half size orifice is approximately 1/16 inch. The number of applicators and size of orifices for the different types of operations are shown in table 10.

Anhydrous ammonia has been applied in the following operations in Mississippi:

1. Before planting on prepared level land, in which the applicators are mounted on the cultivator tool bars and the ammonia is sealed with disc hillers.

2. Before planting on bedded land, in which the applicators are mounted on the cultivator tool bars and the ammonia is sealed by disc hillers.

3. Before planting while bedding with listers, which seal the ammonia.

4. In the planting operation with the applicators mounted on the cultivator tool bars and the ammonia is sealed with the cultivator sweeps.

5. In side dressing, in which the applicators are mounted on cultivator tool bars and the ammonia is sealed with the cultivator sweeps.

The applicators should be run 5 to 6 inches deep; and the disc hillers, where used, should be set at approximately half the depth of the applicators so that they will completely seal the ammonia. If it is desired to apply ammonia to small grains the applicators should be run 5 to 6 inches deep and spaced 16 inches apart. There is some difficulty in sealing ammonia in top dressing oats and research is being continued on the development of more satisfactory equipment.

Construction of Applicators. The importance of properly designed and constructed applicators cannot be over emphasized. After one year of field experience, the farmers and equipment people should know that anhydrous ammonia must be sealed in the soil to prevent waste and to get the desired crop response.

The ability to seal ammonia in the soil is dependent upon the use of well designed and constructed applicators. There has been continuous work on the improvement in the design of the applicator by workers of the Mississippi Agricultural Experiment Station since the research program on anhydrous ammonia was started, and the results are available to those who are interested in the design and construction of applicators.

The applicator described in this bulletin has proven superior to any other design tested up to the present time. In constructing the new applicator, a bar of ½- x 2-inch steel 17 inches long was cut square at the top and at a 30° angle at the bottom. The center width was reduced by cutting out ¼-inch in middle of the front and tapering the cut out at each end. Then, the applicator knife was

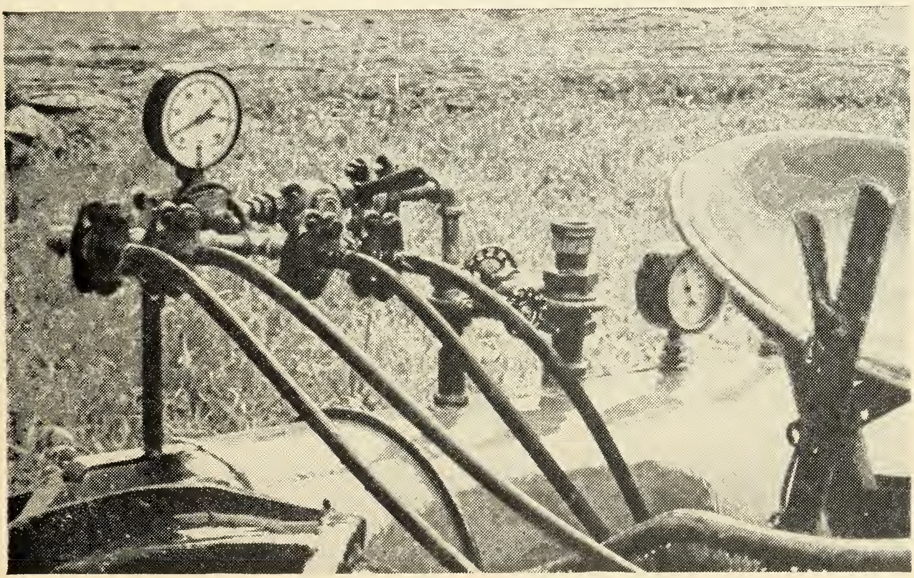

Figure 11. Fittings on tractor tank for applying anhydrous ammonia.

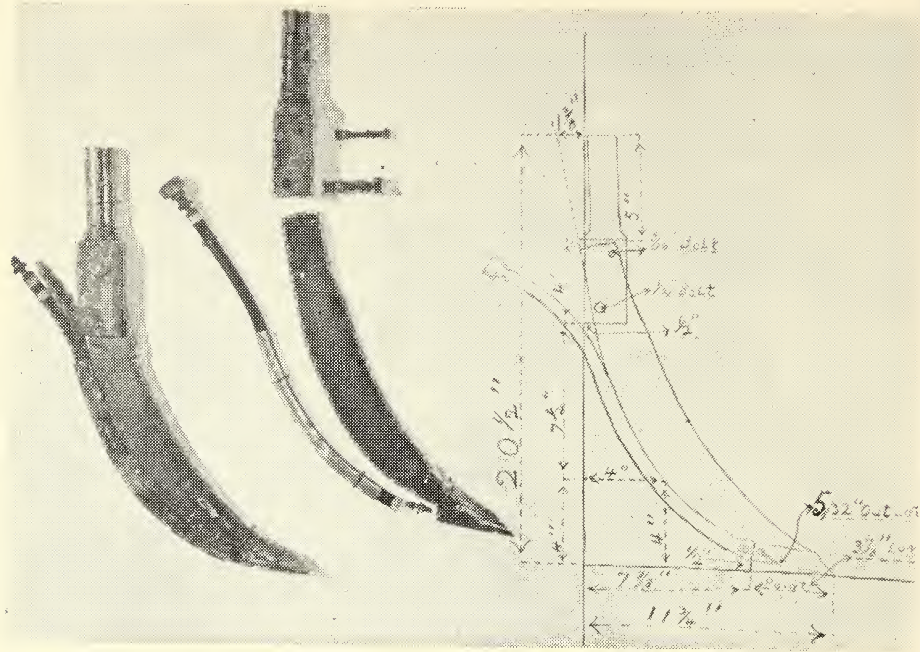

Figure 12. Anhydrous ammonia applicator, showing details of construction.

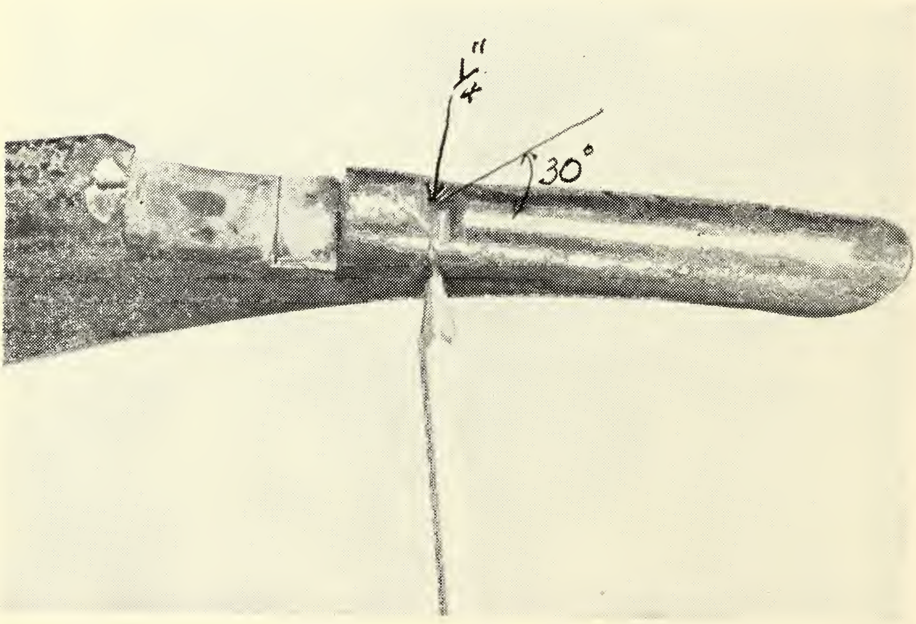

Figure 13. The point and bottom of the anhydrous ammonia applicator showing details of construction and the outlet for ammonia.

given the desired curve and a knife edge was cut and ground on the front. When the applicator knife is properly curved, there should be a horizontal distance of 8 inches from the point of the applicator to a vertical line extending down from the top at back of the knife to the level of the point. Up 4 inches from the level of the point along the vertical line, there should be a horizontal distance of 2⅛ inches between the vertical line and the back of the knife. This curvature should gradually blend out at 4½ inches from the top of the knife.

The suction point was built from a ¾-inch hard steel shaft 4 inches long. A 5/16-inch hole 1¼ inches deep was drilled into the back of the suction point. Into this hole a piece of pipe 2 inches long, with a 5/16-inch outside diameter and 5/32-inch inside diameter, was welded. Then the point was welded to the applicator knife and cut or ground as shown in figure 14.

After the suction point was welded to the knife, a ¼-inch hole was drilled into the 5/16-inch hole at a 30 degree angle forward with the bottom of the point (figure 13). After the hole was drilled, a bird mouth was cut ¼ inch over the hole to prevent the hole from stopping up.

A 5/8-inch steel conduit pipe was curved to fit the back of the knife and spot welded at the top and bottom with a 1½-inch clearance at the bottom and back of the suction point to provide room to clamp the hose to the 5/16-inch steel pipe behind the point. After the hose had been clamped at the bottom, the pipe was flattened to prevent excessive wear and hold the hose in the pipe. After the applicator knife has been fitted into the holder, all dimensions should check with those shown in figure 12.

Where anhydrous ammonia enters the soil through an iron pipe welded to the back of the applicator, the low temperature produced by the ammonia may cause wet soil and water to freeze to the applicator; this increases its thickness and interferes with its operation. Similar results are obtained where ammonia is released while the tractor is still and the applicators are in the ground. The use of the rubber hose, which passes through the pipe attached to the applicator, as described above, prevents freezing of soil to the applicator.

The standard is round and about 4½ inches long. The fork holder is made of two pieces of ½-inch x 2-inch x 4½-inch bar steel welded to each side of the standard separated by a distance of ½-inch to take the applicator. The applicator should be set at a 15-degree angle with the fork holder. The over-all vertical height of the applicator, holder and standard should be 19 to 20 inches. The applicator is placed in the fork, after which suitable holes spaced 2½ inches apart are drilled. The upper hole is drilled for a 3/16-inch bolt, while the lower hole is drilled for a ½-inch bolt. Bolts placed in these holes fasten the applicator in the fork that is welded to the round standard, and the 3/16-inch bolt at the top acts as a break pin.

OPERATING ANHYDROUS AMMONIA TRACTOR EQUIPMENT

The rate of delivery of anhydrous ammonia is controlled (1) by means of a differential pressure regulating valve and pressure gauge, or (2) by means of a needle valve and pressure gauge. The rate of delivery of ammonia is related to time, which makes it necessary for the speed of the tractor to be known.

Before the equipment is calibrated, it should be adjusted to apply ammonia at the desired depth (six inches is recommended), and the covering device should

Table 13. Pressure setting for the differential pressure regulating valve; 4-row equipment, 3/32" orifices in each line.[1]

Pounds per hour		Tank pressure—pounds						
Anhydrous ammonia	Nitrogn	70	90	115	125	150	170	190
		Regulator valve gauge reading in pounds						
400	333	43	50	59	65	71	74	80
380	311	41	48	56	62	67	71	76
360	295	39	45	53	59	64	67	72
340	278	36	42	49	55	60	63	67
320	262	34	40	46	52	56	59	63
300	246	32	37	43	48	52	55	59
280	230	30	34	40	45	49	51	55
260	213	28	32	37	42	45	48	51
240	197	25	29	34	38	41	44	47
220	180	23	26	31	35	38	40	42
200	164	21	23	28	32	34	36	38
180	148	19	21	24	28	30	32	34
160	131	16	18	21	24	26	28	30
140	115	14	16	18	21	23	24	26
120	98	12	13	15	17	19	20	22
100	92	9	10	12	14	15	16	17

[1]Manifold built of ¼" x 2" nipples, tees and elbows.

be adjusted. Then, the gear and throttle setting of the tractor should be established. After the equipment has been adjusted, the speed of the tractor in feet per second is determined by trial runs of a measured distance.

With the speed of the tractor in feet per second known, the pounds of ammonia per hour required for a given rate of nitrogen per acre may be obtained from table 12. As an example, these data show that 340 pounds of ammonia per hour is required to give 40 pounds of nitrogen per acre on four 42-inch rows with a tractor speed of 5.9 feet per second. Since the data are for four-row equipment, the pounds of ammonia per hour should be half as much for two-row equipment.

Setting the Regulating Valve

The rate of ammonia per hour was calculated by the following formula: speed of tractor in feet per second x 3,600 x number of rows x row width in feet x pounds of nitrogen per acre divided by 43,560 times 0.82 as shown below:

5.88 x 3,600 x 4 x 3½ x 40 divided by 43,560 x 0.82 equals 332 pounds of ammonia per hour. Since the table is set up in 20-pound divisions the table shows 340 instead of 332.

The factors which determine the pounds of ammonia delivered per hour are:

1. Pressure of ammonia in the tank.
2. Pressure of ammonia on the orifices, as shown by the regulating valve pressure gauge.
3. Size of the orifices.
4. The size of the feed lines.

The size of the feed lines and the size of the orifices are constant for any one machine, which reduces the variables to tank pressure and pressure on the orifices. The data reported in table 13 were obtained while using equipment which contained 3/32-inch precision orifices, and ¼-inch rubber hose feed lines.

The pressure of ammonia on the orifices is controlled by (1) a differential pressure valve and pressure gauge, or (2) by a needle valve and pressure gauge. The pounds of ammonia delivered per hour with different tank pressures and different regulating gauge pressures are reported in table 13. As an example, where 340 pounds of ammonia (278 pounds of nitrogen) is desired, the pressure on the

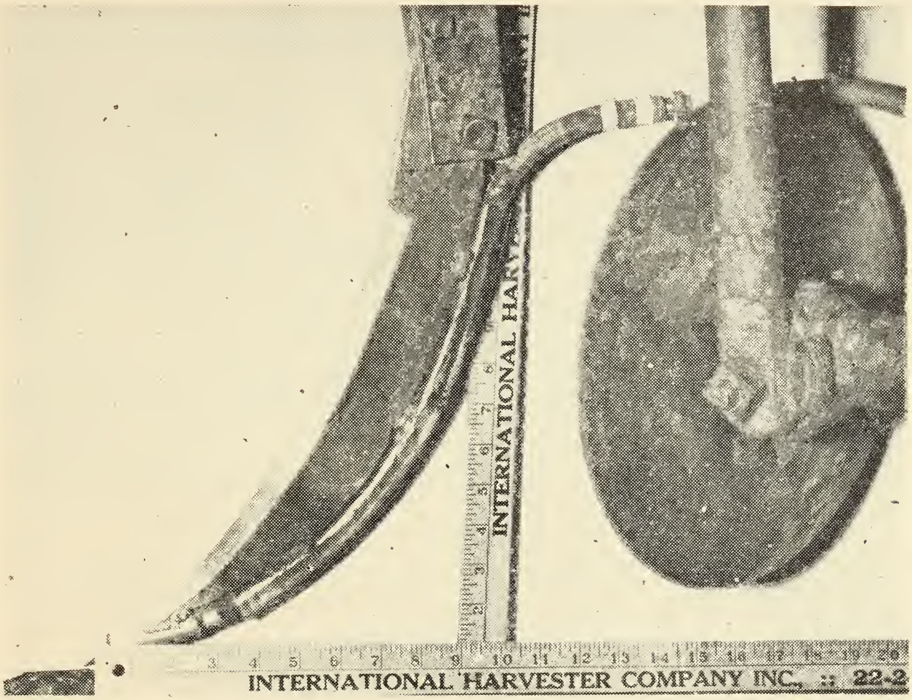

Figure 14. Applicator with rubber hose enclosed in iron pipe and disc hiller for covering. Note angle of knife, and flat suction point.

regulating-valve gauge is 63 pounds per square inch where the pressure of the ammonia in the tank is 170 pounds per square inch. For two-row equipment, the pressure on the regulating-valve gauge is obtained for twice the desired rate of ammonia. As an example, where 170 pounds of ammonia is required per hour for two-row equipment, the regulating-valve gauge reading is obtained for 340 pounds of ammonia per hour.

All manufacturers of equipment should calibrate their equipment with a rotameter and supply the information with the equipment. The data reported in table 13 were obtained using the equipment as described, except the feed line did not have the restriction at the outlet on the applicator described in this bulletin. The outlet through the applicator described will require a slightly higher regulating valve setting.

The rate of ammonia delivered through each line is essentially independent of the number of feed lines. Where more than four rows are applied at one time, as in the application of anhydrous ammonia to oats, the pounds of ammonia per hour is changed to correspond to the width covered. If the regulating valve pressure is obtained from four rows the additional applicators do not influence the rate of application.

Where anhydrous ammonia is applied to oats, with a 16-inch spacing of the applicators, the pounds of ammonia per hour is 40 percent of that with a 40-inch spacing.

Filling Tanks with Anhydrous Ammonia

Tanks are filled by: (1) Bleeding gas off the tank being filled. (2) Pumps. (3) Compressors.

Where bleeding off is used to fill tanks with anhydrous ammonia, the operation is carried out in the following order: (1) connect the vapor hose to the tractor tank, (2) connect the liquid line between the tanks, (3) open the vapor valve on tractor tank, (4) open the liquid valve on tractor tank, (5) open the liquid valve on the hose line next to the tractor tank (if not already open; it should be open), (6) open the valve on liquid line on the storage tank, and (7) continue to open the vapor valve on the tractor tank until the pressure gauge shows 10 pounds less pressure than is shown by the gauge on the storage tank. If a greater pressure differential is obtained, one may expect a greater loss of ammonia, as shown in table 11.

The recommended difference in gauge reading of 10 pounds will give a loss of only about one percent of the ammonia, yet this difference in pressure should be sufficient for the tank to be filled in a short time. If bleeding is rapid enough to accumulate moisture on the tank, and particularly for ice to form on the tank, the loss of ammonia is excessive. In fact, bleeding to atmospheric pressure may result in a loss of as much as 36 percent of the total ammonia.

When the tank is filled to 90 percent of capacity, a white spray will start escaping from the vapor line. When the white spray starts, the valve on the liquid line next to the storage tank should be closed at once. Then the vapor line valve on the tractor tank, followed by the liquid hose valve next to the tractor should be closed, after which the filling valve on the tractor tank is closed. The union should then be loosened and the ammonia in the short nipple should be drained before the connection is completely broken. The filling hose should be drained in order to prevent accidents such as bursting of the hose or releasing ammonia on the operator while making connections. If the liquid line is not to be drained after each filling, a safety valve should be put on the line. However, it is recommended that the hose be drained.

Where pumps are used to fill tanks with anhydrous ammonia, the procedure should be in the following order: (1) connect the vapor hose line to the vapor outlets, (2) open valves on vapor line, (3) connect the liquid line, (4) open the fill valve on the tractor tank, (5) open the liquid line valve next to the tractor tank, (6) open the liquid line valve on the storage or field tank, (7) open the depth fill gauge valve on tractor tank and (8) start the pump.

As soon as the white spray starts to escape from the vapor valve the pump should be cut off, and the valves closed in the following order: (1) liquid valve on storage tank, (2) vapor valve on storage tank, (3) vapor valve on tractor tank, (4) disconnect vapor line connection on tractor tank, (5) close depth gauge valve on tractor tank, (6) close liquid valve on hose line next to tractor tank, (7) close fill valve on tractor tank, (8) loosen liquid line connection on tractor tank and let the material in the short nipple drain out. The line is then completely disconnected and drained.

Where compressors are used to fill tanks with anhydrous ammonia, the operation of valves and connections is the same as in filling with the pump except the compressor is connected into the vapor line.

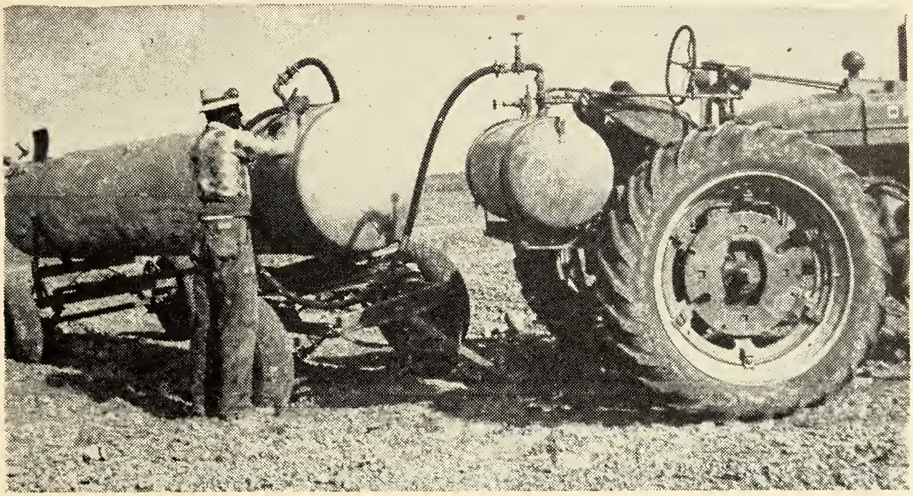

Figure 15. Filling tractor tank with anhydrous ammonia by bleeding.

EQUIPMENT FOR APPLYING AQUA AMMONIA TO THE SOIL

Since the pressure exerted by a 30 percent solution of ammonia should not exceed 10 pounds per square inch, a low pressure metering pump is the most satisfactory means of controlling the rate of application. The pump is driven from the axle of the equipment on which it is mounted.

With pumps driven from the axle of the equipment on which they are mounted, a constant speed is not necessary. For this reason, aqua ammonia may be used very satisfactorily on horse-drawn as well as on tractor equipment. So far as the rate of application is concerned, when the pump is once calibrated correctly, it should operate accurately with little attention.

All tanks for handling aqua ammonia should have the following fittings:

1. Filling valve.
2. Pop-off valve set on 10 pounds pressure.
3. Bleeding valve.
4. Air inlet check valve.
5. Outlet valve and hose.
6. Liquid level gauge.

All fittings should be made of iron or steel. Copper or brass fittings are not suitable.

The pump recommended is a 20 DV Yale-Towne rotary-positive-displacement pump, with a variable-volume-manual control for quantities up to 1.5 gallons per hundred revolutions. The pump is driven from the axle of the machine on which it is mounted through a counter shaft which steps the speed up to 400 revolutions per minute. A 1¼-inch hose connects the pump to the supply tank. A fine screen should be placed over the hose outlet from the tank to keep trash out of the metering equipment. A 5- to 10-pound pressure-relief-discharge valve is put in the line after the pump to stop the flow of aqua ammonia through the pump when the equipment is not in use.

The manifold is connected to the pressure relief valve. The manifold, feed lines and applicators are the same as described above for anhydrous ammonia, except that aqua ammonia may be conducted through iron pipe welded to the back of the applicators. The same care should be used in covering aqua ammonia instantaneously in application to the soil as is necessary with anhydrous ammonia.

The size of the orifices in the manifold for aqua ammonia may need to be increased where heavy rates of application are used.

A hose pump was developed for the application of aqua ammonia by the Tennessee Agricultural Experiment Station as reported in Circular 87. The pump consists of heavy walled rubber tubing, size ¼- to ½-inch, mounted over rollers, spaced 2 inches from the shaft which is driven by a chain or belt. The revolutions of the pump vary up to 200 per minute.

The quantities of aqua ammonia delivered per 100 revolutions by hoses of different sizes are:

Inside diameter of tube in inches	Gallons per 100 revolutions
1/4	0.16
5/16	0.20
3/8	0.31
1/2	0.56

Some farmers have controlled the rate of application of aqua ammonia by the use of small compressors to maintain a constant tank pressure instead of a pump. However, it appears to the authors that the pump recommended should be more satisfactory.

The quantity of ammonia delivered is varied by varying (a) the size of the sprocket wheel or drive pulley, (b) the number of hoses for the width covered, and (c) the size of the hoses.

Where the wall thickness of the hose is 3/16 of an inch, the pump will withstand the pressure ordinarily encountered with aqua ammonia.

Where the hose pump is used, the safety valve, the back pressure valve, and the manifold and orifices are not needed. A hose is used for each aqua ammonia applicator. One advantage of the hose pump is that sizes may be made for one-horse as well as for larger equipment. Insofar as the authors are aware, the hose pump is not in commercial production. Patents on the pump are held by the University of Tennessee Research Corporation, Knoxville, Tennessee.

GENERAL DISCUSSION

Anhydrous ammonia is the cheapest source of nitrogen available. The equipment available for storage, transportation, and application of anhydrous ammonia is satisfactory.

The data on crop response to anhydrous ammonia and information on the equipment for applying it were made public on March 7, 1947. At that time no commercial equipment was available for applying it. During 1947 approximately 500 tractors were equipped for applying anhydrous ammonia in Mississippi.

The farmers of Mississippi applied anhydrous ammonia to over 200,000 acres in 1947, and its use moved into Louisiana and Arkansas. It is anticipated that Mississippi farmers will apply anhydrous ammonia to approximately 400,000 acres in 1948, and that the total acreage fertilized with this source of nitrogen will be nearly a million acres. New states which will use it are Alabama, Tennesse, and Illinois.

The pressure which anhydrous ammonia exerts varies with the temperature and is 197 pounds per square inch at 100° F. Even though the pressure exerted by anhydrous ammonia is dangerous, the fact that about 500 unskilled Mississippi farm hands applied anhydrous ammonia in 1947 without a serious accident suggests that the equipment contains the features which are necessary to insure the safety of the operators.

Anhydrous ammonia may be diluted with water to make up to a 30 percent solution of ammonia. This solution, aqua ammonia, exerts little or no pressure except during prolonged periods of high temperature, and then only low pressures are developed. Anhydrous ammonia and solutions of ammonia have equal value for crop production.

In a large number of tests anhydrous ammonia and solutions of ammonia (aqua ammonia) have been found to have crop-producing value equal to or superior to ammonium nitrate for row crops. Where the application of nitrogenous fertilizers at depths of 4 to 6 inches is superior to shallower depths, ammonia may be applied at these depths more easily than can solid sources of nitrogen.

Ammonia is an excellent source of nitrogen for oats and other small grains. Ammonia may be applied easily to oats for grazing before they are planted. Ammonia may be applied after oats are up provided the soil is in good physical condition. Where soils are in poor physical condition there are difficulties in top dressing oats with ammonia. When nitrogenous fertilizers were applied to oats for grain before March 1, ammonia has been superior to ammonium nitrate on most soils.

Germinating seed are killed by ammonia if it comes in contact with them. In two known cases farmers have applied ammonia in the zone where the seed were planted afterward and poor stands of cotton resulted. However, where ammonia has been placed 4 to 6 inches below the depth of planting the seed, no injury to the germinating seed has been observed.

With the equipment which is now in use for applying anhydrous ammonia and solid sources of nitrogen, farmers usually apply anhydrous ammonia to about twice as many acres per day with one man and a tractor as they apply solid sources of nitrogen with two men and a tractor. The acreage fertilized with anhydrous ammonia usually varies between 25 and 40 acres per day per tractor unit.

Both anhydrous and aqua ammonia may be used for pre-planting and side-dressing applications. Anhydrous ammonia has been applied for row crops in the following operations by farmers in Mississippi: (1) Before planting on level land, (2) before planting on bedded land, (3) before planting when bedding simultaneously with listers, and (4) as a side-dressing.

Ammonia may be applied as a side-dressing simultaneously with cultivation with only a minor reduction in the acreage cultivated. The distance from the plants at which ammonia should be applied depends upon the size of the plants. For immediate response, which is desirable with cotton at least, it should be applied close enough to the young plants so that the roots will come in contact with it immediately. For best results cotton should be side-dressed by the time it is cultivated the second time.

Ammonia may also be applied in the planting operation, and in other land-breaking operations.

A relatively large acreage has been fertilized with anhydrous ammonia on a contract basis. Contract application of ammonia is one means of bringing low cost nitrogen in ammonia to small farmers who cannot afford to invest in the equipment required for applying it.

A question is often raised concerning the application of anhydrous ammonia during the winter months. Unfortunately, no tests have been conducted on the application of ammonia for row crops prior to March. However, the indirect information suggests that anhydrous ammonia and other sources of nitrogen should not be applied before March.

There is only one test in which fall application has been compared to spring application of different sources of nitrogen. In this test fall application was practically as good as spring application for corn, cotton, and oats. In ten tests with oats, October application of ammonium nitrate was unsatisfactory in all ten tests; however, in five of the tests where the pH of the soil was pH 5.1 or below, anhydrous ammonia was as good as spring applied ammonium nitrate. On the less acid soils, fall applied anhydrous ammonia was not satisfactory. In four other tests October applied anhydrous ammonia was unsatisfactory. In three tests in which the soils were not strongly acid, anhydrous ammonia applied to oats the last week in November was considerably inferior to February application. Fall application of nitrogen to oats should be much more satisfactory than for row crops, because row crops are two to three months later in growth.

Even though there are no direct data for row crops, the indirect evidence points strongly toward fall and winter application of nitrogen from any source being unsatisfactory; however, the evidence indicates that fall and winter application of anhydrous ammonia is superior to ammonium nitrate, and it should be equal to or superior to any other source of nitrogen.

At the present time, because of a shortage of storage equipment, as well as a general shortage of nitrogen, some farmers are applying anhydrous ammonia for row crops in January and February. In these cases, even though no direct data are available, it is recommended that the rate be increased fifty percent for January applications, and 25 percent for February applications.

There are patents concerning the use of anhydrous ammonia.

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