Alberta Farm Machinery Research Centre

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Tested at Lethbridge
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Group 7 (h)

Evaluation Report 723

TESTING OF NH_3 CONTROLLERS

CHARACTERISTICS OF ANHYDROUS AMMONIA (NH_3)

Liquid/Gas

Anhydrous Ammonia (NH_3) consists of 82% nitrogen and 18% hydrogen by weight. Anhydrous ammonia controllers meter NH_3 while in a liquid form. To remain liquid, NH_3 must be stored at a temperature of -28°F (-33° C) or kept under pressure at higher temperatures. If not, the NH_3 begins to boil and changes from liquid to gas.

For agricultural purposes storage under pressure maintained NH_3 in a liquid form in a nurse tank. When liquid ammonia is released from the nurse tank there is pressure loss due to friction of the liquid flowing through the delivery lines. The reduced pressure and change in temperature allows the liquid to boil and convert some liquid into gas. The gas created reduces the controller metering system's accuracy. To help reduce pressure loss in the delivery hoses all of the system parts should be sized properly. All pipeline fittings should be steel (do not use copper, brass or plastic fittings) and rated for NH_3 or propane use. The system should minimize pipe size changes and avoid using excess elbows and tees.

Temperature/Pressure

Figure 1 outlines how the density and pressure of NH_3 changes as the temperature changes in the nurse tank. Variations in atmospheric temperature change the temperature of the NH_3 in the nurse tank. Typically, NH_3 weighs 6.32 lb/gal (0.63 kg/L) at 41°F (5°C) and 61 psi (421 kPa). Increasing the NH_3 temperature to 59°F (15°C) decreases the density to 6.17 lb/gal (0.62 kg/L) while increasing the pressure to 87 psi (600 kPa). Therefore, as the temperature changes in the nurse tank, the corresponding change in pressure affects the number of gallons of NH_3 released from the nurse tank.

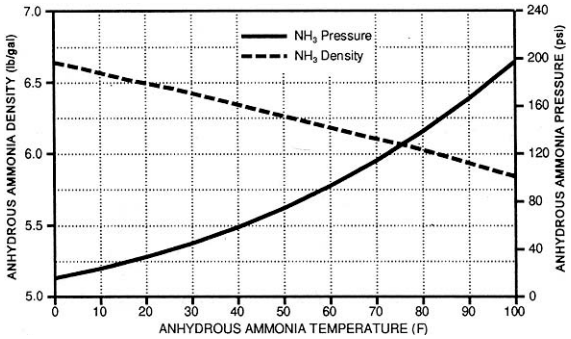

Figure 1. NH_3 physical properties.

A Co-operative Program Between

ALBERTA FARM MACHINERY RESEARCH CENTRE

PAMI
PRAIRIE AGRICULTURAL MACHINERY INSTITUTE

DICKEY-john DjCCS100 and DjCMS100 NH3 CONTROL AND MONITOR SYSTEM

MANUFACTURER:

DICKEY-john Canada Inc.
700 Campbell Street
Cornwall, ON K6H 6C9
Phone: 613/933-9000

RETAIL PRICE:

$4,767.90 (February 1996, f.o.b. Lethbridge, AB) DICKEY-john NH_3 control system complete with DjCCS100 control console, DjCMS100 monitor console, 2 thermal transfer units, radar speed sensor, vapour detector and 1 in (25 mm) control ball valve.

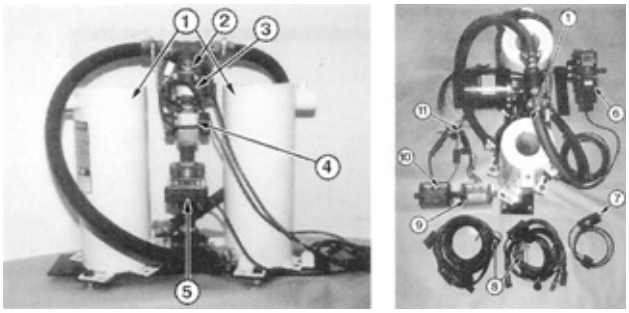

Figure 2. DICKEY-john NH_3 Control System: (1) Thermal Transfer Unit, (2) Actuator Assembly, (3) Motorized Control Valve, (4) Vapour Detector, (5) Flow Meter, (6) Radar II Speed Sensor, (7) Off/Auto/Flush Switch, (8) Electrical Cables, (9) Control Console, (10) Monitor Console and (11) Y-Cable.

SUMMARY

QUALITY OF WORK

The metering accuracy of the DICKEY-john DjCCS100 automatic controller was good for nitrogen rates between 40 and 180 lb/ac (45 and 202 kg/ha) and fair for rates below 40 lb/ac (45 kg/ha) or above 180 lb/ac (202 kg/ha). Entering the desired rate into the control console set the nitrogen application rate.

The thermal transfer unit's ability to maintain NH_3 in a liquid form was good. The vapour detector monitored the vapour (ammonia gas) in the flow of liquid from the thermal unit. A "check mark" displayed on the control console warned the operator when the acceptable level of vapour was exceeded.

The motorized control valve's response time in the automatic mode was very good. The valve responded quickly to adjust and stabilize the nitrogen flow due to changes in ground speed or application rates. Manual operation of the motorized control valve was not possible with the DICKEY-john DjCCS100 control console.

EASE OF OPERATION AND ADJUSTMENT

Ease of performing maintenance was good. A pressure relief valve to drain the control system and a strainer assembly to prevent foreign material from entering the thermal units was not provided.

Ease of programming and operating the control console was very good. The console was calibrated for Imperial (acres) and a radar ground speed sensor. Programming the console required entering and storing calibration numbers into memory. Disconnecting the battery power did not affect console memory. Changing the nitrogen application rate was easy. A new rate was programmed into the control console or changed by the "Application Rate +/-" adjustment constant.

Ease of programming and operating the monitor console was very good. The console was calibrated for Imperiat (acres) units and a radar ground speed sensor. Programming the console required entering and storing calibration numbers into memory. Disconnecting the battery power did not affect console memory.

EASE OF INSTALLATION

Ease of installing the DICKEY-john DjCCS100 and DjCMS100 NH_3 control system was good. Installation of the control system took 2 people, 7 hours. A mounting bracket was fabricated to support the 2 thermal units.

OPERATOR SAFETY

Safe operation of the DICKEY-john DjCCS100 and DjCMS100 control system was directly related to the operator's knowledge of handling NH_3. Classified as a dangerous good, extreme caution and care must used always when around NH_3. Safety features supplied with the DICKEY-john DjCCS100 and DjCMS100 control system were the procedure for entering the set-up mode and message area on the control console, operation of the off/auto/flush switch and the preset pressure relief valve on the thermal transfer units.

The DICKEY-john DjCCS100 and DjCMS100 control system relied on a continuous power source for safe operation. Unsafe operation of the control system could occur with a loss of power to one or more of the electrically controlled components.

OPERATOR'S MANUALS

The operator's manuals were good. The manufacturer supplied manuals for the control and monitor consoles. The manuals contained useful information on calibration and operation of consoles when applying anhydrous ammonia. Safety precautions when using anhydrous ammonia were included in the control console manual.

Separate installation manuals were provided for the thermal unit, fiowmeter, control valve, vapour detector, ground speed sensor and consoles. A detailed part's list was not included.

MECHANICAL HISTORY

No mechanical problems were encountered during 102 hours of field operation.

RECOMMENDATIONS

The Alberta Farm Machinery Research Centre (AFMRC) recommends the manufacturer:

1. Supply a pressure relief safety valve to drain the system of anhydrous ammonia.
2. Supply a safe and reliable method to stop NH_3 flow to the control system.
3. Supply a strainer assembly as standard equipment.
4. Supply an approved NH_3 pipe sealant to assemble the components.
5. Supply a reliable shut down system when unsafe electrical conditions exist.
6. Consider reorganizing the material in the control console manual, with an anhydrous ammonia safety section at the front of the manual.

Project Technologist: Greg Magyar
Manager: R. P. Atkins

MANUFACTURER REPLIES TO RECOMMENDATIONS

The manufacturer stated that with regard to recommendation number:

1. Dickey-john will recommend a safety release valve in the manual and supply the documentation on its correct installation.
2. Dickey-john are in the process of adding a hydraulic shut-off and a safety shut-off valve to our product lines. These will not be included in the systems, but will be offered as options.
3. Dickey-john will recommend in its manual that a strainer be used with the system.
4. Dickey-john will recommend a pipe sealant in its manual.
5. See Reply 2.
6. The NH_3 control console manual is in the process of being reorganized. This suggestion will be strongly considered.

GENERAL DESCRIPTION

The test unit was a DICKEY-john DjCCS100 control console with a thermal transfer unit (TTU), a vapour detector and 1 in (25 mm) NH_3 control ball valve. Optional equipment included a DICKEY-john DjCMS100 monitor console, a second thermal transfer unit and a DICKEY-john radar II ground speed sensor. The test unit was mounted on a 34 ft (10.4 m) cultivator equipped with NH_3 knives.

The DICKEY-john DjCCS100 and DjCMS100 controller meters liquid NH_3 to fertilizer distribution manifolds. The DjCCS100 control system monitors the application rate, flow rate, application rate error and vapour detection. The DjCCS100 also automatically adjusts the application rate due to changes in ground speed and controls the flow of NH_3 to the fertilizer manifolds. The DjCMS100 monitoring system monitors the ground speed, area covered, work rate, nurse tank volume, volume of NH_3 applied and distance travelled. The DICKEY-john controller consists of the DjCCS100 and DjCMS100 consoles, thermal transfer units, flow meter, control valve, NH_3 vapour detector, off/auto/flush switch and radar ground speed sensor.

The control and monitor consoles mount in the operator's cab. The control console consists of a 4-digit LCD display screen, a power switch, a bar graph, a 6-function keyboard and a message display area. The monitor console consists of a 6-digit LCD display screen, a power switch, a 6-function keyboard and a function point indicator. The monitors are calibrated in either Imperial or metric (SI) units. The NH_3 flows under pressure from the nurse tank through the delivery hose and breakaway coupler to the inlet side of the thermal transfer unit mounted on the tillage unit. The NH_3 enters the "warm" chamber of the thermal unit in a liquid/gas state. A flow meter is connected to the outlet side of the "warm" chamber and measures liquid NH_3 released from the thermal unit. The motorized control ball valve regulated the flow of liquid ammonia to the "cool" chambers of the thermal unit. The "warm" and "cool" chambers of the thermal unit enabled the cooling properties of NH_3 to convert the ammonia gas into liquid. The control valve controls the flow of NH_3 to the fertilizer manifolds. The vapour detector mounts between the flow meter and control valve detects the vapour in the flow of liquid NH_3. The control monitor displayed a check mark when the acceptable level was exceeded.

A speed sensor indicates ground speed to the control monitor. A number of options are available to measure ground speed.

A pressure relief valve at the inlet of the thermal transfer unit releases NH_3 when the set pressure is exceeded. Approved pipe fittings are supplied to assemble the controller system. A "Y" cable connects the monitor console to the control console. The tractor's electrical system powers the DICKEY-john control system.

Detailed specifications are given in **Appendix I** while **Figure 2** shows the DICKEY-john DjCCS100 and DjCMS100 control system.

SCOPE OF TEST

The DICKEY-john DjCCS100 and DjCMS100 automatic NH_3 control system was used for 102 hours while fertilizing 1695 ac (686 ha). The systems were evaluated for quality of work, ease of operation and adjustment, ease of installation, operator safety and suitability of the operator's manuals.

The controller was operated in the lab to determine application rate accuracy and controller response over a range of operating temperatures. Work included testing the effect of changes in ground speed, application rates and system variables. The applicator width for lab testing was 35 ft (10.7 m).

A laboratory set-up consisted of supplying the controller with NH_3 from a 180 gal (818 L) nurse tank. Load cells connected to AFMRC's data acquisition system recorded the change in weight of the nurse tank. Pressure gauges monitored the nurse tank and controller discharge hose pressures. A temperature probe inserted into the nurse tank monitored the NH_3 temperature. A speed simulator input ground speeds into the controller.

The unit evaluated by the AFMRC was configured as described in the General Description, **Figure 2**, and the Specifications section in **Appendix I** of this report. The manufacturer may have built different configurations of this unit before and after AFMRC tests. Therefore, when using this report, be sure to first check the unit under consideration is the same as the one reported here. If differences exist, assistance can be obtained from AFMRC or the manufacturer to determine changes in performance.

RESULTS AND DISCUSSION

QUALITY OF WORK

Controller Accuracy: The metering accuracy of the DICKEY-john DjCCS100 automatic controller was good for nitrogen rates between 40 and 180 lb/ac (45 and 202 kg/ha) and fair for rates below 40 lb/ac (45 kg/ha) or above 180 lb/ac (202 kg/ha). The nitrogen application rate was equal to 82 percent of the NH_3 rate. Entering the desired rate into the controller set the application rate.

Figure 3 shows measured nitrogen application rates for the DICKEY-john DjCCS100 controller over a range of application rates at 5 mph (8 km/h) and at 3 different NH_3 temperatures. At an NH_3 temperature of 23°F (-5°C) the controller maintained application rate accuracy for set rates between 40 and 180 lb/ac (45 and 202 kg/ha). At a set application rate of 40 lb/ac (45 kg/ha) the monitor displayed an application rate between 20 and 50 lb/ac (23 and 56 kg/ha), while the average measured rate was 23.4 lb/ac. For application rates above 180 lb/ac (202 kg/ha) the control console displayed the vapour detection check mark.

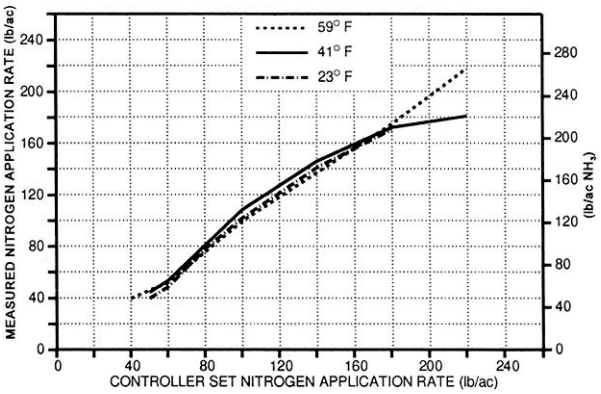

Figure 3. Measured nitrogen application rates.

At an NH_3 temperature of 41°F (5°C) the controller maintained application rate accuracy for set rates below 180 lb/ac (202 kg/ha). When increasing the set rate to 220 lb/ac (247 kg/ha) the monitor displayed an application rate varying between 200 and 238 lb/ac (225 and 267 kg/ha), while the average measured rate was 181 lb/ac (220 kg/ha). The control console continuously displayed the vapour detection check mark.

At an NH_3 temperature of 59° F (15°C) the controller maintained application rate accuracy for set rates below 180 lb/ac (202 kg/ha). At a set rate of 180 lb/ac (247 kg/ha) the monitor displayed an application rate between 174 and 187 lb/ac (196 and 210 kg/ha) while the average measured rate was 170.4 lb/ac (191 kg/ha). The control console continuously displayed the vapour detection check mark.

Heat Exchanger: The thermal transfer unit's ability to maintain NH_3 in a liquid form was good. As the NH_3 temperature and application rate increased there was an increased demand on the thermal unit to maintain the NH_3 in a liquid form. The vapour detector monitored how much vapour (ammonia gas) was in the flow of liquid from the thermal unit. A check mark displayed on the control console warned the operator when the acceptable level of vapour was exceeded.

Motorized Control Valve: The motorized control valve's response time was very good. The motorized ball valve responded quickly to adjust and stabilize nitrogen flow due to a change in ground speed or application rates. Manual operation of the motorized control valve was not possible with the DICKEY-john DjCCS100 control console.

Figure 4 shows a typical response curve when decreasing the ground speed from 5 to 3 mph (8 to 5 km/h) at an application rate of 60 lb/ac (67 kg/ha). Figure 5 shows a typical response curve when increasing the ground speed from 5 to 7 mph (8 to 12 km/h) at an application rate of 60 lb/ac (67 kg/ha). The graphs show the average response time required for the motorized control valve to adjust and stabilize the flow of nitrogen to compensate for a change in ground speed. The average response time required was 1.5 seconds.

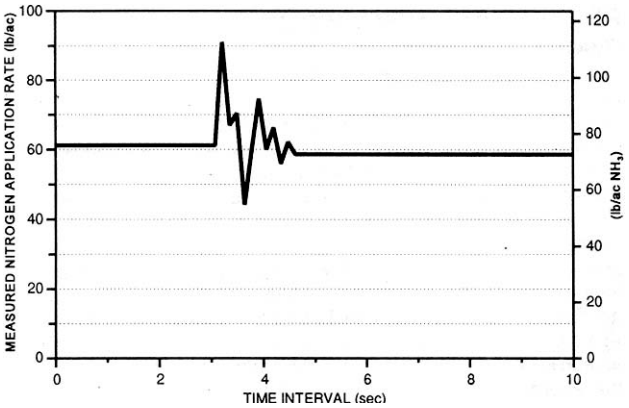

Figure 4. Controller response curve with a decrease in ground speed from 5 to 3 mph (8 to 5 km/h) at an application rate of 60 lb/ac (67 kg/ha).

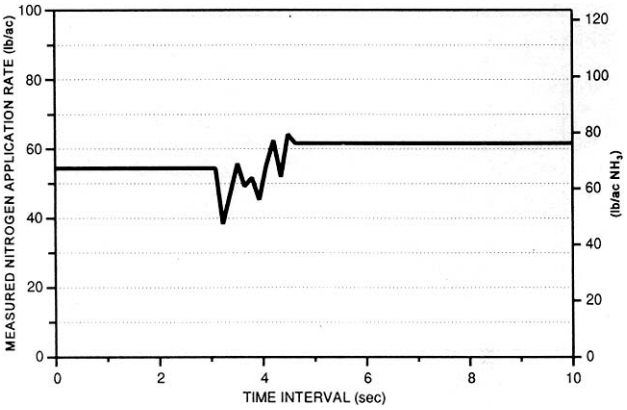

Figure 5. Controller response curve with an increase in ground speed from 5 to 7 mph (8 to 12 km/h) at an application rate of 60 lb/ac (67 kg/ha).

Figure 6 shows a typical response curve when decreasing the application rate from 100 to 60 lb/ac (112 to 67 kg/ha) at a ground speed of 5 mph (8 km/h). **Figure 7** shows a typical response curve when increasing the application rate from 100 to 140 lb/ac (112 to 157 kg/ha) at a ground speed of 5 mph (8 km/h). The graphs show the average response time required for the motorized control valve to adjust and stabilize the flow of nitrogen to compensate for a change in the set application rate. The average response time required was 1.3 seconds.

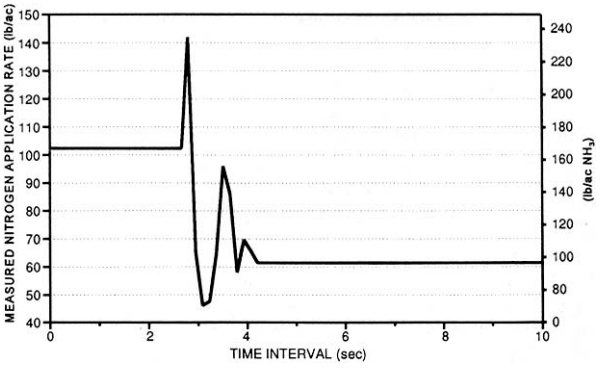

Figure 6. Controller response curve with a decrease in application rate from 100 to 60 lb/ac (112 to 67 kg/ha) at a ground speed of 5 mph (8 km/h).

Speed Sensor: The radar ground speed sensor was accurate when properly calibrated. A proper calibration required performing a field distance calibration check. To reduce wrong speed readings, the radar ground speed sensor should be mounted as close as possible to the centreline of the tillage unit. Reducing vibration of the speed sensor also helped reduce wrong speed readings.

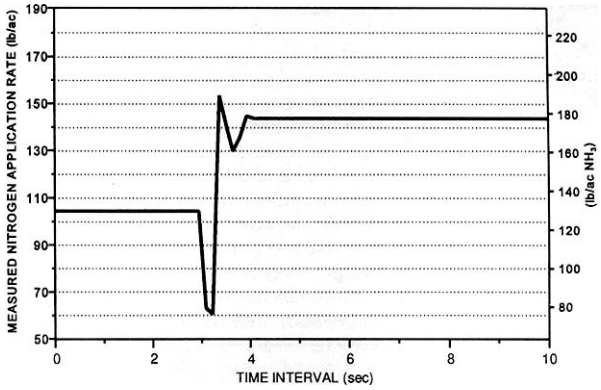

Figure 7. Controller response curve with an increase in application rate from 100 to 140 lb/ac (112 to 157 kg/ha) at a ground speed of 5 mph (8 km/h).

The variation of residue on the soil surface caused slight speed fluctuations. The fluctuations were small, considered insignificant.

Electrical Power Requirements: No excessive demands were made on the tractor battery or electrical charging system.

EASE OF OPERATION AND ADJUSTMENT

Maintenance: Ease of performing routine maintenance was good. Maintenance included checking and fixing all NH_3 leaks. No pressure relief valve was supplied to drain NH_3 from the system. The AFMRC recommends the manufacturer supply a pressure relief valve to drain the system of NH_3 safely. No strainer assembly to prevent foreign material from entering the thermal units was supplied. The AFMRC recommends the manufacturer supply a strainer assembly as standard equipment.

Control Console: Ease of programming and operating the console was very good. The console was placed into the set-up mode by pressing and holding the "OPER/SETUP" function keypad, (**Figure 8**). The "-" and "+" keypads were used to enter the calibration numbers into the control console. The 4-digit LCD readout displayed the selected calibration constant as indicated by the set-up indication cursor on the bar graph display. The keyboard was convenient to operate.

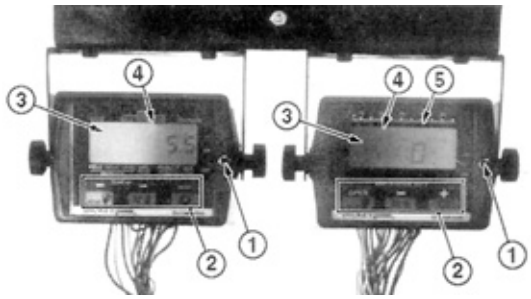

Figure 8. LEFT: DICKEY-john DjCMS100 Monitor Console: (1) power switch, (2) function keypads, (3) data display screen and (4) function's pointer. RIGHT: DICKEY-john DjCCS100 Control Console: (1) power switch, (2) function keypads, (3) data display screen, (4) bar graph display and (5) setup position location.

The controller console evaluated was programmed for Imperial (acres) units and a radar ground speed sensor. The console could also be programmed for metric (SI) units and wheel drive sensors. During initial set-up 10 calibration constants were entered and stored into the console. Once programmed, loss of power to the control console did not affect the console memory. The 10 calibration constants were entered under the following functions:

A. FUNCTION - used to store the console NH3 constant.
B. APPLICATION RATE - used to enter the target application rate in pounds per acre.
C. APPLICATION RATE (+/-) - used to store the application rate adjustment number. The "+/-" number determined the amount the application rate was increased or decreased.

D. IMPLEMENT WIDTH - used to store the implement width (ft) of the tillage unit.
E. DENSITY - used to store the density constant of the NH_3 in the nurse tank. The density and application rate constants must have the same units.
F. FLOW SENSOR CONSTANT - used to store the flow meter calibration number on the flow meter.
G. FLUSH FLOW RATE - used to store the desired NH_3 flush flow rate.
H. BAR GRAPH MAX. FLOW RATE - used to store the calibration number constant for the bar graph flow rate.
I. SYSTEM RESPONSE - used to store the constant for the control valve response time.
J. GROUND SPEED CALIBRATION - used to store the constant for the ground speed sensor.

Initial field use or use after a period of time required, operating the system in the flush mode. Holding the "Off/Auto/Flush" switch" in the flush position opened the control valve to the programmed flush flow rate and allowed NH_3 to flow through the system. After charging the system and the thermal transfer units, the control console was placed into the auto mode by releasing the switch from the flush position. The control console then automatically adjusted the motorized control valve when changes in forward speed or flow oocu rred.

Changing the nitrogen application rate was easy. The new rate was programmed into the control console or changed by the "Application Rate +/-" adjustment constant. Pressing the "+" or "-" keypad while in the "Operate Mode" adjusted the application rate. Changing the application rate with the adjustment constant did not store the new rate in memory. The display screen flashed the new application rate until the "OPER" keypad was pressed, changing the application rate back to the programmed value.

The control console allowed for a stationary field check of the NH_3 system by holding the "Off/Auto/Flush" toggle switch in the flush position. The function was useful in determining proper operation of the control system and applicator knives.

The bar graph display indicated the flow rate of NH_3 in lb/h. The fluctuation of the bar graph indicated the stability of the system. A steady and consistent display indicated proper operation of the control system, while an erratic display indicated an adjustment to the system response constant was required.

Monitor Console: Ease of programming and operating the console was very good. The console was placed in the set-up mode by pressing and holding the"DISPLAY/SETUP" function keypad, (**Figure 8**). The "RESET" and "DISPLAY" keypads were used to enter the calibration numbers into the monitor console. The 6-digit LCD readout displayed the selected calibration constant as indicated by the monitor function pointer.

The monitor console was programmed for Imperial (acres) and a radar ground speed sensor. The console could also be programmed for metric (SI) units and wheel drive sensors. During initial set-up 9 calibration constants were entered and stored into the console. Once programmed, disconnecting battery power did not affect console memory. The monitor console displayed an "OFF" message and would not function when the power supply from the tractor's ignition switch or battery was disconnected. The 9 calibration constants were entered under the following functions:

C0. FUNCTION - same as control console constant.
C1. DENSITY - same as control console constant.
C2. FLOW SENSOR CONSTANT - same as control console constant.
C6. TANK LEVEL (Full) - used to store the capacity of the nurse tank in pounds of anhydrous ammonia or nitrogen.
C7. TANK ALARM LEVEL - used to store the nurse tank low level alarm value.
U2. VOLUME UNITS CONSTANT - used to store the unit's conversion number.
U6. GROUND SPEED CALIBRATION - same as control console constant.
E0. APPLICATOR SWITCH SENSE - used to indicate when the console was recording accumulated area.
EI. APPLICATOR SECTION 1 - used to store the applicator width in feet.

The monitor console received sensor inputs from the control console. When selected, 10 monitor functions indicated various operating conditions during anhydrous ammonia application. The 10 operating functions were:

1. SPEED - displayed actual ground speed.
2. FIELD AREA - displayed field area covered.
3. TOTAL AREA - displayed total area covered.
4. AREA/HR - displayed area per hour rate calculated using present ground speed.
5. DISTANCE - displayed cumulative distance travelled.
6. FIELD PRODUCT - displayed pounds of product applied for the field area.
7. TOTAL PRODUCT - displayed pounds of product applied for the total area.
8. PRODUCT LEVEL - displayed the pounds of product remaining in the nurse tank.
9. APPL RATE - displayed "CCS". Application rate displayed on control console.
10. PRODUCT SENSOR - displayed frequency output of the flow meter.

To reset a number under the area or product functions the desired function was selected and then the "RESET" keypad pressed until zero was displayed.

EASE OF INSTALLATION

Ease of installing the DICKEY-john DjCCS100 and DjCMS100 system was good. Installation of the control system included assembling the NH_3 components, mounting the control system and radar speed sensor, installing the control and monitor consoles, routing the electrical harness and connecting the control system to the NH_3 nurse tank and manifolds. Installation of the DICKEY-john DjCCS100 and DjCMS100 system took 2 people, 7 ,hours.

Assembly of the NH_3 components required plumbing the flowmeter, vapour detector, motorized control valve and hoses to the 2 thermal transfer units. The manufacturer supplied the necessary pipe fittings and mounting hardware to assemble the components. A pipe sealant compatible with NH_3 was not supplied. The AFMRC recommends the manufacturer supply an approved NH_3 pipe sealant to assemble the components. A schematic was provided detailing the correct assembly of the components.

A mounting bracket was fabricated to support the 2 thermal units. Three U-bolts (not supplied) secured the control system to a 4 x 4 in (102 x 102 mm) beam on the tillage unit (**Figure 9**). Two types of ground speed sensors were available with the control system; radar speed sensor or drive wheel sensor. The DICKEY-john DjRVS II radar velocity sensor was used to measure ground speed. The manufacturer supplied a radar velocity sensor installation. The radar speed sensor was mounted near the centreline of the tillage unit.

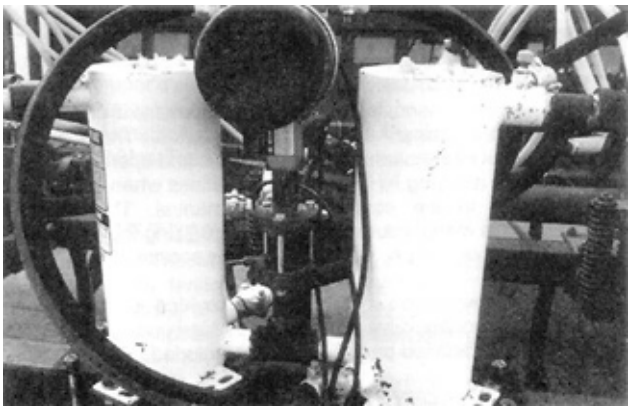

Figure 9. Control system mounted 0ha tillage unit.

A bracket was fabricated to install the control and monitor console into the tractor cab. A "Y" electrical cable connected the monitor console to the control console. The length of the main harness and implement harness cables allowed for safe connection of the consoles to the control system, radar sensor and power source. The electrical wire connecting the "Y" cable to the tractor's ignition switch was also sufficient in length.

OPERATOR SAFETY

Safe operation of the DICKEY-john DjCCS100 and DjCMS100 system was directly related to the operator's knowledge of handling NH_3. Classified as a dangerous good, extreme caution and care was always necessary when around anhydrous ammonia. Safety features supplied with the DICKEY-john DjCCS100 and DjCMS100 system were the procedure for entering the set-up mode and message area on the control console, the operation of the "Off/Auto/Flush" switch and the preset pressure relief valve on the thermal transfer units.

Entering the set-up mode required pressing and holding the "OPER/SETUP" keypad until the control console displayed "SET-UP" in the message area. The procedure prevented accidental changes to the stored values. The message area also displayed "APER" when the control valve was fully open and a check mark when the vapour in the system exceeded the acceptable limit.

The"Off/Auto/Flush" switch too had to be moved to the "OFF" position whenever the control console displayed the "OFF" message. The safety feature prevented operation of the control console due to the wrong positioning of the "Off/Auto/Flush" switch. The "FLUSH" position allowed the operator to check the operation of the system from the tractor cab when stationary. This function was considered a positive safety feature.

The manufacturer did not supply a safe and reliable method to stop the flow of NH3 from the nurse tank to the control system. The AFMRC recommends the manufacturer supply a safe and reliable method to stop the flow of anhydrous ammonia to the control system.

The DICKEY-john DjCCS100 and DjCMS100 system relied on a continuous power source for safe operation of the system. **Table 1** outlines the reaction of the system with a power loss to any of the electrically-controlled components. Unsafe operation of the control system occurred with a loss of power to 1 or more of the electrically-controlled components. The AFMRC recommends the manufacturer supply a reliable shut down system when unsafe electrical conditions existed.

Table 1. Electrical cable test.

ELECTRICAL TEST (disconnected cables)	CONTROL SYSTEM RESPONSE	
	Cable Disconnected Before Operating System	System Operating When Power Disconnected
Main power from consoles	Does not work	Continues to apply NH_3, with no reading on control console
Flow meter	Continues to apply NH_3, control valve wide open with "APER" displayed in message area	Continues to apply NH_3, control valve wide open with "APER" displayed in message area
Control valve	Does not work	
Speed	Does not work	Stops applying NH_3

OPERATOR'S MANUALS

The operator's manuals were good. The manufacturer supplied manuals for the control and monitor consoles. The manuals contained useful information on the calibration and operation of the consoles when applying NH_3. Safety precautions when using NH_3 were included in the control console manual. The AFMRC recommends the manufacturer consider reorganizing the material in the control console manual, with an NH_3 safety section at the front of the manual.

Separate installation manuals were provided for the thermal unit, flow meter, control valve, vapour detector, ground speed sensor and consoles. A detailed parts list was not included.

MECHANICAL HISTORY

No mechanical problems were encountered during 102 hours of field operation. The intent of the test was evaluation of functional performance. An extended durability evaluation was not conducted.

MICRO-TRAK MT3000 NH_3 CONTROL SYSTEM

MANUFACTURER:

Micro-Trak Systems Inc.
P.O. Box 99
Eagle Lake, MN, USA 56024-0099
Phone: 507/257-3600 (1-800-328-9613)

RETAIL PRICE:

$2865.00 U.S. (February, 1996, f.o.b. Eagle Lake, MN) Micro-Trak NH_3 Control System complete with MT3000 control console, NH3500 heat exchanger, 1 in (25 mm) NH_3 shut-off valve, 0.75 in (19 mm) FM750 flow meter, 0.75 in (19 mm) servo butterfly valve and ground speed radar interface cable.

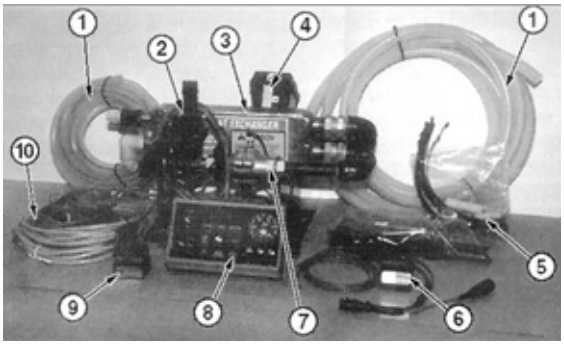

Figure 2. Micro-Trak MT3000 NH_3 Control System: (1) Vapour Hoses, (2) Motorized Control Servo Valve, (3) Heat Exchanger, (4) On/Off Valve, (5) Mounting Hardware, (6) Radar Interface Cable and Module, (7) Flow Meter, (8) Control Console, (9) Hold Cut-out Module and (10) Electrical Cables.

SUMMARY

QUALITY OF WORK

The metering accuracy of the Micro-Trak MT3000 automatic controller was good for nitrogen rates between 40 and 140 lb/ac (45 and 157 kg/ha) and fair for rates below 40 lb/ac (45 kg/ha) or above 140 lb/ac (157 kg/ha). Entering the desired rate into the controller set the nitrogen application rate. Field tests showed as the NH_3 temperature increased above 59°F (15°C) the minimum controlled application rate also increased. Adjusting the butterfly valve did not reduce the application rate as the system pressure prevented the butterfly valve from closing. Plugging 1 hole on the buttedly valve reduced the pressure, allowing for lower application rates.

The heat exchanger's ability to maintain NH_3 in a liquid form was good. The vapour produced from the heat exchanger was discharged through vapour lines. The amount of vapour discharged was related to the metering accuracy of the controller and the percentage of nitrogen loss corresponded to the actual application rate.

The motorized control valve's response time in the automatic mode was very good. The valve responded quickly to adjust and stabilize the flow of nitrogen due to changes in ground speed or application rates. Manual operation of the control system reduced the efficiency of the motorized control valve, therefore manual operation was limited to initial field use or when the controller was not used for a period of time.

EASE OF OPERATION AND ADJUSTMENT

Ease of pedorming maintenance was very good. Maintenance included checking and fixing all NH_3 leaks and cleaning the strainer assembly and flow meter.

Ease of programming and operating the console was very good. The console was programmed for American English (US) units and a radar ground speed sensor. Programming the console required 8 calibration numbers be entered and stored in memory. Changing the nitrogen application rate was very easy. A new rate was programmed into the control console or changed by the Delta Rate function.

EASE OF INSTALLATION

Ease of installing the Micro-Trak MT3000 control system was good. The manufacturer assembled the components of the NH3500

control system. Installation of the MT3000 control system took 2 people, 5 hours. The main harness cable supplied was too shod to connect the console to the hold cutout module so a 10 ft (3 m) extension cable was ordered.

OPERATOR SAFETY

Safe operation of the Micro-Trak MT3000 controller was directly related to the operator's knowledge of handling NH_3. Classified as dangerous goods, extreme caution always was necessary when around the NH_3. Safety features supplied with the Micro-Trak MT3000 controller were the on/off valve placed before the control system and the procedure for entering the calibration mode.

The Micro-Trak MT3000 control system relied on a continuous power source for safe operation. Unsafe operation occurred with a loss of power to 1 or more of the electrically controlled components.

OPERATOR'S MANUALS

The operator's manuals were fair. The manufacturer supplied a manual for both the control console and the NH_3 control system. The manual supplied for the control console was written mainly for spraying operations. The NH3500 installation/operator's manual supplied useful information on the installation, operation and maintenance of the control system. The manual was similar to the 1 supplied with the control console. A detailed pads list was not included. A detailed section on the mandatory safety precautions to be followed when using NH_3 was not included.

MECHANICAL HISTORY

The in-tine power fuse was replaced and 1 hole on the butterfly valve was plugged.

RECOMMENDATIONS

The Alberta Farm Machinery Research Centre (AFMRC) recommends the manufacturer:

1. Supply a motorized control valve not restricted by the system pressure.
2. Supply a pressure relief valve to safely drain the system of NH3.
3. Supply sufficient cable lengths to install the control system properly.
4. Supply a safe and reliable on/off valve for stopping the flow of NH3 to the heat exchanger.
5. Supply a reliable shut down system when unsafe electrical conditions existed.
6. Supply a control console manual specifically for NH_3.
7. Supply a detailed safety section on the proper handling of NH_3 in the operator's manual.

Project Technologist: Greg Magyar

Manager: R.P. Atkins

MANUFACTURER'S REPLIES TO RECOMMENDATIONS

The manufacturer stated with regard to recommendation number:

1. The motorized control valve is not restricted by pressure. It has built-in leakage to prevent the flow meter from stalling.
2. Micro-Trak are currently implementing a new NH_3 kit design with a relief valve for safe NH_3 drainage.
3. The system comes with enough cable for standard installation of an NH_3 kit. Micro-Trak offer extension cables to customize the operators needs. The need for more cable length for larger tool bars will be evaluated.

   Operators should use a rope pull or hydraulic valve for safe shut off. Most applicators already have a hydraulic shut-off valve.

   By having a rope pull or hydraulic valve on/off valve, operators have the ability to shut down safely when unsafe electrical conditions exist.
6. Micro-Trak are in the process of putting a manual together especially for the NH_3 system.
7. Having a detailed safety section is an excellent idea and will be discussed when putting together a new manual for the NH_3 kit.

ADDITIONAL MANUFACTURER'S COMMENTS

Maximum application rate: To increase the nitrogen application rate above the stated values an orifice hose barb should be installed.

GENERAL DESCRIPTION

The test unit was a 19 US gal/min (72 L/min) Micro-Trak NH3500 NH_3 metering system with a Micro-Trak MT3000 sprayer control monitor, 1 in (25 mm) NH_3 shut-off ball valve, 0.75 in (19 mm) FM750 flow meter, 0.75 in (19 mm) servo butterfly control valve, ground speed radar interface cable and a 10 ft (3.0 m) extension flow control cable. The test unit was mounted on a 35 ft (10.7 m) cultivator equipped with NH_3 knives. The vapour tubes were secured to 4 knives on the front row of the cultivator's centre and wing sections.

The Micro-Trak MT3000 controller meters liquid NH_3 to fertilizer distribution manifolds. The MT3000 system monitor the application rate, ground speed, volume and rate of NH_3 applied, percentage error and area covered. The MT3000 automatically adjusts the application rate due to changes in ground speed and controls the flow of NH_3 to the fertilizer manifolds. The Micro-Trak MT3000 controller consists of the MT3000 sprayer control monitor, NH3500 heat exchanger, flow meter, control and shut off valves, hold cut-out module, vapour hoses and steel vapour tubes.

The control monitor mounts in the operator's cab. The monitor consists of a 5-digit LCD display screen, 3 individual boom switches, a multifunction increase/decrease switch, master spray switch and a rotary selector with 16 functions. The monitor is calibrated in American English (US) units. The NH_3 flows under pressure from the nurse tank through the delivery hose, breakaway coupler and shut-off valve to the inlet side of the heat exchanger mounted on the tillage unit. The NH_3 enters the "hot" chamber of the heat exchanger in a liquid/gas state. The flow meter connected to the outlet side of the "hot" chamber measures liquid NH_3 released from the heat exchanger. A hose connected to the outlet side of the motorized control valve feeds a portion of the liquid ammonia to the inlet side of the "cold" chamber on the heat exchanger. The "hot" and "cold" chambers of the heat exchanger enables the cooling properties of NH_3 to convert the ammonia gas into liquid. Vapour produced through the cooling process is discharged from the "cold" chamber outlet port. Vapour flows through hoses to steel tubes attached behind 4 injection knives. The shut-off ball valve plumbed to the inlet side of the heat exchanger controls the flow of NH_3 to the heat exchanger. The hold cut-out module transmits nitrogen flow to the control console only when the shut-off valve is open.

A speed sensor indicates ground speed to the control monitor. A number of options are available to measure ground speed.

The tractor's electrical system powers the Micro-Trak MT3000 control system.

Detailed specifications are given in **Appendix I** while **Figure 2** shows the Micro-Trak MT3000 NH_3 control system.

SCOPE OF TEST

The Micro-Trak MT3000 automatic control system was used for 92 hours while fertilizing 1500 ac (607 ha). The system was evaluated for quality of work, ease of operation and adjustment, ease of installation, operator safety and suitability of the operator's manuals.

The controller was operated in the lab to determine application rate accuracy and controller response over a range of operating temperatures. Work included testing the effect of changes in ground speed, application rates and system variables. The applicator width for lab testing was 35 ft (10.7 m).

Laboratory set- up consisted of supplying the controller with NH_3 from a 180 gal (818 L) nurse tank. A 900 gal (4091 L) water holding tank collected the NH_3 metered by the controller. Controller vapour lines were plumbed into a 300 gal (1364 L) vapour water holding tank. Load cells connected to AFMRC's data acquisition system recorded the change in weight of the nurse tank and vapour water holding tank. Pressure gauges monitored the nurse tank and

controller discharge hose pressures. A temperature probe inserted into the nurse tank monitored the NH_3 temperature. A speed simulator input ground speed into-the controller.

The unit evaluated by the AFMRC was configured as described in the General Description, **Figure 2**, and the Specifications section in **Appendix I** of this report. The manufacturer may have built different configurations of this unit before and after AFMRC tests. Therefore, when using this report, be sure to first check the unit under consideration is the same as the one reported here. If differences exist, assistance can be obtained from AFMRC or the manufacturer to determine changes in performance.

RESULTS AND DISCUSSION

Quality of Work

Controller Accuracy: The metering accuracy of the Micro-Trak MT3000 automatic control system was good for nitrogen application rates between 40 and 140 lb/ac (45 and 157 kg/ha) and fair for rates below 40 lb/ac (45 kg/ha) or above 140 lb/ac (157 kg/ha). The nitrogen application rate was equal to 82% of the NH_3 rate. Entering the desired rate into the controller set the application rate. A red application error warning light showed the application rate had exceeded 10% of the set rate.

Figure 3 shows measured nitrogen application rates for the Micro-Trak MT3000 controller over a range of application rates at 5 mph (8 km/h) and at 3 different NH_3 temperatures. At an NH_3 temperature of 23°F (-5°C) the controller maintained application rate accuracy for set rates below 140 lb/ac (157 kg/ha). Increasing the set rate to 180 lb/ac (202 kg/ha), the monitor displayed an application rate between 179 and 182 lb/ac (201 and 204 kg/ha), while the average measured rate was 158 lb/ac (177 kg/ha).

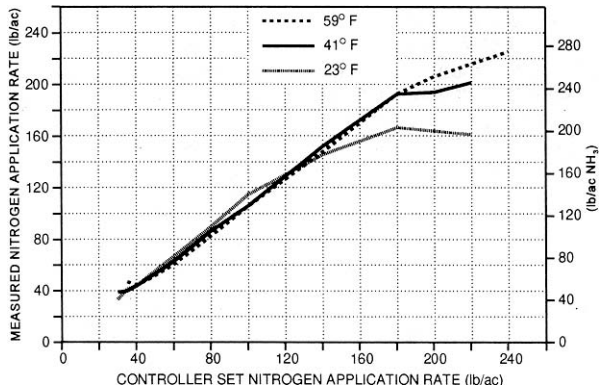

Figure 3. Measured nitrogen application rates.

At an NH_3 temperature of 41°F (5°C) the controller maintained application rate accuracy for set rates between 40 and 180 lb/ac (45 and 202 kg/ha). When decreasing the set rate to 35 lb/ac (39 kg/ha) the monitor displayed an application rate between 35.2 and 39.3 lb/ac (40 and 44 kg/ha) with the red warning light flashing. The average measured rate was 39.7 lb/ac (45 kg/ha). Increasing the set rate to 200 lb/ac (225 kg/ha) the monitor displayed an application rate between 198 and 201 lb/ac (222 and 226 kg/ha) while the average measured rate was 183.2 lb/ac (206 kg/ha).

At an NH_3 temperature of 59°F (15°C) the controller maintained application rate accuracy for set rates between 40 and 200 lb/ac (45 and 225 kg/ha). Decreasing the set rate to 35 lb/ac (39 kg/ha) the monitor displayed an application rate between 44 and 45.3 lb/ac (49 and 51 kg/ha) with the red warning light on. The average measured rate was 44.6 lb/ac (50 kg/ha). When increasing the set rate to 240 lb/ac (270 kg/ha) the monitor displayed an application rate between 241 and 243 lb/ac (271 and 273 kg/ha) while the averaged measured rate was 212.1 lb/ac (238 kg/ha).

As the NH_3 temperature increased above 59°F (15°C), field tests showed the minimum controlled application rate also increased. For example, with a set application rate of 50 lb/ac (56 kg/ha) and a temperature increase to 68°F (20°C) the controller displayed a gradual increase in application rate until stabilizing between 62 and 65 lb/ac (70 and 73 kg/ha). Whether in automatic mode or switching to manual, adjusting the butterfly valve did not reduce the application rate. The system pressure prevented the butterfly valve from closing. The manufacturer stated by plugging 1 hole on the butterfly valve the reduction in pressure would allow for lower application rates. The AFMRC recommends the manufacturer supply a motorized control valve not restricted by system pressure.

Heat Exchanger: The heat exchanger's ability to maintain NH_3 in a liquid form was good. As the NH_3 temperature increased there was an increased demand on the heat exchanger to maintain the NH_3 in a liquid form. Keeping NH_3 as a liquid, the heat exchanger produced vapour which was discharged through the vapour lines.

Vapour loss in the form of nitrogen from the heat exchanger was related to the metering accuracy of the controller. The percentage of nitrogen loss corresponded to the measured application rate and not the set rate. **Figure 4** shows the pementage of nitrogen loss through the vapour lines for the measured temperatures and application rates. At a temperature of 23°F (-5°C) the percentage of nitrogen loss varied between 2.0 and 6.2%. At a temperature to 41°F (5°C) the percentage of nitrogen loss varied between 2.7 and 5.4% and between 2.81 and 5.9% for a temperature of 59°F (15°C).

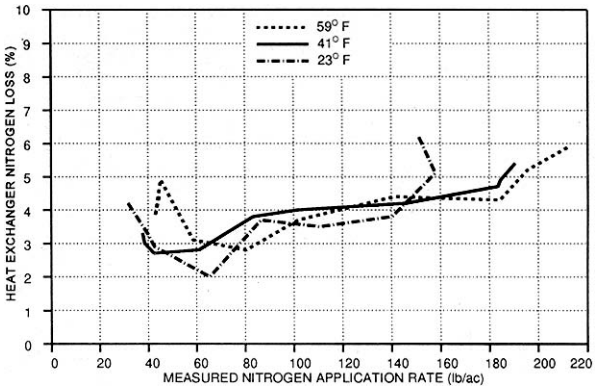

Figure 4. Percentage of nitrogen loss from the vapour lines.

Motorized Control: The motorized control valve's response time in the automatic mode was very good. The motorized butterfly valve responded quickly to adjust and stabilize nitrogen flow due to a change in ground speed or application rate. Manual operation of the control system reduced the efficiency of the motorized control valve, therefore manual operation was limited to initial field use or when the controller was not used for a period of time.

Figure 5 shows a typical response curve when decreasing the ground speed from 5 to 3 mph (8 to 5 km/h) at an application rate of 100 lb/ac (112 kg/ha). **Figure 6** shows a typical response curve when increasing the ground speed from 5 to 7 mph (8 to 12 km/h) at an application rate of 100 lb/ac (112 kg/ha). The graphs show the average response time required for the motorized control valve to adjust and stabilize the flow of nitrogen to compensate for change in ground speed. The average response time required was 1.7 seconds.

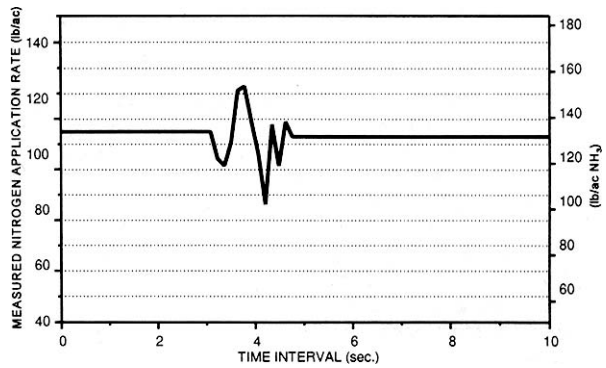

Figure 5. Controller response curve with a decrease in ground speed from 5 to 3 mph (8 to 5 km/h) at an application rate of 100 lb/ac (112 kg/ha).

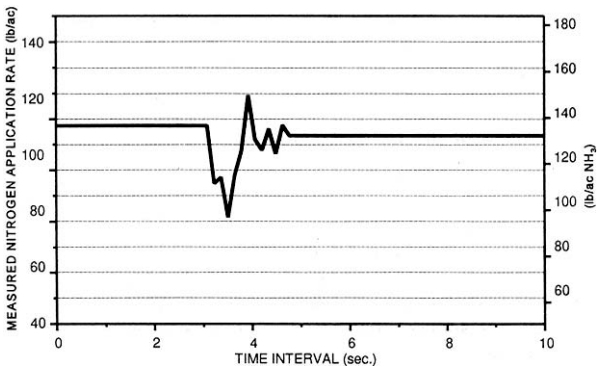

Figure 6. Controller response curve with an increase in ground speed from 5 to 7 mph (8 to 12 km/h) at an application rate of 100 lb/ac (112 kg/ha).

Figure 7 shows a typical response curve when decreasing the application rate from 100 to 60 lb/ac (112 to 67 kg/ha) at a ground speed of 5 mph (8 km/h). **Figure 8** shows a typical response curve when increasing the application rate from 100 to 140 lb/ac (112 to 157 kg/ha) at a ground speed of 5 mph (8 km/h). The graphs show the average response time required for the motorized control valve to adjust and stabilize the flow of nitrogen to compensate for a change in the set application rate. The average response time required was 1.5 seconds.

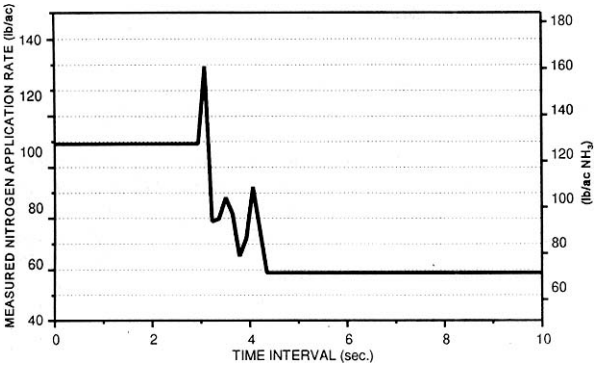

Figure 7. Controller response curve with a decrease in application rate from 100 to 60 lb/ac (112 to 67 kg/ha) at a ground speed of 5 mph (8 km/h).

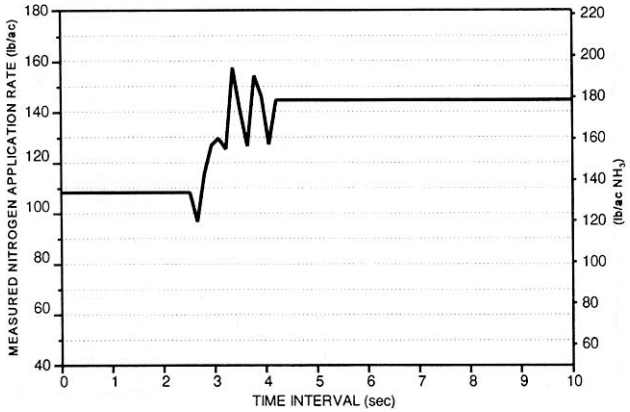

Figure 8. Controller response curve with an increase in application rate from 100 to 140 lb/ac (112 to 157 kg/ha) at a ground speed of 5 mph (8 km/h).

Speed Sensor: The radar ground speed sensor was accurate when properly calibrated. A proper calibration required performing a field distance calibration check. To reduce wrong speed readings the radar ground speed sensor was mounted as close as possible to the centreline of the tillage unit. Reducing vibration of the speed sensor also helped reduce wrong speed readings.

The variation of residue on the soil surface caused slight speed fluctuations. The fluctuations were small and considered insignificant.

Electrical Power Requirements: No excessive demands were made on the tractor battery or electrical charging system.

EASE OF OPERATION AND ADJUSTMENT

Maintenance: Ease of performing routine maintenance was very good. Maintenance included checking and fixing all NH_3 leaks and cleaning the strainer assembly. The strainer assembly prevented foreign material from entering the heat exchanger and was cleaned regularly. The manufacturer supplied instructions on cleaning the flow meter when improper operation was detected. The manufacturer did not supply a safe way to drain the control system of NH_3. The AFMRC recommends the manufacturer supply a pressure relief valve to drain the system of NH_3 safely.

Controller Console: Ease of programming and operating the console was very good. Programming the console required moving the "Master Spray Switch" to the "hold" position and selecting "CAL" with the rotary selector dial, (Figure 9). The console "Adjust Switch" entered the calibration numbers into the 8 calibration settings. The 5-digit LCD readout displayed the selected function value as determined by the rotary selector dial.

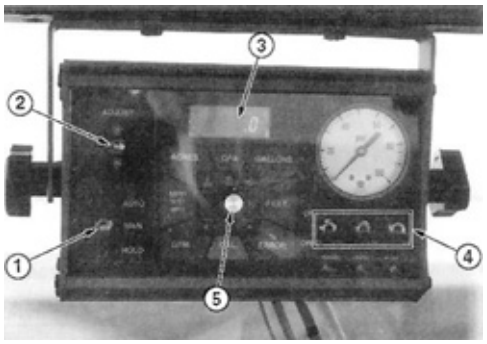

Figure 9. Micro-Trak MT3000 Control Console: (1) Master Spray Switch, (2) Adjust Switch, (3) Data Display Screen, (4) Boom Switches and (5) Rotary Selector Dial.

The controller console evaluated was calibrated for American English (US) units and programmed for a radar ground speed sensor. The console could also be programmed for wheel drive sensors and available in metric (SI) units. During initial set-up, 8 calibration numbers were entered and stored into the console. Once programmed, the on/off power supplied by the tractor's ignition switch did not effect console memory. Console memory was not lost when the console was disconnected from the battery. The 8 calibration numbers were entered under the following functions:

1. LEFT BOOM - used to store the width (in) of the tillage unit.
2. CENTRE BOOM - not used.
3. RIGHT BOOM - not used.
4. MINIMUM POUNDS OF NITROGEN PER MINUTE - used to store the minimum nitrogen flow rate. The manufacturer's recommended setting was 8 lb/min of nitrogen.
5. DELTA RATE ADJUST - used to enter the pounds of nitrogen per acre rate adjustment number (lb/ac). The Delta Rate number determined the amount the target application rate was increased or decreased. When the Delta Rate feature was not used, "0" was entered.
6. TARGET APPLICATION RATE - used to enter the desired nitrogen application rate (lb/ac) to be automatically controlled.
7. FLOW METER - used to store the flow meter calibration number stamped on the label attached to the flow meter.
8. DISTANCE/SPEED - used to store the radar speed sensor calibration number. The number was obtained from the Radar Interface Kit Installation Instructions. Performing a Distance/Speed Auto Calibration checked the calibration number. The procedure required driving a distance of 1,000 ft (305 m) and comparing the "FEET" number displayed to the distance travelled. An adjustment to the calibration number was performed when the feet displayed exceeded 2% of the actual distance.

The 8 operating functions, when selected by the rotary selector dial, indicated various operating conditions during anhydrous ammonia application. The 8 operating functions were:

1. CAL - placed control console into calibration mode.
2. GPM - displayed flow rate in pounds of nitrogen per minute.
3. MPH - displayed actual ground speed.
4. ACRES - displayed acres covered from last reset.
5. GPA - displayed application rate in pounds of nitrogen per acre.
6. GALLONS - displayed volume in pounds of nitrogen from last reset.
7. FEET - displayed cumulated distance travelled from last reset.
8. PERCENT ERROR - displayed the % of the actual application rate differed from the set application rate. A difference greater than 10% lit the red application error warning light.

Initial field use or use after a period of time required operating the system in manual mode. Manual operation allowed the control console to properly prime the heat exchanger with NH_3 before switching the motorized control valve to automatic operation. The "Master Spray Switch" was moved to the "MAN" position, while the "L", "C" and "R" boom switches were turned off. With the applicator knives in the ground and the tractor at operating speed, the "L" boom switch was turned on, opening the on/off ball valve. The nitrogen flow through the motorized control valve was manually adjusted with the "ADJUST" switch until the desired application rate was displayed on the data display screen. Once the rate stabilized, the master switch was moved to "AUTO", allowing the controller to adjust the motorized control valve automatically when changes in forward speed or flow occurred.

Changing the nitrogen application rate was very easy. A new rate was programmed into the control console or changed by the Delta Rate function. The Delta Rate function worked only in the automatic mode. The programmed delta rate number determined the amount the application rate was adjusted. The rotary selector dial was moved to the "GPA" or "% ERROR" position and then the "adjust switch" moved to set the new application rate. The new application rate was stored in memory.

EASE OF INSTALLATION

Ease of installing the Micro-Trak MT3000 control system was good. The manufacturer assembled the components of the NH3500 control system. Installation included mounting the control system and radar speed sensor, installing the control console, hold cutout and radar interface modules and steel vapour tubes, routing the electrical harness and vapour lines and connecting the control system to the NH_3 nurse tank and manifolds. Installation of the MT3000 system took 2 people, 5 hours.

Mounting hardware secured the control system to a 4 x 4 in (102 x 102 mm) beam on the tillage unit, (**Figure 10**). Two types of ground speed sensors were available with the Micro-Trak MT3000 system: radar speed sensor or drive wheel sensor. The AFMRC's radar speed sensor was used to measure ground speed. The manufacturer supplied a radar speed sensor installation kit containing information on the installation of various makes and models of speed sensors used with the MT3000 system. The radar speed sensor was mounted near the centreline of the tillage unit. The supplied radar interface module and cable connected the radar speed sensor to the MT3000 control console. The power cable for the interface module was connected to the tractor's battery.

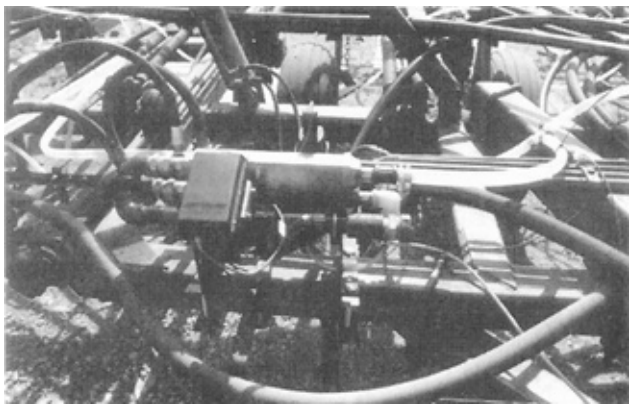

Figure 10. Control system mounted on a tillage unit.

A bracket was fabricated to install the control console into the tractor cab. The hold cutout module was installed with plastic ties on the tillage frame near the NH3500 control system. The blue electrical wire supplied was used to ground the console and control system together through the frames of the tillage unit and tractor. A supplied 7.5 amp fuse and fuse holder was installed between the positive lead of the console cable and the positive post on the battery. The console ignition wire was connected to a positive terminal on the tractor's electrical system that only received power when the ignition was turned on. The length of the power and ignition soume cables connecting the console to the tractor's power sources were sufficient. However, the supplied main harness cable was too short to connect the console to the hold cutout module so a 10 ft (3 m) extension cable was ordered. The AFMRC recommends the manufacturer supply sufficient cable length to install the control system properly.

OPERATOR SAFETY

Safe operation of the Micro-Trak MT3000 controller was directly related to the operator's knowledge of handling NH_3. Classified as dangerous goods, extreme caution and care always had to be used around the NH_3. Safety features supplied with the Micro-Trak MT3000 controller were the on/off valve placed before the control system and the procedure for entering the calibration mode.

The on/off valve stopped the flow of NH_3 from the nurse tank to the heat exchanger. Proper operation of the valve required full movement of the valve to the "ON" or "OFF" position before changing the direction of the valve. The AFMRC recommends the manufacturer supply a safe and reliable on/off valve to stop NH_3 flow to the heat exchanger.

Entering the calibration mode required moving the master spray switch to the "HOLD" position and rotary selector dial to the "CAL" location when the tractor was stationary. The console exited the calibration mode when the master switch was moved or ground speed detected. The calibration procedure prevented accidental changes to the stored values.

The Micro-Trak MT3000 control system relied on a continuous power source for safe operation of the system. **Table 1** outlines the reaction of the system with a power loss to any of the electrically controlled components. Unsafe operation of the control system occurred with a loss of power to 1 or more of the electrically controlled components. The AFMRC recommends the manufacturer supply a reliable shut down system when unsafe electrical conditions existed.

Table 1. Electrical Cable Test.

ELECTRICAL TEST (disconnected cables)	CONTROL SYSTEM RESPONSE	
	Cable Disconnected Before Operating System	**System Operating When Power Disconnected**
Main power from consoles	Does not work	Stops applying NH_3 in either manual or automatic mode
Speed Signal	*Manual:* continues to apply NH_3 with no values recorded for speed, acres or rate. Boom switch shuts system down. *Auto:* stops applying NH_3.	*Manual:* continues to apply NH_3 with no values recorded for speed, acres or rate. Boom switch shuts system down. *Auto:* stops applying NH_3.
Speed Power	Does not work	
System Ground	Does not work	*Manual and Auto:* continues to apply NH_3, boom or master switches do not shut down the system.

OPERATOR'S MANUALS

The operator's manuals were fair. The manufacturer supplied a manual for the control console and the NH_3 control system. The installation/operator's manual supplied for the control console was written mainly for spraying operations. The manual did contain some information on the operation of the console with NH_3. The AFMRC recommended the manufacturer supply a control console manual specifically for NH_3. The NH3500 installation/operator's manual

supplied useful information on the installation, operation and maintenance of the control system. The manual was similar to the 1 supplied with the control console. A detailed parts list was not included. A detailed safety section on the mandatory safety precautions to be followed when using NH_3 was not included. The AFMRC recommends the manufacturer supply a detailed safety section on the proper handling of NH3.

MECHANICAL HISTORY

The Micro-Trak MT3000 was operated in the field for 92 hours. The intent of the test was evaluation of functional performance. An extended durability evaluation was not conducted. **Table 2** outlines the mechanical problems that occurred during the functional testing.

Table 2. Mechanical History.

ITEM	OPERATING HOURS	EQUIVALENT FIELD AREA	
		ac	ha
Replaced in-line power fuse	12	179	72
Plugged hole in butterfly valve	36	580	235

NITRO-TRAK NH_3 AUTOMATIC CONTROL SYSTEM

MANUFACTURER:

Micro-Trak Systems Inc.
P.O. Box 99
Eagle Lake, MN USA 56024-099
Phone: 507/257-3600 (1-800-328-9613)

RETAIL PRICE: $1510.00 US (February 1996, f.o.b. Eagle Lake,MN) Nitro-Trak NH_3 Automatic Control System complete with TNc9541 Display Console, TNsc942 Servo Control Module, B-9500 Meter Control Kit, and Magnetic Speed Pick-up.

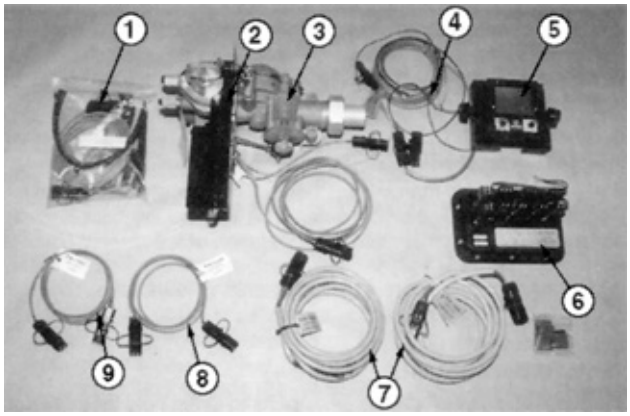

Figure 2. Nitro-Trak NH3 Automatic Control System: (1) Magnetic Speed Sensor Kit, (2) B-9500 Meter Control Kit, (3) Continental B-9500 Meter, (4) Power Cable, (5) TNc9541 Display Console, (6) TNsc942 Servo Control Module, (7) Extension Cables, (8) Run/Hold Cable and (9) Temperature Cable.

SUMMARY

QUALITY OF WORK

The metering accuracy of the Nitro-Trak TNc9541 automatic control system was good for nitrogen application rates between 40 and 120 lb/ac (45 and 135 kg/ha) and fair for rates below 40 lb/ac (45 kg/ha) or above 120 lb/ac (135 kg/ha).

Nitrogen application rates below 40 lb/ac (45 kg/ha) required operating the Continental meter near its low limit application range. Field tests showed how variations in ground speed allowed the actuator arm to turn the meter dial beyond the operating range of the meter. The clamp secudng the actuator arm to the meter dial turned, changing the calibration settings on the Nitro-Trak TNc9541 controller. Improper application rates resulted, which required recalibration of the system to ensure the dial reading on the display monitor and Continental meter was similar.

The actuator arm assembly's response time in the automatic mode was very good. The actuator arm assembly of the meter control kit controlled the movement of the Continental meter dial position to adjust and stabilize the flow of nitrogen due to a change in ground speed or application rates.

EASE OF OPERATION AND ADJUSTMENT

Ease of performing maintenance was very good. Maintenance included checking and fixing all NH_3 leaks and cleaning the Continental meter screen assembly.

Ease of programming and operating the console was very good. The console was programmed for either American English (US) or metric (SI) units. Radar or wheel drive sensors recorded ground speed. Programming the console required 13 calibration numbers be entered and stored in memory. Changing the nitrogen application rate was very easy. A new rate was programmed into the display console or changed by the Delta Rate function.

EASE OF INSTALLATION

Ease of installing the Nitro-Trak TNc9541 control system was good. The manufacturer assembled the components of the meter control kit. Installation of the Nitro-Trak system took 1 experienced person, 5 hours. The main harness cable supplied was too shod to

connect the console to the servo control module. A 10 ft (3 m) extension cable was ordered to connect the display console to the module.

OPERATOR SAFETY

Safe operation of the Nitro-Trak TNc9541 controller was directly related to the operator's knowledge of handling NH_3. Classified as dangerous goods, extreme caution and had to be always used around NH_3. Safety features supplied with the Nitro-Trak control system were the condensed calibration mode and security function.

The Nitro-Trak control system relied on a continuous power source for safe operation of the system. The console displayed an "ERR" message when a power toss was detected from any of the electrically-controlled components of the system. Unsafe application of NH_3 occurred with power loss to 1 or more of the electrically-controlled components. However, the control system could not stop the flow of NH_3 through the meter. The shut-off valve hydraulically controlled the flow of NH_3 on the meter.

OPERATOR'S MANUAL

The operator's manual was good. The manufacturer supplied a manual for the display console. The manual contained useful information on the calibration and operation of the display console when applying NH_3 with a Continental meter. A detailed safety section on the mandatory safety precautions to be followed when using NH_3 was not included.

MECHANICAL HISTORY

The Nitro-Trak TNc9541 was operated in the field for 86 hours. The intent of the test was evaluation of functional performance. An extended durability evaluation was not conducted.

RECOMMENDATIONS

The Alberta Farm Machinery Research Centre (AFMRC) recommends the manufacturer:

1. Supply sufficient cable lengths to install the control system properly.
2. Incorporate the "SECURITY STATUS" function into the required programming steps of the display console.
3. Supply a system controlled shut-off valve to stop the flow of NH3 when unsafe operating conditions existed.
4. Supply a detailed safety section on the proper handling of NH3.

Project Technologist: Greg Magyar

Manager: R. P. Atkins

MANUFACTURER'S REPLIES TO RECOMMENDATIONS

The manufacturer stated with regard to recommendation number:

1. The system comes with enough cable for a standard installation of the Nitro-Trak system. Micro-Trak offer extension cables to customize the operators' needs.
2. Micro-Trak give their customers the ability to arm or disarm this feature based on their preference, but this will be looked into further if any programming changes are made in the future.
3. Operators should use a rope pull or hydraulic valve to stop the flow of anhyrdous ammonia when unsafe operating conditions exist.
4. Having a detailed safety section is an excellent idea. It will be something we would want to add to the Nitro-Trak manual.

ADDITIONAL MANUFACTURER'S COMMENTS

Continental Products Flow Meter: Micro-Trak does not supply the Continental Meter with each Nitro-Trak system.

GENERAL DESCRIPTION

The test unit was the Nitro-Trak TNc9541 stand-alone NH_3 automatic control system with the Nitro-Trak TNsc942 servo control plug-in module and magnetic speed sensor. Optional equipment included a Continental Products B-9500 super flow NH_3 meter, a Nitro-Trak B-9500 meter control kit and a 10 ft (3 m) extension flow control cable. The test unit was mounted on a 33 ft (10.1 m) cultivator equipped with NH_3 knives and a cold flow system.

The Nitro-Trak TNc9541 automatic controller adjusts the meter opening on Continental meter to control the flow of liquid NH_3 to fertilizer distribution manifolds. The TNc9541 system monitors the application rate, ground speed, volume of NH_3 applied, calculated nurse tank level, meter dial setting and area covered. The TNc9541 automatically adjusts the application rate due to changes in ground speed and temperature. The Continental meter controls the flow of NH_3 to the fertilizer manifolds. The Nitro-Trak TNc9541 automatic control system consists of the TNc9541 display console, TNsc942 servo module, magnetic speed sensor, Continental meter and meter control actuator assembly kit.

The display console mounts in the operator's cab. The console consists of a multifunction display screen, master switch and rate adjust switch. The console could be calibrated in either American English (US) or metric (SI) units. The NH_3 flows under pressure from the nurse tank through the delivery hose and breakaway coupler to the inlet side of the Continental meter mounted on the tillage unit. The shut-off ball valve situated at the inlet side of the meter controls the flow of NH_3 from the nurse tank. The Nitro-Trak control actuator assembly mounts on the Continental meter. The electrically-controlled actuator arm connects to the meter dial and regulates the flow of NH_3 through the meter. The TNsc942 servo control plug-in module mounts on the tillage unit and allows the display console to control the various components of the control system. The servo control module could control 2 Continental meters.

A speed sensor indicates ground speed through the servo module to the display console. A number of options are available to measure ground speed.

The tractor's electrical system powers the Nitro-Trak automatic controller. Various Nitro-Trak meter control kits are available to mount on different Continental meters.

Detailed specifications are given in **Appendix I** while **Figure 2** shows The Nitro-Trak TNc9541 NH_3 controller.

SCOPE OF TEST

The Nitro-Trak TNc9541 controller was used for 86 hours while fertilizing 1546 ac (607 ha). The system was evaluated for quality of work, ease of operation and adjustment, ease of installation, operator safety and suitability of the operator's manual.

The controller was operated in the lab to determine application rate accuracy and controller response over a range of operating temperatures. Work included testing the effect of changes in ground speed, application rates and system variables. The applicator width for lab testing was 35 ft (10.7 m).

Laboratory set-up consisted of supplying the controller with NH_3 from a 180 gal (818 L) nurse tank. A 900 gal (4091 L) water holding tank collected the NH_3 metered by the controller. Controller vapour lines were plumbed into a 300 gal (1364 L) vapour water holding tank. Load cells connected to AFMRC's data acquisition system recorded the change in weight of the nurse tank and vapour water holding tank. Pressure gauges monitored the nurse tank and controller discharge hose pressures. A temperature probe inserted into the nurse tank monitored the NH_3 temperature. A speed simulator input ground speed into the controller.

The unit evaluated by the AFMRC was configured as described in the General Description, **Figure 2**, and the Specifications section in **Appendix I** of this report. The manufacturer may have built different configurations of this unit before and after AFMRC tests. Therefore, when using this report, be sure to first check the unit under consideration is the same as the one reported here. If differences exist, assistance can be obtained from AFMRC or the manufacturer to determine changes in performance.

RESULTS AND DISCUSSION

Quality of Work

Controller Accuracy: The metering accuracy of the Nitro-Trak TNc9541 automatic control system was good for nitrogen application rates between 40 and 120 lb/ac (45 and 135 kg/ha) and fair for rates

below 40 lb/ac (45 kg/ha) or above 120 lb/ac (135 kg/ha). The nitrogen application rate was equal to 82% of the NH_3 rate. Entering the desired rate into the controller set the application rate.

Figure 3 shows measured nitrogen application rates for the Nitro-Trak Tnc9541 controller over a range of application rates at 5 mph (8 km/h) and at 3 different NH_3 temperatures. At an NH_3 temperature of 23°F (-5°C) the controller maintained application rate accuracy for set rates between 40 and 140 lb/ac (45 and 157 kg/ha). Increasing the set rate to 180 lb/ac (202 kg/ha) the monitor displayed an application rate of 179 lb/ac (201 kg/ha), while the average measured rate was 130.7 lb/ac (147 kg/ha).

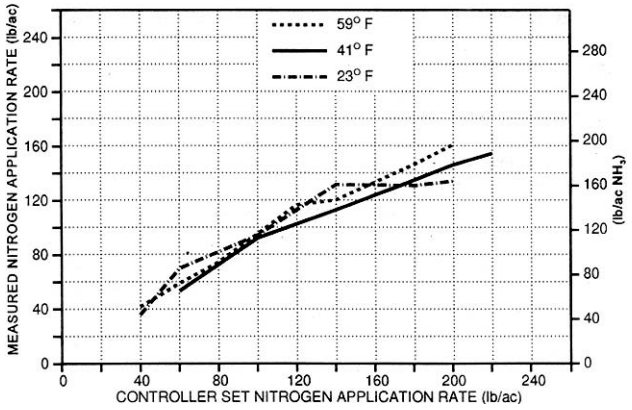

Figure 3. Measured nitrogen application rates.

At an NH_3 temperature of 41°F (5° C) the controller maintained application rate accuracy for set rates between 40 and 120 lb/ac (45 and 202 kg/ha). Increasing the set rate to 180 lb/ac (157 kg/ha) the monitor displayed an application rate of 179 lb/ac (201 kg/ha) while the average measured rate was 134.6 lb/ac (151 kg/ha).

At an NH_3 temperature of 59°F (15°C) the controller maintained application rate accuracy for set rates between 40 and 140 lb/ac (45 and 225 kg/ha). Increasing the set rate to 180 lb/ac (157 kg/ha) the monitor displayed an application rate of 180 lb/ac (157 kg/ha) while the averaged measured rate was 146.3 lb/ac (164 kg/ha).

Nitrogen application rates below 40 lb/ac (45 kg/ha) required operating the Continental meter near its low limit application range. Field tests showed how variations in ground speed allowed the actuator arm to turn the meter dial beyond the operating range of the meter. The clamp securing the actuator arm to the meter dial turned, changing the calibration settings on the Nitro-Trak TNc9541 controller. Improper application rates resulted, which required recalibration of the system to ensure the dial reading on the display monitor and Continental meter was similar.

Meter Control Kit: The actuator arm assembly's response time in the automatic mode was very good. The actuator arm assembly of the meter control kit controlled the movement of the Continental meter dial position to adjust and stabilize the flow of nitrogen due to a change in ground speed or application rate.

Figure 4 shows a typical response curve when decreasing the ground speed from 5 to 3 mph (8 to 4.8 km/h) at an application rate of 100 lb/ac (112 kg/ha).

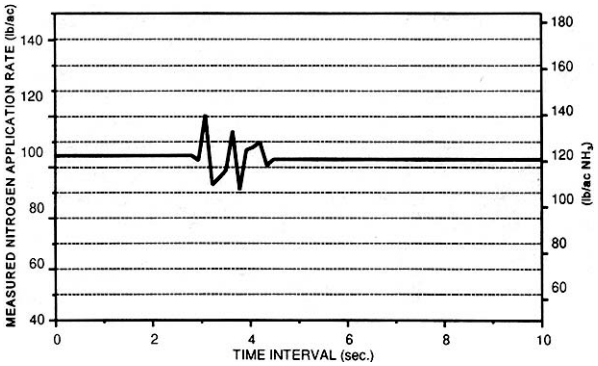

Figure 4. Controller repsonse curve with a decrease in ground speed from 5 to 3 mph (8 to 4.8 km/h) at an applicaton rate of 100 lb/ac (112 kg/ha).

Figure 5 shows a typical response curve when increasing the ground speed from 5 to 7 mph (8 to 12 km/h) at an application rate of 100 lb/ac (112 kg/ha). The graphs show the average response time required for the meter control kit to adjust and stabilize the flow of nitrogen to compensate for a change in ground speed. The average response time required was 1.7 seconds.

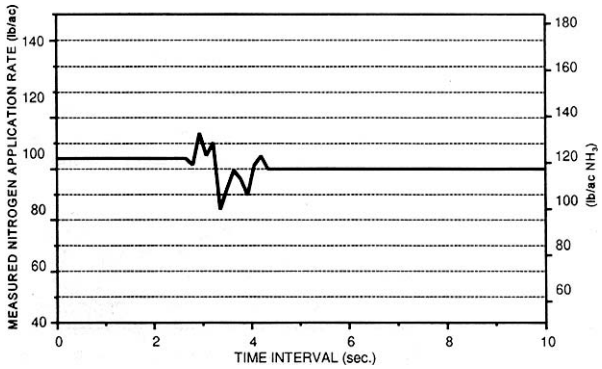

Figure 5. Controller respone curve with an increase in ground speed from 5 to 7 mph (8 to 11.3 km/h) at an application rate of 100 lb/ac (112 kg/ac).

Figure 6 shows a typcial response curve when decreasing the application rate from 100 to 60 lb/ac (112 to 67 kg/ha) at a ground speed of 5 mph (8 km/h). **Figure 7** shows a typical response curve when increasing the application rate from 100 to 140 lb/ac (112 to 157 kg/ha) at a ground speed of 5 mph (8 km/h). The graphs show the average response time required for the mter control kit to adjust and stabilize the flow of nitrogen to compensate for a change in the set application rate. The average response time required was 1.33 seconds.

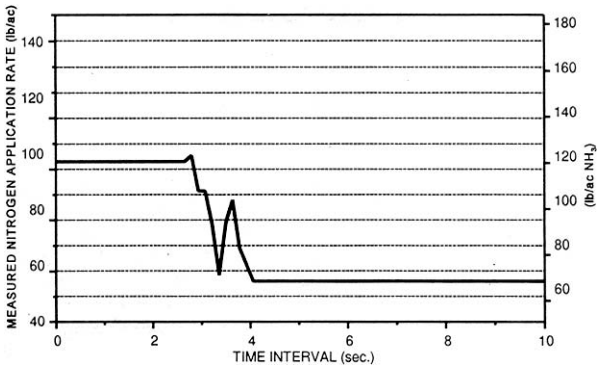

Figure 6. Controller response curve with a decrease in application rate from 100 to 60 lb/ac (112 to 67 kg/ha) at a ground speed of 5 mph (8 km/h).

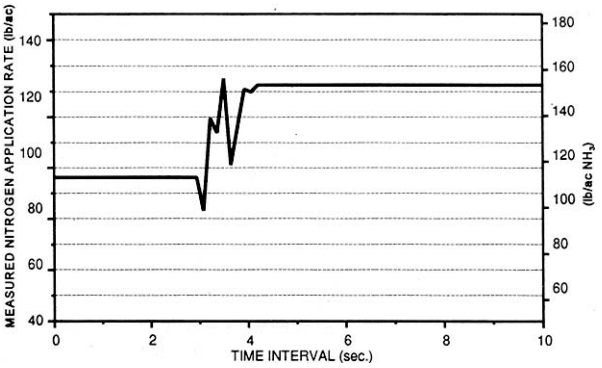

Figure 7. Controller response curve with an increase in application rate from 100 to 140 lb/ac (112 to 157 kg/ha) at a ground speed of 5 mph (8 km/h).

Speed Sensor: The magnetic ground speed sensor was accurate when properly calibrated. Proper speed sensor calibration required performing a field distance calibration in conditions similar to those encountered during NH_3 application. Speed sensor readings were constant and consistent when the magnets and pick-up assembly were set up according to the manufacturer's

specifications. Inaccurate speed sensor readings occurred when the pick-up assembly was more than 0.25 in (6 mm) away from the magnets or when the pick-up angle exceeded 45° from perpendicular to the magnets.

Electrical Power Requirements: No excessive demands were made on the tractor battery or electrical charging system.

EASE OF OPERATION AND ADJUSTMENT

Maintenance: Ease of performing routine maintenance was very good. Maintenance included checking and fixing all NH_3 leaks and cleaning the Continental meter screen assembly. The screen assembly prevented foreign material from entering the meter and was cleaned periodically.

Display Console: Ease of programming and operating the display console was very good. The console was placed into the complete calibration (ALL) mode by holding the "Master Switch" in the down position, then flipping the "Rate Switch" to the up position twice. Once the console displayed "ALL", the master switch was released to the centre position, (**Figure 8**). The rate switch was then used to enter the values into the display console while the master switch stored the values and advanced the console to the next calibration step.

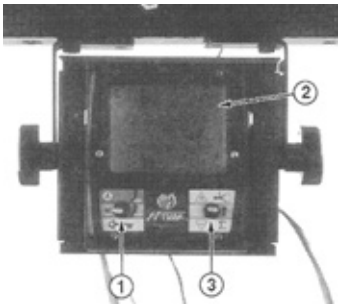

Figure 8. Nitro-Trak TNc9541 Display Console: (1) Master Switch, (2) Data Display Screen and (3) Rate Switch.

The display console evaluated was calibrated for American English (US) units and for a magnetic ground speed sensor. The console could also be programmed for metric (SI) units and radar ground speed sensors. During initial set-up 13 calibration numbers were entered and stored into the console. Once programmed, the on/off power supplied by the tractor's ignition switch did not effect console memory. The 13 calibration numbers were entered under the following functions:

1. CONTRAST - used to set the brightness of the display screen.
2. SYSTEM UNITS - to select the desired working units.
3. WHEEL CIRCUMFERENCE - to store the speed sensor calibration number.
4. WIDTH #1 - to store the implement width of the tillage unit.
5. WIDTH #2 - not used.
6. TARGET APPLICATION RATE - to enter the desired nitrogen application rate (lb/ac) to be automatically controlled.
7. DELTA RATE ADJUSTMENT - to enter the pounds of nitrogen per acre rate adjustment number (lb/ac). The Delta Rate number determined the amount the target application rate was increased or decreased. When the delta rate feature was not used "0" was entered.
8. DELIVERY FACTOR METER #1 - to store the delivery factor for the Continental meter.
9. DELIVERY FACTOR METER #2 - not used.
10. TANK SIZE - to store the pounds of NH_3 the nurse tank held.
11. TNsc942 SERIAL NUMBER - to store the serial number of the TNsc942 servo control module.
12. METER TYPE - to store the model number of the Continental meter.
13. CONTROL-METER MAX POSITION- to set the display console to the maximum dial position of the meter.
14. CONTROL-METER #1 MIN POSITION - to set the display console to the minimum dial position of the meter.
15. CONTROL-METER #2 MIN POSITION - not used.
16. SECURITY STATUS - to prevent accidental changes to calibration values.

Once programmed, access to calibration values normally changed during field operation was through the condensed (Abr) calibration mode. The condensed calibration mode allowed changes to the target application rate, Delta Rate adjustment, delivery factor and tank size values. A field calibration check was completed to determine the accuracy of the delivery factor value. The procedure required comparing the actual volume of NH_3 applied from the nurse tank to the value indicated on the display console.

Operation of the Nitro-Trak control system was very easy. The master switch in the "AUTO" position allowed the control system to adjust the meter dial automatically when changes in forward speed or flow occurred. The meter's shut-off valve controlled nitrogen flow to the applicator knives. A remote lever in the tractor cab hydraulically operated the valve. With the applicator knives in the ground and the tractor at operating speed the shut-off valve was turned to the "RUN" position. The actuator arm assembly adjusted the nitrogen flow through the meter dial barrel until the desired application rate was displayed on the data display screen.

Changing the nitrogen application rate was very easy. A new rate was programmed into the display console or changed by the Delta Rate function. The Delta Rate function worked only in the automatic mode. The programmed delta rate number determined the amount the application rate was adjusted. The "Rate" switch was toggled to set the new application rate. Each movement of the rate switch increased/decreased the target application rate by the programmed Delt.a Rate value. The new application rate was stored in memory.

EASE OF INSTALLATION

Ease of installing the Nitro-Trak TNc9541 system was very good. The manufacturer assembled the components of the meter control kit to the Continental meter. Installation included mounting the Continental meter and servo control plug-in module, installing the display console, magnetic speed sensors and meter shut-off valve hydraulic lines, routing the electrical harness and connecting the control system to the NH_3 nurse tank and manifolds. Installation of the Nitro-Trak system took 1 experienced person, 5 hours.

A bracket was fabricated to secure the meter to a 4 x 4 in (102 x 102) beam on the tillage unit, (**Figure 9**). The servo control plug-in module was secured to the implement frame near the Continental meter. Two hydraulic lines (not supplied) were installed from the Continental meter shut-off valve to the remote hydraulics of the tractor. Two types of ground speed sensors were available with the Nitro-Trak TNc9541 system; a radar speed sensor or drive wheel sensor. The magnetic drive wheel speed sensor was used to measure ground speed. The operator's manual contained information on installation of the magnetic speed sensor. Five speed sensor magnets were secured to an implement rim on the main frame of the tillage unit and the sensor pick-up assembly secured to the implement tire arm. The pick-up sensor was adjusted to the proper angle and gap. The pick-up sensor extension cable connected the sensor to the TNSC942 SERVO control plug-in module.

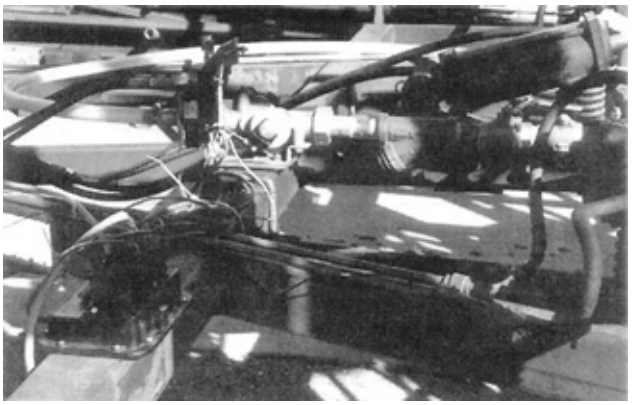

Figure 9. Control system mounted on a tillage unit.

A bracket was fabricated to install the display console in the tractor cab. The blue electrical wire supplied, grounded the console and control system together through the frames of the tillage unit and

tractor. A supplied 2 A fuse and fuse holder was installed between the positive lead of the console power cable and a positive terminal on the tractor's electrical system that received power when the ignition was on. The meter control kit cables (temperature, run/hold and actuator) were plugged into the servo contro! plug-in module. The length of the power source cable was sufficient. However, the main harness cable supplied was too short to connect the console to the servo control plug-in module and a 10 ft (3 m) extension cable was ordered. The AFMRC recommends the manufacturer supply sufficient cable lengths to install the control system properly.

OPERATOR SAFETY

Safe operation of the Nitro-Trak TNc9541 controller was directly related to the operator's knowledge of handling NH_3. Classified as dangerous goods, extreme caution had to be always used when around NH_3. Safety features supplied with the Nitro-Trak TNc9541 control system were the condensed calibration mode and security function.

Once programmed, entering the condensed (Abr) calibration mode prevented accidental changes to stored values normally not changed during field operation. When activated, the controller's "SECURITY STATUS" function prohibited entry of data into the controller without first entering the security code. The function was considered a positive feature for operator safety. However, the operator had the option of using or disabling the "SECURITY STATUS" function. The AFMRC recommends the manufacturer incorporate the "SECURITY STATUS" function into the required programming steps of the display console.

The Nitro-Trak TNc9541 control system relied on a continuous power source for safe system operation. The console displayed an "ERR" message when a power loss was detected from any of the electrically-controlled components of the system. Unsafe application of NH_3 occurred with a loss of power to 1 or more of the electrically-controlled components. However, the control system could not stop the flow of NH_3 through the meter. The shut-off valve on the meter hydraulically controlled the flow of NH_3. A shut-off valve controlled by the Nitro-Trak system, installed before the meter, would have allowed the Nitro-Trak system to stop the flow of NH_3. The AFMRC recommends the manufacturer supply a system controlled shut-off valve to stop of NH_3 flow when unsafe operating conditions existed.

OPERATOR'S MANUAL

The operator's manual was good. The manufacturer supplied a manual for the display console. The manual contained useful information on the calibration and operation of the display console when applying NH_3 with a Continental meter. A detailed parts list was not included. A detailed safety section on the mandatory safety precautions to be followed when using NH3 was not included. The AFMRC recommends the manufacturer supply a detailed safety section on the proper handling of NH3.

MECHANICAL HISTORY

The Nitro-Trak TNc9541 was operated in the field for 86 hours. The intent of the test was evaluation of functional performance. An extended durability evaluation was not conducted.

RAVEN SCS440 NH_3 CONTROL SYSTEM

MANUFACTURER:

Raven Industries
205 East Street, P.O. Box 5107
Sioux Falls, SD USA 57117
Phone: 605/336-2750

RETAIL PRICE: $4,530.00 (February 1996, f.o.b. Calgary, AB)
Raven SCS440 Anhydrous Ammonia control system complete with SCS440 control monitor, 30 US gal/min heat exchanger, 1 in (25 mm) motorized control and on/off ball valves, RFM 55A flow meter and ground speed interlace cable.

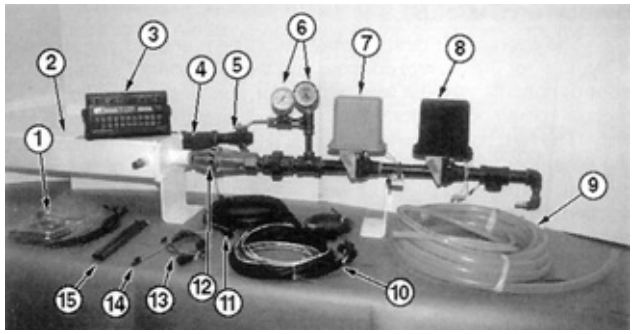

Figure 2. Raven SCS440 Anhydrous Ammonia Control System: (1) Mounting Hardware, (2) Heat Exchanger, (3) Control Console, (4) Strainer Assembly, (5) Emergency Shut-off Valve, (6) Pressure and Temperature Gauges, (7) Motorized Control Valve, (8) On/Off Valve, (9) Vapour Hoses, (10) Console Control Cable, (11) Flow/Meter Cable, (12) Flow Meter (13) Radar Interface Cable, (14) Motorized Control Valve Reversing Cable and (15) Steel Vapour Tubes.

SUMMARY

QUALITY OF WORK

The metering accuracy of the Raven SCS440 automatic controller was good for nitrogen rates below 140 lb/ac (157 kg/ha) and fair for rates above 140 lb/ac (157 kg/ha). The nitrogen application rate was set by entering the desired rate into the control console.

The heat exchanger's ability to maintain NH3 in a liquid form was good, The vapour produced from the heat exchanger was discharged through vapour lines. The amount of vapour discharged was related to the metering accuracy of the controller and the percentage of loss corresponded to the actual application rate.

The motorized control valve's response time in the automatic mode was very good. The valve responded quickly to adjust and stabilize the flow of nitrogen due to changes in ground speed or application rate, Manual operation of the control system reduced the efficiency of the motorized control valve, therefore manual operation was limited to initial field use or when the controller was not used for a period of time.

EASE OF OPERATION AND ADJUSTMENT

Ease of performing maintenance was very good. A pressure relief valve was used to drain the anhydrous ammonia before working on the system.

Ease of programming and operating.the console was very good. The console was calibrated for American English (US) and radar (SP2) ground speed sensor. Programming the console required 8 calibration numbers to be entered and stored into memory. Changing the nitrogen application rate was very easy. The flow control rate switch was moved to the second programmed application rate or a new rate programmed into the control console.

EASE OF INSTALLATION

Ease of installing the Raven SCS440 NH_3 control system was good. Installation took 2 people, 7 hours. To read the temperature and pressure gauges from the tractor cab required the control system be mounted toward the front of the tillage unit. The control cables supplied were too short to connect-the console to the flow meter and valves and a 24 ft (7.3 m) extension cable was ordered.

OPERATOR SAFETY

Safe operation of the Raven SCS440 controller was directly related to the operator's knowledge of handling NH_3. Classified as dangerous goods, extreme caution and care had to be used at all times around NH_3. Safety features supplied with the Raven SCS440 NH3 controller were an emergency shut-off valve, a pressure relief valve, and the "DATA-LOCK" and "SELF TEST" functions on the control console.

The Raven SCS440 control system relied on a continuous power source for safe operation of the system. Unsafe operation of the control system occurred with a loss of power to 1 or more of the electrically-controlled components.

OPERATOR'S MANUALS

The operator's manuals were fair. The manufacturer supplied a manual for the control console and the NH_3 control system. The control console manual was written for spraying operations. The manual contained no information on the operation of the console with NH3. The NH3 control system manual supplied useful information on the assembly, installation, operation and maintenance of the control system. A detailed parts list was also included. A detailed safety section on the mandatory safety precautions when using NH_3 was not included.

MECHANICAL HISTORY

No mechanical problems were encountered during 56 hours of field operation.

RECOMMENDATIONS

The Alberta Farm Machinery Research Centre (AFMRC) recommends the manufacturer:

1. Supply sufficient cable length to properly install the control system.
2. Supply a safe and reliable method to stop NH_3 flow to the heat exchanger.
3. Supply detailed safety information on the hazards of discharging NH_3 into the atmosphere.
4. Incorporate the "DATA-LOCK" function into the initial programming steps of the control console.
5. Supply a reliable shut-down system when unsafe electrical conditions existed.
6. Supply a control console manual specifically for NH_3.
7. Supply a detailed safety section on the proper handling of NH_3 in the operator's manuals.

Project Technologist: Greg Magyar

Manager: R.P. Atkins

MANUFACTURER'S REPLIES TO RECOMMENDATIONS

The manufacturer state with regard to recommendation number:

1. Different lengths of extension cable are available from Raven distributors. The responsibility of individual machine knowledge lies with our distributors and/or their dealer who has specific knowledge of the tractor and toolbar.
2. The system has a hand shut-off valve between the cooler and the nurse tank. Raven will furnish a ring attached to the valve handle in which a rope can be attached for manual emergency flow shut-off. Raven will provide a diagram in the manual for a recommended configuration of rigging an emergency pull rope. The manual will also warn that before pulling the shut-off rope, the tractor must be positioned crosswind.
3. Although the Accu-Flow system is not designed to vent vapour into the atmosphere, the manual will be updated to include potential health hazards associated with NH_3 in the atmosphere.
4. The Raven SCS440 console is a multi-functional controller therefore the "DATA-LOCK" feature will remain optional.
5. This recommendation was answered in 2.
6. The Accu-Flow manual will be updated to include more specific console programming for the application of NH_3.
7. The manual will be updated to refer to proper governing authorities for specific rules and regulations. This information should be available through the proper governmental agencies and/or the supplier of the NH3 because the Accu-Flow is sold in various countries and states/provinces within countries.

ADDITIONAL MANUFACTURER'S COMMENTS

Loss of calibration constants. The Raven SCS440 no longer requires a 9 V battery to retain the calibration numbers if power is removed because the SCS440 now has non-volatile memory.

High flow rate variance. The variance at the higher flow rates from our experience can be caused by a pressure drop from the nurse tank to the cooler. Potential trouble areas we have found that can cause high pressure drops from the nurse tank to the cooler are hose and fitting sizes. Typically with units installed correctly in the field, we do not see this problem. Using 1-1/4" delivery hoses and breakaway couplers increased the maximum application rates. Raven now supplies a 1-1/4" emergency shut-off valve with all new systems.

Vapour tubes. We suggest that the 2 vapour tubes be attached to the NH_3 injector knives which follow the tractor wheel tracks.

GENERAL DESCRIPTION

The test unit was a 30 US gal/min (114 L/min) Raven SCS440 NH_3 metering system with a Raven SCS440 sprayer control monitor and 1 in (25 mm) NH_3 on/off ball valve. Optional equipment included an RFM 55A flowmeter, a 1 in (25 mm) NH_3 control valve, a ground speed radar interface cable and a 24 ft (7.3 m) extension flow control cable. The test unit was mounted on a 37 ft (11.3 m) cultivator equipped with NH_3 knives. The vapour tubes were secured to 2 knives on the front row of the cultivator's centre section

The Raven SCS440 controller meters liquid NH_3 to fertilizer distribution manifolds. The SCS440 system monitors the application rate, ground speed, volume of NH_3 applied, area covered and calculated nurse tank volume. The SCS440 automatically adjusts the application rate due to changes in ground speed and controls the flow of NH_3 to the fertilizer manifolds. The Raven SCS440 controller consists of the SCS440 sprayer control monitor, heat exchanger, flow meter, pressure and temperature gauges, pressure relief valve, control and on/off valves, vapour hoses and steel vapour tubes.

The control monitor mounts in the operator's cab. The monitor consists of 2, 4-digit LCD display screens, a power on/off switch, a master and 3 individual boom switches, a flow control adjustment and rate control switch, and a 22-function keyboard. The monitor is calibrated in either American English (US) or metric (SI) units. The NH_3 flows under pressure from the nurse tank through the delivery hose, break-away coupler and emergency shut-off valve to the inlet side of the heat exchanger mounted on the tillage unit. The NH_3 entered the "hot" chamber of the heat exchanger in a liquid/gas form. The flow meter connected to the outlet side of the "hot" chamber measures liquid NH_3 released from the heat exchanger. The liquid ammonia then flows through the motorized control and on/off valves. A hose at the end of the shut-off valve feeds a portion of the liquid ammonia to the inlet side of the "cold" chamber of the heat exchanger. The "hot" and" cold" chambers of the heat exchanger enables the cooling properties of NH_3 to convert the ammonia gas to liquid. Vapour produced through the cooling process is discharged from the "cold" chamber outlet ports. Vapour flows through vapour hoses to steel vapour tubes attached behind 2 injection knives. The pressure and temperature of the liquid ammonia are displayed on gauges located between the flow meter and motorized control valve. The motorized control valve regulates the flow of liquid ammonia to maintain the desired application rate. The on/off valve controls the flow of NH_3 to the fertilizer manifolds.

A speed sensor indicates ground speed to the control monitor. A number of options are available to measure ground speed.

A pressure relief valve located near the pressure gauge drained the system of NH_3. Approved pipe fittings were supplied to assemble

the controller system. The SCS440 control system was powered by the tractor's electrical system.

Detailed specifications are given in **Appendix I**, while **Figure 2** shows the Raven SCS440 anhydrous ammonia control system.

SCOPE OF TEST

The Raven SCS440 control system was used for 56 hours while fertilizing 950 ac (384 ha). The system was evaluated for quality of work, ease of operation and adjustment, ease of installation, operator safety and suitability of the operator's manual.

The controller was operated in the lab to determine application rate accuracy and controller response over a range of operating temperatures. Work included testing the effect of changes in ground speed, application rates and system variables. The applicator width for lab testing was 35 ft (10.7 m).

Laboratory set-up consisted of supplying the controller with NH_3 from a 180 gal (818 L) nurse tank. A 900 gal (4091 L) water holding tank collected the NH_3 metered by the controller. Controller vapour lines were plumbed to a 300 gal (1364 L) vapour water holding tank. Load cells connected to AFMRC's data acquisition system recorded the change in weight of the nurse tank and vapour water holding tank. Pressure gauges monitored the nurse tank and controller discharge hose pressures. A temperature probe inserted into the nurse tank monitored the NH_3 temperature. A speed simulator input ground speed into the controller.

The unit evaluated by the AFMRC was configured as described in the General Description, **Figure 1**, and the Specifications section in **Appendix I** of this report. The manufacturer may have built different configurations of this unit before and after AFMRC tests. Therefore, when using this report, be sure to first check the unit under consideration is the same as the one reported here. If differences exist, assistance can be obtained from AFMRC or the manufacturer to determine changes in performance.

RESULTS AND DISCUSSION

Quality of Work

Controller Accuracy: The metering accuracy of the Raven SCS440 automatic controller was good for nitrogen rates below 140 lb/ac (157 kg/ha) and fair for rates above 140 lb/ac (157 kg/ha). The nitrogen application rate was equal to 82% of the NH_3 rate. The application rate was set by entering the desired rate into the controller.

Figure 3 shows measured nitrogen application rates for the Raven SCS440 controller over a range of application rates at 5 mph (8 km/h) and at 3 different NH_3 temperatures. At an NH_3 temperature of 23°F (-5°C) the controller maintained application rate accuracy for set rates below 140 lb/ac (157 kg/ha). At a set rate of 140 lb/ac (157 kg/ha) the monitor displayed an application rate between 119 and 150 lb/ac (134 and 169 kg/ha), while the average measured rate was 129.8 lb/ac (146 kg/ac).

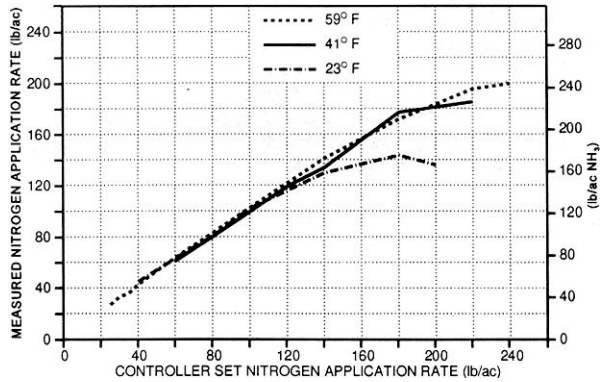

Figure 3. Measured nitrogen application rates.

At an NH_3 temperature of 41°F (5°C) the controller maintained application rate accuracy for set rates below 180 lb/ac (202 kg/ha). Increasing the set rate to 220 lb/ac (247 kg/ha) the monitor displayed an application rate between 180 and 250 lb/ac (202 and 281 kg/ha), while the average measured rate was 195.4 lb/ac (220 kg/ha).

At an NH_3 temperature of 59°F (15°C) the controller maintained application rate accuracy for set rates below 180 lb/ac (202 kg/ha). Increasing the set rate to 220 lb/ac (247 kg/ha) the monitor displayed an application rate between 190 and 250 lb/ac (213 and 281 kg/ha) while the average measured rate was 185.3 lb/ac (208 kg/ha).

Heat Exchanger: The heat exchanger's ability to maintain NH3 in a liquid form was good. As the NH_3 temperature increased there was an increased demand on the heat exchanger to maintain the NH3 in a liquid form. Maintaining anhydrous ammonia as a liquid in the "cool" chamber on the heat exchanger produced vapour. The vapour (classified as vapour loss) was discharged through vapour lines to 2 vapour tubes attached to 2 injector knives.

The amount of nitrogen vapour loss from the heat exchanger was related to the metering accuracy of the controller. The nitrogen loss percentage corresponded to the measured application rate and not the set rate. **Figure 4** shows the nitrogen loss percentage through the vapour lines for the measured temperatures and application rates. At a temperature of 23°F (-5°C) the nitrogen loss percentage loss varied between 0.8 and 5.8. At a temperature to 41°F (5°C) the nitrogen loss percentage varied between 3.6 and 6 and between 3.9 and 6.3 at a temperature of 59°F (15°C).

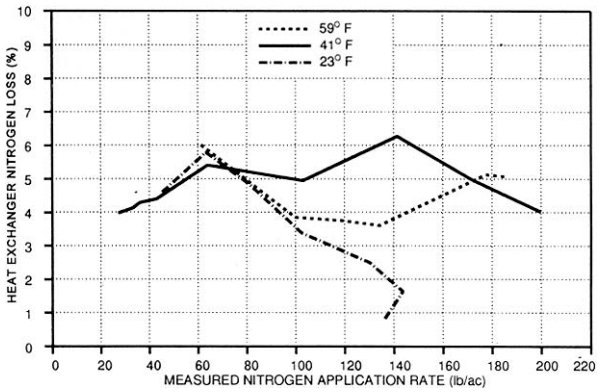

Figure 4. Percentage of nitrogen discharged from the vapour lines.

Motorized Control Valve: The motorized control valve's response time in the automatic mode was very good. The manufacturer supplied a motorized control valve calibration number ensured the valve responded quickly to adjust and stabilize the flow of nitrogen due to a change in ground speed or application rate. Manual operation of the control system reduced the efficiency of the motorized control valve. Therefore, manual operation was limited to initial field use or when the controller was not used for a period of time.

Figure 5 shows a typical response curve when decreasing the ground speed from 5 to 3 mph (8 to 4.8 km/h) at an application rate of 60 lb/ac (67 kg/ha).

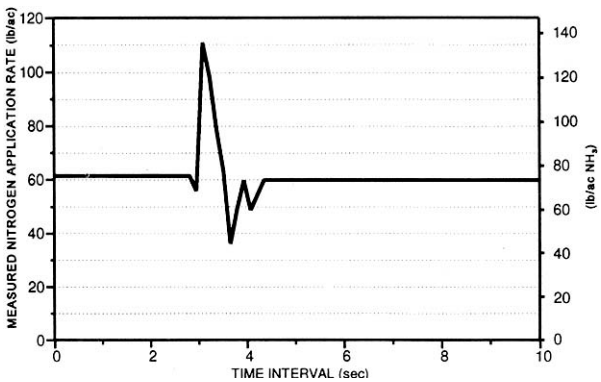

Figure 5. Controller response curve with a decrease in ground speed from 5 to 3 mph (8 to 5 km/h) at an application rate of 60 lb/ac (67 kg/ha).

Figure 6 shows a typical response curve when increasing the ground speed from 5 to 7 mph (8 to 11.3 km/h) at an application rate of 60 lb/ac (67 kg/ha). The graphs show the average response time required for the motorized control valve to adjust and stabilize the flow of nitrogen to compensate for a change in ground speed. The average response time required was 1.6 seconds.

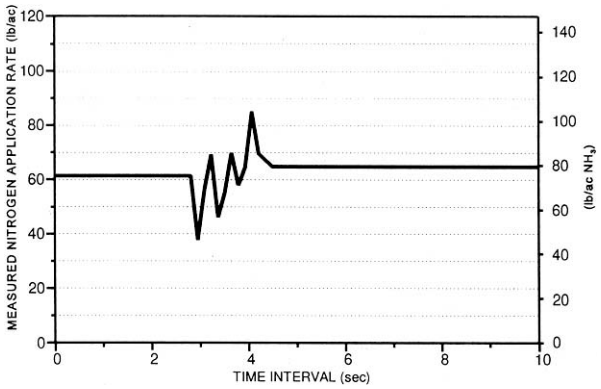

Figure 6. Controller response curve with an increase in ground speed from 5 to 7 mph (8 to 12 km/h) at an application rate of 60 lb/ac (67 kg/ha).

Figure 7 shows a typical response curve when decreasing the application rate from 100 to 60 lb/ac (112 to 67 kg/ha) at a ground speed of 5 mph (8 km/h),

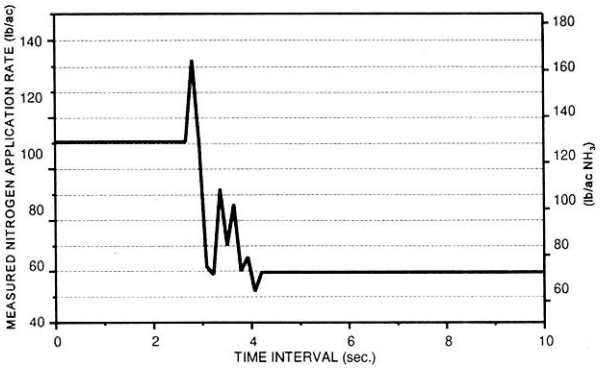

Figure 7. Controller response curve with a decrease in application rate from 100 to 60 lb/ac (112 to 67 kg/ha) at a ground speed of 5 mph (8 km/h).

Figure 8 shows a typical response curve when increasing the application rate from 100 to 140 lb/ac (112 to 157 kg/ha) at a ground speed of 5 mph (8 km/h). The graphs show the average response time required for the motorized control valve to adjust and stabilize the flow of nitrogen to compensate for a change in the set application rate. The average response time required was 1.8 seconds.

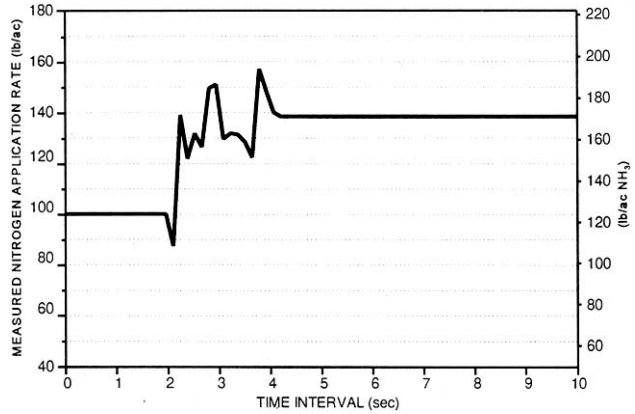

Figure 8. Controller response curve with an increase in application rate from 100 to 140 lb/ac (112 to 157 kg/ha) at a ground speed of 5 mph (8 km/h).

Speed Sensor: The radar ground speed sensor was accurate when properly calibrated. Proper calibration required performing a field distance calibration check. To reduce erroneous speed readings the radar ground speed sensor was mounted as close as possible to the centreline of the tillage unit. Minimizing speed sensor vibration also helped reduce erroneous speed readings.

The variation of residue on the soil surface caused slight speed and considered insignificant.

Electrical Power Requirements: No excessive demands were made on the tractor battery or electrical charging system. An optional 9 V battery installed in the console prevented recalibration of the unit if the voltage supply was disconnected.

EASE OF OPERATION AND ADJUSTMENT

Maintenance: Ease of .pedorming routine maintenance was very good. A. pressure relief valve was used to drain NH_3 before performing any maintenance. Maintenance included checking and fixing all NH_3 leaks and cleaning the strainer assembly. The strainer assembly prevented foreign material from entering the heat exchanger and was cleaned every 4 or 5 nurse tank loads. At the end of each season the manufacturer recommended cleaning the heat exchanger.

Controller Console: Ease of programming and operating the console was very good. The console keyboard, (**Figure 9**), was used for entering numbers (calibration keys) or monitoring (function keys) console operation. The "RATE" 4-digit LCD readout displayed the controller-applied application rate. The "DATA" 4-digit LCD readout displayed data by pressing either the calibration or function keys. The keyboard was convenient to operate.

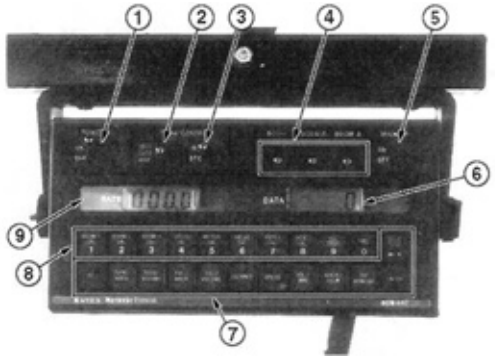

Figure 9. Raven SCS440 Control Console: (1) Power Switch, (2) Flow Control Rate Switch, (3) Flow Control Adjust Switch, (4) Boom Switches, (5) Master Switch, (6) Data Display Screen, (7) Function Keys, (8) Calibration Keys and (9) Rate Display Screen.

During the controller evaluation the console was programmed for American English (US) units and a radar ground speed (SP2) sensor. The console could also be programmed for metric (SI) units and wheel drive (SP1)sensors. During initial set-up the "RATE" display continually flashed "CAL" until the 8 calibration numbers were entered and stored in the console. Calibration was complete when "0.0" was displayed on the "RATE" screen. Once programmed, the on/off power switch did not affect console memory. Console memory was lost when the console was disconnected from the battery. Installation of the optional 9 V stand-by battery prevented memory loss when the battery was disconnected. The 8 "CAL" numbers were entered under the following functions:

1. BOOM 1 - used to store implement width (in) of the tillage unit.
2. BOOM 2- not used.
3. BOOM 3 - not used.
4. SPEED - used to store speed calibration number. The number was obtained from the distance calibration procedure outlined in the Radar Speed Sensor Installation manual. The procedure required driving a distance of 1 mi (1.6 km) and recording the "distance" number displayed. The number was entered in an equation to determine the speed cal. value for the radar speed sensor.
5. METER - used to store flow meter calibration number. The flow meter calibration number was divided by 4.2 to display the application rate in lb/ac.
6. VALVE - used to store control valve calibration number 2123.
7. RATE 1 - used to enter the first desired nitrogen application rate

to be automatically controlled. The application rate and meter calibration units had to be identical.

8. RATE 2 - used to enter the second desired nitrogen application rate to be automatically controlled. The application rate and meter calibration units had to be identical.

After programming the console, 2 optional functions could be programmed into the console. The NH_3 nurse tank volume (TANK VOLUME) and time of day (TIME). The calculated tank volume decreased as NH_3 was discharged from the nurse tank. A new "TANK VOLUME" was re-entered each time the nurse tank was filled. The time entered was based on a 24-hour clock.

The 8 function keys, when depressed, indicated various operating conditions during NH3 application. The 8 operating functions were:

1. TOTAL AREA - displayed total area covered.
2. TOTAL VOLUME ~ displayed volume discharged total area.
3. FIELD AREA - displayed field area covered.
4. FIELD VOLUME - displayed volume discharged for field area.
5. DISTANCE - displayed cumulative distance travelled.
6. SPEED - displayed actual ground speed.
7. VOL/MIN - displayed volume of nitrogen discharged per minute.
8. AREA/HOUR - displayed area per hour rate calculated using present ground speed.

Initial field use or use after a period of time required operating the control console in the manual mode. Manual operation allowed the control console to properly prime the heat exchanger with NH_3 before switching the motorized control valve to automatic operation. The "POWER" and "BOOM 1" switches were turned on while the flow control rate switch was moved to the "MAN" position. The "MASTER", "BOOM 2" and "BOOM 3" switches were turned off. The "MASTER" switch was turned on with the applicator knives in the ground and the tractor at operating speed. The nitrogen flow through the motorized control valve was manually adjusted with the "INC/DEC" switch until the desired application rate was displayed on the "RATE" screen. Once the rate stabilized the nitrogen temperature and pressures were recorded. To ensure the controller was metering liquid nitrogen the values were plotted on the manufacturers supplied temperature vs. pressure chart. Moving the flow control switch to "RATE 1" allowed the controller to automatically adjust the motorized control valve when changes in forward speed or flow occurred.

Changing the nitrogen application rate was very easy. The flow control switch was moved to the second programmed application rate (RATE 2) or a new rate was programmed into the control console.

The operation of the motorized control valve was determined by the control valve calibration number. Each digit of the "Valve Cal" number controlled a specific function on the operation of the motorized control valve. A change in the "Valve Cal" affected the speed, accuracy and stability of the motorized control valve.

The controller allowed for a stationary field check of the NH_3 system by simulating a forward ground speed. The desired ground speed was entered into the controller by depressing the "SELF TEST" function key. The radar speed sensor cable was disconnected for the stationary check. This function was useful in determining proper operation of the controller and applicator knives.

EASE OF INSTALLATION

Ease of installing the Raven SCS440 system was good. Installation of the control system included assembling the NH_3 components, mounting the control system and radar speed sensor, installing the control console and steel vapour tubes, routing the electrical harness and vapour lines, and connecting the control system to the NH_3 nurse tank and manifolds. Installation of the Raven SCS440 system took 2 people, 7 hours.

Assembly of the NH_3 components required plumbing the flow meter, pressure and temperature gauges, motorized control and on/off valves, strainer assembly and emergency shut-off valve to the heat exchanger. The manufacturer supplied the necessary pipe fittings and sealant to assemble the components. A schematic was provided detailing correct assembly of the components.

Reading the temperature and pressure gauges from the tractor cab required the control system to be mounted towards the front of the tillage unit. Mounting hardware secured the control system to a 4 x 4 in (102 x 102 mm) beam on the tillage unit, (**Figure 10**). Two types of ground speed sensors were available with the Raven SCS440 system: radar speed sensor or drive wheel sensor. The AFMRC's radar speed sensor was used to measure ground speed. The manufacturer supplied a radar speed sensor installation manual containing information on the installation of various makes and models of speed sensors used with the SCS440 system. The radar speed sensor was mounted near the centreline of the tillage unit. A interface cable supplied connected the radar speed sensor to the SCS440 control console.

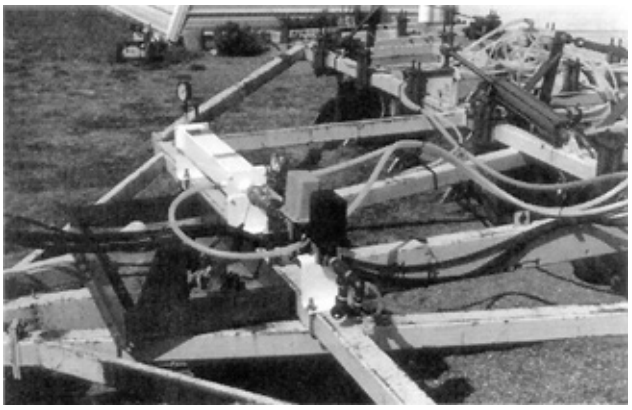

Figure 10. Control system mounted on a tillage unit.

A bracket was fabricated to install the control console into the tractor cab. The length of the power source cable connecting the console to the tractor's power source was sufficient. However, the control cables supplied were too short to connect the console to the flow meter and valves and 24 ft (7.3 m) extension cable was ordered. The AFMRC recommends the manufacturer consider supplying sufficient cable lengths to safely install the control system.

OPERATOR SAFETY

Safe operation of the Raven SCS440 controller was directly related to the operator's knowledge of handling NH_3. Classified as dangerous goods, extreme caution and care had to be used when around NH_3. Safety features supplied with the Raven SCS440 controller were an emergency shut-off valve, a pressure relief valve and the "DATA-LOCK" and "SELF TEST" functions on the control console.

The emergency shut-off valve stopped the flow of NH_3 from the nurse tank to the heat exchanger. The valve was manually operated by a rope (not supplied) from the tractor cab. The AFMRC recommends the manufacturer supply a safe and reliable method of stopping NH_3 flow to the heat exchanger.

The pressure relief valve discharged trapped ammonia from the control system. The AFMRC recommends the manufacturer supply detailed safety information on the hazards of discharging NH_3 into the atmosphere.

When activated, the controller's "DATA-LOCK" function prohibited entry of data into the controller without first entering the "DATA-LOCK CODE". The function was considered a positive feature for operator safety. However, the operator had the option of using or disabling the "DATA-LOCK" function. The AFMRC recommends the manufacturer incorporate the "DATA-LOCK" function into the required programming steps of the control console.

The "SELF TEST" function allowed the operator to check the operation of the system from the tractor cab when stationary. This function was considered a positive safety feature.

The Raven SCS440 control system relied on a continuous power source for safe operation of the controlled components of the system. Unsafe operation of the control system occurred with a power loss to 1 or more of the electrically controlled components. The AFMRC recommends the manufacturer supply a reliable shut-down system when unsafe electrical conditions existed.

Table 1. Electrical cable test.

OPERATOR'S MANUALS

The operator's manuals were fair. The manufacturer supplied manuals for the control console and the NH_3 control system. The installation and service manual for the control console was written for spraying operations and contained no console information for NH_3. The AFMRC recommends the manufacturer supply a control console manual specifically for NH_3. The Accu-Flow installation and service manual supplied useful information on assembly, installation, operation and maintenance of the control system. A detailed parts list was also included. A detailed safety section on the mandatory safety precautions to be followed when using NH_3 was not included. The AFMRC recommends the manufacturer supply a detailed safety section on the proper handling of NH3 in the operator's manuals.

MECHANICAL HISTORY

No mechanical problems were encountered during 56 hours of field operation. The intent of the test was evaluation of functional pedormance. An extended durability evaluation was not conducted.

APPENDIX I - SPECIFICATIONS

MAKE AND MODEL:	DICKEY-john DjCC Sl00 Control System	DICKEY-john DjCMS100 Monitor System
MANUFACTURER:	DICKEY-john Canada Inc. 700 Campbell Street Cornwall, ON K6H 6C9 Phone: 613/933-9000	
SERIAL NUMBERS:	0790-13456	1429-12121
CONTROL CONSOLE:		
-model number	45790-2302A	46429-0011A
-size (h x w x l)	4 x 5.75 x 3 in (102 x 146 x 76 mm)	
-controls	power on-off switch, 6 function keyboard	
-display	4-digit display screen	6-digit display screen
-mounting	3.3 x 5.8 in (64 x 147 mm) hanging bracket	
-power supply	12 vdc	12 vdc from "Y" cable and tractor ignition switch
-cables	9.5 in (241 mm) console 10 in (254 mm) "Y" adaptor 13.1 ft (4.0 m) main harness 5 ft (1.5 m) speed cable 4 ft (1.2 m) switch cable 11.8 ft (3.6 m) power cable 22 ft (6.7 m) implement	9.5 in (241 mm) console 6 ft (1.8 m) ignition cable
SPEED SENSOR:		
-type/serial number	Radar/456401910/0640-41791	
-size (h x w x l)	4 x 4 x 12 in (102 x 102 x 305 mm)	
-cable	20 ft (6.1 m)	
FLOW METER:		
-type/serial number	paddle wheel/CS170620	
-calibration no.	2.11	
-size (h x w x l)	6.5 x 4.5 x 12 in (165 x 114 x 305 mm)	
-mounting	plumbed in-line with 2, 1 x 4 in (25 x 102 mm) flanges, 1.25 in (32 mm) npt male and female outlets	
-cable	5.8 ft (1.8 m)	
MOTORIZED CONTROL VALVE:		
-serial number	12678	
-type/serial number	1 in (25 mm) carbon steel ball valve with actuator valve/12678	
-size (h x w x l)	5 x 6 x 3.8 in (127 x 152 x 97 mm)	
-actuator size	6.8 in (173 mm) dia., 8 in (203 mm) height	
-mounting	plumbed in-line, 1 in (25 mm) npt female inlet and outlet	
-power	12 vdc	
-cable	5.3 ft (1.6 m)	
VAPOUR DETECTOR:		
-type/serial number	DICKEY-john/1431-10118	
-size (h x w x l)	2 x 3.3 x 5 in (51 x 84 x 127 mm)	
-mounting	plumbed in-line, 1.25 in (32 mm) npt female inlet and 1 in (25 mm) outlet	
-cable	5.8 ft (1.8 m)	
HEAT EXCHANGER:		
-type/serial number	2 thermal transfer units/CS167329, CS167322	
-size	8 in (203 mm) dia., 20.5 in (521 mm) height	
-mounting	4, 0.625 in (16mm) slotted pads	
OFF/AUTO/FLUSH SWITCH:		
-type	3-position toggle switch	
-size(hxwxl)	2 x1.1x 5 in (51x 30 x127 mm)	
-cable	4.2 ft (1.3 m)	
OPTIONAL EQUIPMENT:	0.75 in (19 mm) NH_3 control ball valve, ground speed sensor and low flow meter insert	

MAKE AND MODEL: Micro-Trak - MT3000

MANUFACTURER:	Micro-Trak Systems Inc. P.O. Box 99 Eagle Lake, MN USA 56024-0099 Phone: 507/257-3600 (1-800-328-9613)
CONTROL CONSOLE:	
-serial number	92M8046
-size (h x w x l)	5.25 x 2.20 x 7.75 in (133mm x 56mm x 197 mm)
-controls	master spray (auto-man-hold) switch, adjust switch, three individual boom switches and rotary selector dial
-display	5-digit display screen
-mounting	1 x 8.25 in (25 x 210 mm) hanging bracket
-power supply	main power 12 V dc, 7.5 A in-line fuse on/off power 12 V dc from tractor ignition source
-cables	14 ft (4.3 m) console cable 6 ft (1.8 m) speed sensor cable 10 ft (3 m) flow extension (optional) 17.5 ft (5.3 m) power cable 30 ft (9.1 m) 14 gauge ground wire 5.5 ft (1.7 m) ignition wire
SPEED INTERFACE MODULE:	
-type	radar/g.m, interface module
-size (h x w x l)	1.75 x 2 x 2.25 in (44 x 51 x 57 mm)
-mounting	plastic tie strap
-cable	6 ft (1.8 m) inter/ace module power cable 14 in (356 mm) Dickey-john inter/ace cable
FLOW METER:	
-model	FM 750 SS
-type/serial number	axial flow turbine, 150 psi (1034 kPa) rating/RE83293
-calibration no.	40.6
-mounting	plumbed in-line, 0.75 in (19 mm) npt female inlet and female outlet, secured to NH3500 bracket
-cable	3 ft (0.9 m)
MOTORIZED CONTROL VALVE:	
-model	servo-valve
-type	stainless steel butter/ly valve, 150 psi (1034 kPa) rating
-power	6 V dc, 6 to 8 rpm
-mounting	plumbed in-line, 0.75 in (19 mm) npt female inlet and outlet, secured to NH3500 bracket
-cable	3 ft (0.9 m)
ON-OFF VALVE:	
-make	KZCO Incorporated
-model	EHII
-type	carbon stainless steel vented ball valve
-mounting	plumbed in-line, 1 in (25 mm) npt female inlet and outlet, secured to NH3500 bracket
-power	12 V dc from control console
HEAT EXCHANGER:	
-model	NH3500
-type	Heat Exchanger
-size (h x w x l)	4.25 x 1.75 x 22 in (108 x 44 x 559 mm)
OPTIONAL EQUIPMENT:	magnetic speed sensor kit, Trak-Star ultrasonic speed sensor and NH3350 heat exchanger

APPENDIX I - SPECIFICATIONS

MAKE AND MODEL:	Micro-Trak Nitro-Trak NH_3 Automatic Control System
MANUFACTURER:	Micro-Trak Systems Inc. P.O. Box 99 Eagle Lake, MN USA 5602-0099 Phone: 507/257-3600 (1-800-328-9613)
DISPLAY CONSOLE:	
-model	TNc9541
-serial number	0120
-size (h x w x l)	4 x 2.5 x 4.75 in (102 x 64 x 121 mm)
-controls	master and rate switches
-display	multifunction display screen: application rate, speed, tank level, area or NH_3 counter, meter dial position, calibration and reset modes, and error display
-mounting	console plugged into mounting assembly, 2 L-shaped brackets connect to mounting assembly
-power supply	12 V dc from tractor ignition source, 2 A in-line fuse
-cables	14.5 ft (4.4 m) console cable 14.5 ft (4.4 m) speed sensor cable 10 ft (3 m) flow extension (optional) 10 ft (3 m) power cable 30 ft (9.1 m) 14 gauge ground wire
SPEED SENSOR:	
-make	Micro-Trak
-type	magnetic speed sensor
-magnets (6)(h x w x l)	0.5 x 1 x 0.125 in (13 mm x 25 mm x 3 mm)
-mounting	6 magnet clips, 6 x 1.25 in (152 x 32 mm)
-sensor	3 ft (0.9 mm) pick-up
-mounting (h x w x l)	I-shaped bracket, 4 x 5.5 x 8 in (102 x 140 x 203 mm)
-cables	3 ft (0.9 m) pick-up
SERVO CONTROL MODULE:	
-model	TNsc942
-type	plug-in control module
-size (h x w x l)	4 x 5.5 x 8 in (203 x 140 x 102mm)
-power	supplied from display console
-mounting	4 dual fastener Velcro tabs
-cable	9 ft (0.9 m) actuator cable 18 in (457 mm) temperature sensor cable 12 in (305 mm) run/hold cable
METER CONTROL KIT:	
-model	B-9500
-type	Continental meter actuator assembly
-mounting	mounting bracket secured actuator to meter, hose clam secured actuator arm meter dial and run/hold magnet bolted to flag of shut-off valve
OPTIONAL EQUIPMENT:	Trak-Star Ultrasonic Speed Sensor, Radar speed sensor interface kits, Continental C-4100 meter control kit, Continental C-2500 meter control kit and extension cables

MAKE AND MODEL:	Raven SCS400 Anhydrous Ammonia Control System
MANUFACTURER:	Raven Industries 205 6 Street East, P.O. Box 5107 Sioux Falls, SD USA 57117 Phone: 605/336-2750
CONTROL CONSOLE:	
-model	SCS440
-serial number	17084
-size (h x w x l)	5.5 x 4.75 x 10.25 in (140 x 121 x 260 mm)
-controls	power on/off switch, flow control rate and manual adjust switches, master and 3 individual boom switches and 22 function keyboard
-display	2, 4-digit display screens, application rate data display
-mounting	2 x 11.5 in (51 x 292 mm) hanging bracket
-power supply	12 V dc, with optional 9 V standby battery (not included)
-cables	10 ft (3.0 m) console cable 12 ft (3.7 m) flow meter extension 24 ft (7.3 m) flow extension (optional) 2 ft (0.6 m) Dickey-john radar interface 25 ft (7.6 m) power, on/off valve
FLOW METER:	
-model	RFM 55A
-type	axial flow turbine, 300 psi (2068 kPa) rating
-calibration no.	730
-size	3.25 in (83 mm) dia., 9 in (229 mm) length
-mounting	plumbed in-line, 1.25 in (32 mm) npt male inlet and 1 in (25 mm) female outlet
MOTORIZED CONTROL VALVE:	
-type/serial number	2 speed carbon steel ball valve/3389J
-size (h x w x l)	10 x 5 x 7 in (254 x 127 x 178 mm)
-mounting	plumbed in-line, 1 in (25 mm) npt female inlet and outlet
-power	12 V dc
-cable	8 in (203 mm) reversing power cable
ON/OFF VALVE:	
-type/serial number	carbon steel ball valve/4078K
-size (h x w x l)	10 x 5 x 7 in (254 x 127 x 178 mm)
-mounting	plumbed in-line, 1 in (25 mm) npt female inlet and outlet
-power	12 V dc from control console and from a tractor power source
HEAT EXCHANGER:	
-model	30 gal/min US (114 L/min)
-type	NH_3 Super Cooler
-size (h x w x l)	10 x 5 x 7 in (254 x 127 x 178 mm)

GAUGES:		
-type	pressure	temperature
-mode		
(stainless steel)	0 to 150 psi	25 to 125°F
-mounting		
(npt male inlet)	0.375 in (9.5 mm)	0.5 in (13 mm)

OPTIONAL EQUIPMENT:	20 US gal/min heat exchanger, various radar ground speed interface kits, wheel drive speed sensor extension cables

APPENDIX II - MACHINERY RATINGS

Rating scale for Alberta Farm Machinery Research Centre's Evaluation Reports.

-Excellent
-Very Good
-Good
-Fair
-Poor
-Unsatisfactory

SUMMARY CHART

DICKEY-john DjCCS100 and DjCMS100 ANHYDROUS AMMONIA CONTROL & MONITOR SYSTEM

RETAIL PRICE: $4767.90 (February 1996, f.o.b. Lethbridge, AB)

QUALITY OF WORK:

-metering accuracy	**good;** between 40 and 180 lb/ac (45 and 202 kg/ha) **fair;** below 40 lb/ac (45 kg/ha) or above 180 lb/ac (202 kg/ha)
-heat exchanger	**good;** vapour detector monitored the level of vapour from thermal transfer units
-motorized control valve:	**very good;** responded quickly to adjust the flow of nitrogen

EASE OF OPERATION AND ADJUSTMENT:

-maintenance	**good;** no pressure relief valve or strainer assembly provided
-control console	**very good;** application rate easy to adjust
-monitor console	**very good;** received sensor inputs from control console

INSTALLATION EASE: **good;** took 2 people, 7 hours to install system

OPERATOR SAFETY: directly related to operators' knowledge of NH_3

OPERATOR'S MANUALS: **good;** safety precautions when using NH_3 included in contol control console manual

MECHANICAL HISTORY: no mechanical problems encountered

NITRO-TRAK NH_3 AUTOMATIC CONTROL SYSTEM

RETAIL PRICE: $1510.00 US (February 1996, f.o.b. Eagle Lake, MN)

QUAUTY OF WORK:

-metering accuracy	**good;** between 40 and 120 lb/ac (45 and 135 kg/ha) **fair;** below 40 lb/ac (45 kg/ha) or above 120 lb/ac (135 kg/ha)
-meter control kit	**very good;** responded quickly to adjust the flow of nitrogen

EASE OF OPERATION AND ADJUSTMENT:

-maintenance	**very good**
-display console	**very good;** a new application rate programmed into console or changed by delta rate function

INSTALLATION EASE: **good;** meter control kit installed to meter by manufacturer, took 1 experienced person, 5 hours to install

OPERATOR SAFETY: directly related to operators knowledge of NH_3

OPERATOR'S MANUAL: **good;** no NH_3 safety section

MECHANICAL HISTORY: no mechanical problems encountered

MICRO-TRAK MT3000 NH_3 CONTROL SYSTEM

RETAIL PRICE: $2865.00 U.S. (February 1996, f.o.b. Eagle Lake, MN)

QUALITY OF WORK:

-metering accuracy	**good;** between 40 and 140 lb/ac (45 and 157 kg/ha) **fair;** below 40 (45 kg/ha) or above 140 lb/ac 157 kg/ha)
-heat exchanger	**good;** vapour was discharged through vapour lines
-motorized control vaJve	**very good;** responded quickly adjust nitrogen flow

EASE OF OPERATION AND ADJUSTMENT:

-maintenance	**very good**
-control console	**very good;** a new application rate programmed into console or changed by Delta Rate function

INSTALLATION EASE: **good;** components of system assembled by manufacturer. took 2 experienced people 5 hours to install

OPERATOR SAFETY: directly related to operator's knowledge on NH_3

OPERATOR'S MANUAL: **fair;** manual written for spraying operations and no NH_3 safety section

MECHANICAL HISTORY: in-line fuse replaced and 1 hole in butterfly valve plugged

RAVEN SCS440 ANHYDROUS AMMONIA CONTROL SYSTEM

RETAIL PRICE: $4350.00 (February 1996, f.o.b. Calgary, AB)

QUALITY OF WORK:

-metering accuracy	**good;** rates below 140 Ib/ac (157 kg/ha) **fair;** rates above 140 lb/ac (157 kg/ha)
-heat exchanger	**good;** vapour was discharged through vapour lines
-motorized control valve	**very good;** responded quickly to adjust the flow of nitrogen

EASE OF OPERATION AND ADJUSTMENT:

-maintenance	**very good;** pressure relief valve drained system of NH_3
-control console	**very good;** 2 application rates can be programmed into the console

INSTALLATION EASE: **good;** 2 experienced people, 7 hours to install

OPERATOR SAFETY: directly related to operators' knowledge of NH_3

OPERATOR'S MANUAL: **fair;** control console manual written for spraying operations and NH_3 safety section

MECHANICAL HISTORY: no mechanical problems encountered

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