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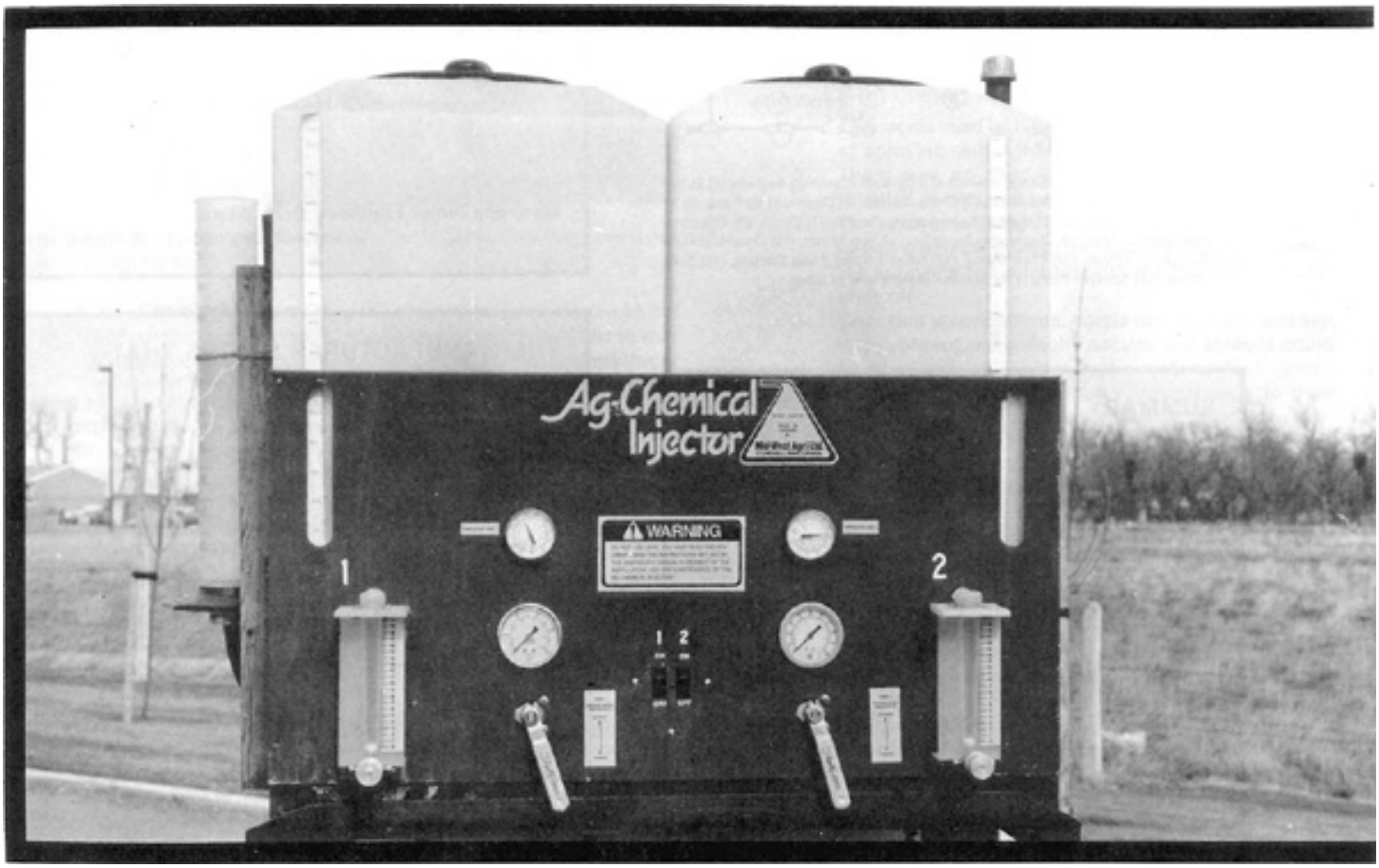

Ag-Chemical Injector Model 240

A Co-operative Program Between

ALBERTA FARM MACHINERY RESEARCH CENTRE

PAMI
PRAIRIE AGRICULTURAL MACHINERY INSTITUTE

AG-CHEMICAL INJECTOR MODEL 240

MANUFACTURER AND DISTRIBUTOR:

Mid-West Agri Limited
Box 879
Stonewall, Manitoba R0C 2Z0

RETAIL PRICE:

$1,995.00 (March, 1986, f.o.b. Lethbridge, Alberta)

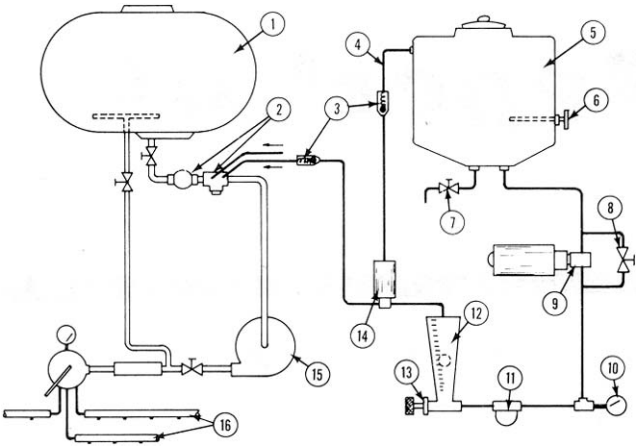

FIGURE 1. Schematic of Ag-Chem Injector in a Sprayer Plumbing System: (1) Sprayer Water Tank, (2) Injection Manifotd, (3) Check Vatves, (4) Chemical By-Pass, (5) Injector Chemical Tank, (6) Chemical Temperature Gauge, (7) Drain, (8) Chemical Pressure Control Valve, (9) Diaphragm Pump and 12 Voit Motor, (10) Chemical Pressure Gauge, (11) Filter, (12) Flow Meter, (13) Needle Vaive Flow Control, (14) Solenoid Valve, (15) Sprayer Pump, (16) Sprayer Booms and Nozzles.

SUMMARY

The Ag Chemical injector model 240 could be installed on a sprayer in about 8 hours. Adequate installation instructions and material were provided to install the injection manifold in the sprayer plumbing system and to connect to the tractor electrical system.

The advantages of chemical injection include simple calculations, no chemical or water measurement required, no tank agitation required and convenient flushing and nozzle checking with clean water. All controls and gauges were adequate and convenient except for the thermometer which only measured actual chemical temperature for the top portion of the tank. Chemical flow rate could be conveniently set with the sprayer stationary, before starting to spray. The on/off controls could be located in the tractor cab for remote operation. For high tractor cabs, it may be necessary to elevate the Ag-Chemical injector for improved visibility. Chemical tank filling and draining were convenient.

An adequate range of chemical metering rates was provided for those chemicals used during the test. Chemical metering flow rate, after several modifications, was constant except at very low flow rates. Calibration curves were supplied for many chemicals. Although some calibration curves for some chemicals agreed with curves determined by PAMI, others differed substantially. Many variables, including metering, chemical viscosity, chemical temperature, chemical flowability and pump speed were possible reasons for these differences. More work is required to solve the problems associated with these many variables. Frequent field recalibrations, using a graduated cylinder plumbed into the system by PAMI, made it possible to accurately meter and apply chemical during the test. Both roller and centrifugal sprayer pumps resulted in adequate mixing of the chemical after it had been injected into the water. Response time or time lag for spot spraying was too excessive to be effective. The chemical tank level indicators were inaccurate.

The 12 volt D.C. tractor battery power supply was adequate to run the chemical pumps and solenoid valves.

The Ag-Chemical injector reduced or eliminated many of the safety hazards normally associated with corn ventional tank-mix systems.

The operator's manual was clear and well written.

Only one mechanical problem occurred during the test. A pressure gauge required replacement due to fluid leaking out of the gauge.

RECOMMENDATIONS

It is recommended that the manufacturer consider:

1. Modifications to effectively measure chemical temperatures for the entire contents of each tank.
2. Providing more accurate calibration curves for chemicals at various temperatures.
3, Providing markings on the chemical tanks that more accurately indicate the amounts of chemical in each tank.
4. Modifications to provide for more effective spot spraying.

Manager/Senior Engineer: E. H. Wiens
Project Engineer: L. R. Coleman

THE MANUFACTURER STATES THAT

With regard to recommendation number:

1. All machines manufactured in 1987 will have the thermometer lowered to within 1/2 inch of the bottom of the tank to ensure chemical temperature for the entire contents of each tank.
2. We recognize the many variables that can affect the accuracy of the chemical calibration curves provided. We are continuing to work at solving the problems associated with these variables and improve calibration curve accuracy.
3. We are now using a new decal that sticks to the tank better.
4. We realize the compromise necessary to effectively use the spot application feature. We are presently working on ways to improve the effectiveness of spot application.

GENERAL DESCRIPTION

The Ag-Chemical injector model 240 is an attachment which can be used with most conventional sprayers. It is a unit for storing one or two chemicals separately so they can be injected into the sprayer's water stream, using the sprayer pump to provide mixing action.

The unit, which is mounted on the sprayer hitch frame, has two independent modules, each consisting of:

a) 16.5 gal (75 L) plastic storage tank for chemical
b) diaphragm pump driven by a 12 volt motor
c) temperature gauge
d) manual by-pass pressure control valve
e) pressure guage
f) needle valve flow control
g) variable area flowmeter
h) solenoid valve
i) remote control box mounted on the tractor
j) check valves
k) filter

l) chemical by-pass

Chemicals are injected into a manifold plumbed into the suction hose between the sprayer tank and the sprayer pump.

FIGURE 1 shows the major components while detailed specifications are given in APPENDIX I.

SCOPE OF TEST

The Ag-Chemical injector model 240 was mounted on the hitch frame of a Great Northern sprayer and operated in the field conditions shown in TABLE 1 for 43 hours while spraying about 1565 ac (626 ha). The injector was evaluated for ease of installation, ease of operation and adjustment, quality of work, safety and suitability of the operator's manual.

During the test both a Great Northern 0.75 in (19 mm), 92 foot (28 m) boom and a McCrea 1 in (25 mm), 64 foot (18.3 m) boom were used. Each boom was used with Delavan LF067 and Tee Jet 8002 flat fan nozzles. The effect of both centrifugal and roller pumps was evaluated.

Laboratory tests included checking the calibration curves provided with water and with those chemicals used during the evaluation at various temperatures and pressures. Mixing effectiveness and delay times for spot spraying were evaluated with both a centrifugal and a roller pump.

TABLE 1. Operating Conditions

CHEMICAL APPLIED	CROP	HOURS	GROUND SPEED mph	(km/h)	FIELD AREA ac	(ha)
Ochemco LV96	Wheat	22	5	(8)	856	(343)
2,4-D Ester LV600	Wheat	2	5	(8)	40	(16)
	Mustard	3	8	(13)	120	(48)
Matavan	Wheat	1	5	(8)	53	(21)
Tordon 202	Wheat	3	5	(8)	138	(55)
Avenge	Wheat	4	5	(8)	100	(40)
Hoe Grass 284	Wheat	5	5	(8)	138	(55)
Banvel	Mustard	3	8	(13)	120	(48)
TOTAL		43			1565	(626)

RESULTS AND DISCUSSION

EASE OF INSTALLATION

Installation Time: It took about 8 hours to install the Ag-Chemical injector on a Great Northern sprayer. Installation instructions were clear and adequate.

Mounting on Trailer Hitch: When mounting the injector tanks on the trailer hitch frame, it was necessary to fabricate an angle iron framework to hold the injector in position. For the test unit, a framework was built up to elevate the entire unit (FIGURE 2) to improve visibility from a tractor cab.

FIGURE 2. Ag-Chemical Injector on Elevated Framework for Improved Visibility from Tractor Cab.

Plumbing: The injection manifold was easily installed in the sprayer plumbing system, ahead of the pump, with the components supplied. Care had to be exercised to ensure plumbing did not allow chemical to enter the sprayer water tank.

Electrical System: Electrical power to operate the two, 12 volt diaphragm pumps was obtained by connecting to the tractor electrical system. The remote electrical control box was installed in the tractor cab in the vicinity of the operator. The wiring provided was easily connected to the tractor battery and a quick-disconnect fitting was provided. Adequate electrical wires and connectors were supplied.

EASE OF OPERATION AND ADJUSTMENT

Advantages of Ag-Chemical Injector: The concept of injectlng chemical into the plumbing system ahead of the sprayer pump had many advantages. Calculations for the amount of chemical to use were simpler than for the conventional tank mix system. No chemical measurement was required, resulting in reduced handling of chemical and improved safety. No water measurements were necessary and it was not necessary to agitate and mix the chemical with the water in the sprayer tank. The sprayer tank was used only for water and thus did not require cleaning when switching back and forth among non-compatible chemicals. The clean water in the sprayer tank also allowed for convenient system flushing after the chemical injector was shut off. This also allowed for safe and convenient checking of nozzle delivery rates, spray patterns and servicing of plugged nozzles and screens.

Controls: A set of controls and gauges (FIGURE 3) were supplied for each of the two chemical tanks on the Ag-Chemical injector. Controls consisted of an on/off switch, pressure adjustment control valve and a flow meter complete with a needle valve flow control adjustment. Gauges were provided for both pressure and temperature measurement.

The on/off switches on the chemical tanks provided for convenient recirculating of the chemicals while setting the needle valve flow control for the desired flow rate.

The thermometer was located approximately half way up the tank. Once chemical was below this point, chemical temperature was no longer correctly measured. It is recommended that the manufacturer make modifications to ensure chemical temperature measurement for the entire contents of each tank.

In tractors with high tractor cabs, the temperature and pressure, with the chemical injector mounted on the sprayer trailer hitch frame, were not visible, For the test, to improve visibility, the injector tank was elevated on a framework as shown in FIGURE 2.

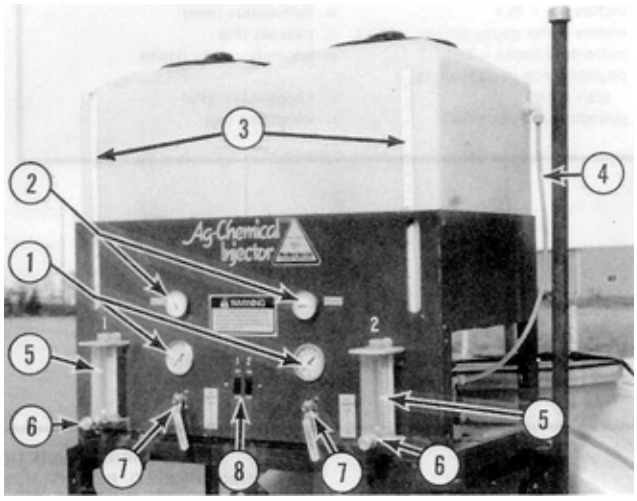

FIGURE 3. Ag-Chemical Injector Controls and Gauges: (1) Pressure Gauge, (2) Thermometer, (3) Tank Level Indicator, (4) Chemical By-Pass, (5) Flow Meter with Ball Indicator, (6) Needle Valve Flow Control, (7) By-Pass Pressure Control Valve, (8) On/Off Switch.

The remote pump control box (FIGURE 4) came supplied with adequate cable and connectors for convenient mounting

in the tractor cab near the operator. In addition to on/off controls for each tank, the control box contained a 50% and 100% switch. This switch reduced the speed of the pump to provide for reducing the amount of chemical being applied should a low concentration of weeds be present in some parts of the field.

FIGURE 4. Remote Pump Control Box Mounted in Tractor Cab.

Setting the Chemical Flow Rate: A procedure for calculating the required chemical flow rate for the sprayer nozzles being used was clearly outlined in the operator's manual. Knowing the required chemical flow rate and chemical temperature, the graph for the appropriate chemical in the operator's manual indicated the flow meter setting. The flow was easily set by adjusting the needle valve and operating pressure until the middle of the flow meter ball (FIGURE 3) was at the required setting. These adjustments were made with the sprayer stationary, prior to commencing spraying. On/off switches for each compartment were conveniently located at the front of the injector tank to allow chemical to recirculate to the tank, without entering the sprayer water stream, while the flow rate was being set.

Tank Filling and Draining: The tank opening, with the injector installed on the sprayer hitch frame, was approximately 48 in (1219 mm) above the ground which allowed for safe and convenient filling while standing on the ground. The 8 in (203 mm) diameter tank openings were adequate for safe and convenient filling with chemicals. The filler opening was equipped with a strainer to prevent foreign material from entering the tank.

Each tank was equipped with a sump and drain valve to provide for safe and complete draining of chemicals. As instructed in the operator's manual, the injector tanks should not be used as storage tanks. Chemicals should be drained after use each day to prevent a change in chemical flowability and viscosity when exposed to the atmosphere.

After tanks were drained, the entire sprayer plumbing system could be conveniently and compeltely flushed using clean water from the sprayer tank.

Field Operation: The application rate was dependent on ground speed. Therefore, it was very important to accurately determine and maintain a constant ground speed in order to ensure a constant and accurate application rate.

QUALITY OF WORK

Range: The Ag-Chemical injector had sufficient range to accommodate the recommended rate for all herbicides used throughout the test.

Chemical Metering: The chemical rate was initially set to the required rate before spraying commenced. During the early stages of the test, the set rate, after a period of operation, would drift and not remain constant. This problem appeared to be greater at flow rate settings below 5 than it was at higher settings. Although operating at as low a pressure as possible reduced the problem, it did not eliminate it completely for all chemicals. To rectify this problem, the manufacturer supplied a modified needle valve flow control and preceded it in the plumbing system with a bowl type filter. Additionally, 10 psi (69 kPa) check valves were installed in the lines to the injection manifold and the chemical by-pass (FIGURE 1). As well, it was recommended to operate at lower chemical pressures. This solved the problem except for some drift at very low meter settings, where continual adjustment was still required to counteract drifting. Usually, it was not required to operate at these low settings.

Calibration Curves: The manufacturer provided calibration curves for a wide variety of chemicals. Although all calibration curves were not checked, PAMI did check the calibration curves for those chemicals used throughout the test.

The initial calibration check was performed using water. PAMI's results, with water, matched those of the manufacturer, indicating the system was capable of accurately metering water. Calibration checks with some chemicals resulted in rates similar to the manufacturer's. For example, when using Hoe Grass 284 at the recommended rate, PAMI's rate matched the manufacturer's rate. However, with other chemicals, large differences occurred. For example, when spraying Avenge at the recommended rate, the manufacturer's rate was 15% higher than PAMI's rate. With other chemicals, even larger differences existed.

To date, this problem has not been satisfactorily resolved. A number of possibilities exist that could contribute to these differences.

First, the separate injection of chemicals into the water stream involves the metering of relatively small amounts of chemical. Therefore, small differences in metering rates can result in large error percentages.

Secondly, the viscosity and flowability of most, if not all, chemicals changes with the temperature of the chemical. All chemicals did not change at the same rate with changes in temperature. As shown in the manufacturer's calibration curves, changes in chemical viscosity and flowability resulted in changes in metering rates as chemical temperature changed. Therefore, careful temperature measurement and related metering rate adjustments must be made for changes in temperature. This results in another possible source for error.

Thirdly, flow meter settings were made by setting the middie of the ball at the required setting. Sighting differences to ensure reading the middle of the ball was another source of error.

Fourthly, the diaphragm pumps used to supply the chemicai were powered by a 12 V tractor battery. Changes in supply voltage caused changes in the pump speed and consequently could result in changes in chemical rates.

A further potential source of error could be changes or differences in the chemical composition of the same chemical over time. For example, is one batch of the same chemical different enough from a second batch that metering is affected? Or, does exposing a chemical to the atmosphere result in changes that could result in changes to the metering rate? For exampie, during the test, following a period of time after initial calibration of one chemical, a second calibration revealed differences up to 30%.

All the above possible sources of error indicate the complexity and difficulty of accurately metering the small amounts of chemical required for effective chemical injection. The many and varied types of chemicals presently being marketed and the varied recommended application rates, further-complicate the situation. It is recommended that the manufacturer further investigate the situation in an attempt to arrive at and provide accurate and consistent chemical calibration curves.

Field Operation: Upon realizing the complexity of the situation surrounding the proper and accurate metering of chemicals for injection as described above, PAMI took steps to attempt to properly apply chemical in the field. Graduated cylinders (FIGURE 5) were mounted and plumbed into the injector to assist in field calibration. Throughout the field testing, whenever the type of chemical was changed or when significant temperature differences occurred, a field calibration was performed and the

required flow meter adjustments were made. Using this method, it was possible to accurately meter and apply chemical in the field. Without this frequent calibration check, chemical could not be applied with any degree of confidence that the proper amount was being applied. It has already been recommended that the manufacturer investigate the possibility of improving accurate chemical metering.

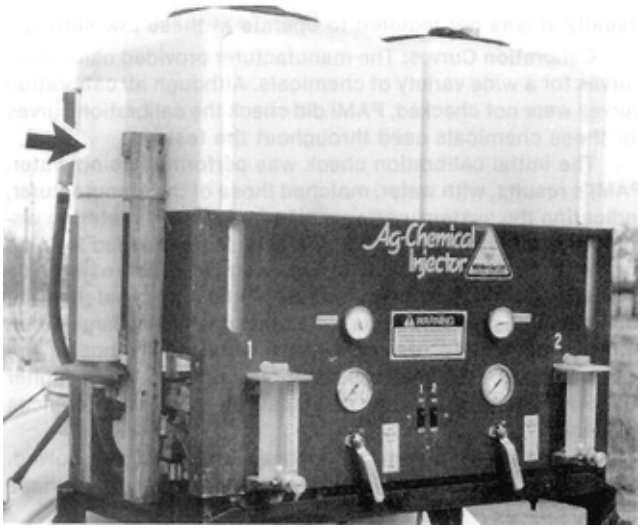

FIGURE 5. Graduated Cylinder Mounted on the Ag-Chemical Injector to Assist in Field Calibration.

Chemical Mixing: Once the chemical was injected into the sprayer plumbing system, the sprayer pump was used to mix the chemical with the water. Tests made with both centrifugal and roller pumps indicated that proper and complete mixing occurred and the proper chemical-water mixture was being delivered to the nozzles.

Spot Spraying: One of the many advantages associated with the concept of chemical injection is its use to inject a second chemical only when patches of certain weeds exist in the field. For example, if the main and overall coverage is a wild oat herbicide, this chemical could be metered and injected from one chemical tank. The second chemical tank could contain a different herbicide for spot spraying of, for example, Canada Thistie. The second tank would only be turned on when patches of Canada Thistle appeared in the field. This would result in considerable cost saving as well as an effective control of both types of weeds.

Although this theory has many merits, the response time or lag time with most sprayers affect the practicality of effectively using the Ag-Chemical injector for this purpose. The time lag inherent in most sprayer systems caused considerable delay from the time of injection at the manifold ahead of the water pump until it reached the nozzle at the outer end of the boom. Time delays ranging from 1.2 to 4.7 minutes (TABLE 2) were experienced, depending on boom size and length and nozzle size. Actual time measurements confirmed the theoretical calculated time lag.

TABLE 2. Time Required, After Injection, for the Chemical to Reach the Outer Nozzle.

BOOM LENGTH		BOOM DIAMETER		NOZZLE	NOZZLE APPLICATION RATE		TIME LAG
ft	(m)	in	(mm)	TYPE	gal/ac	(L/ha)	min.
92	27.4	0.75	19	LF067	3.5	40	3.0
92	27.4	0.75	19	8002	10	110	1.2
60	18.3	1	25	LF067	3.5	40	4.7
60	18.3	1	25	8002	10	110	1.6

These same time lags were also evident when clearing the system after shutting off the chemical. Therefore, it is recommended that the manufacturer consider modifications to provide for more effective spot spraying.

Level Indicators: Stick-on, paper tank level indicators (FIGURE 3), marked in one l itre increments, were affixed to each chemical tank. The tank level indicating strips were inaccurate, and as a result were of l ittle use. I t is recommended the manufacturer consider providing more accurate tank level indicators so they can be used for calibration as well as a check to see how accurately chemical is being metered and applied in the field.

RATE OF WORK

The advantage of the Ag-Chemical injector of not having to measure and agitate chemical, resulted in a higher rate of work than with a conventional tank-mix system. One time filling with chemical was usually adequate to spray most normal sized fields.

POWER REQUIREMENTS

The tractor 12 volt DC power supply was adequate to run the chemical pumps and solenoid valves. Current draw for each tank varied from 2.6 to 4.2 amps.

OPERATOR SAFETY

Use of the Ag-Chemical injector attachment on a sprayer reduced or eliminated several hazards normally associated with conventional tank-mix systems. Some of the safety features are as follows:

1. Chemicals need be handled only once for several hours of spraying rather than at each sprayer tank filling.
2. There was no need to measure chemicals, which resulted in reduced handling of chemicals.
3. The sprayer tank held water only, so it did not require cleaning and the system was easily flushed by running the sprayer a few minutes with the chemical injector shut off.
4. Checking spray patterns, nozzle delivery rates and servicing of plugged or faulty nozzles and screens could be done with only water in the system.
5. Left-over chemicals could be drained back to their original containers. There was not left-over water-chemical mixture to dispose of.

Caution: Operators are cautioned to wear suitable eye protection, respirators and clothing to minimize operator contact with chemicals. Although many commonly used agricultural chemicals appear to be relatively harmless to humans, they may be deadly. In addition, little is known about the l ong-term effects of human exposure to many commonly used chemicals. In some cases, the effects may be cumulative, causing harm after continued exposure over a number of years.

OPERATOR'S MANUAL

The operator's manual was well written, well illustrated, clearly indexed and ruggedly constructed for taking to the field. Coverage was complete, including an illustrated parts list.

Graphs of flow versus flowmeter ball setting were included for use with a large number of chemicals. Instructions were included for making graphs for chemicals not listed.

MECHANICAL PROBLEMS

The Ag-Chemical injector was tested for a total of 88 hours, 43 hours of which consisted of actual field spraying, 18 hours consisted of the unit being switched off but subjected to field vibrations and 27 hours were for stationary laboratory testing and calibrations. The intent of the test was evaluation of functional performance and an extended durability evaluation was not conducted.

During the functional evaluation, only one mechanical failure occurred. The fluid leaked out of one of the pressure gauges and it became inoperative. A new gauge was installed and no further problems were encountered.

APPENDIX I

SPECIFICATIONS

MAKE:	Ag-Chemical Injector
MODEL:	240
MANUFACTURER:	Mid-West Agri Limited Box 879 Stonewall, Manitoba R0C 2Z0
OVERALL DIMENSIONS:	
- length	32.5 in (825 mm)
- width	22.5 in (57 mm)
- height	32.5 in (825 mm)
TANK CAPACITY:	2 tanks at 17.6 gallons (60 L) each
METERING SYSTEM:	
- pumps	2 diaphragm pumps
- motors	12 volt DC electric motors
- pressure control	manual valve in by-pass circuit
- flow control	needle valve
- flow indicator	variable area flow meter (ceramic ball in tapered transparent tube)
INJECTION SYSTEM:	
- location	manifold in sprayer suction line
- mixing	sprayer pump
POWER REQUIREMENT:	12 volt DC (tractor battery)

APPENDIX II

MACHINE RATINGS

The following rating scale {s used in PAMI Evaluation Reports:

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

APPENDIX III

CONVERSION TABLE

acres (ac) x 0.40	= hectares (ha)
feet (ft) x 0.305	= metres (m)
horsepower (hp) x 0.75	= kilowatts (kW)
Imperial gallons (gal) x 4.55	= litres (L)
imperial gallons per acre (gal/ac) x 11.23	= litres/hectare (L/ha)
inches (in) x 25.4	= millimeters (mm)
inches water gauge (in wg) x 249.1	= pascals (Pa)
miles/hour (mph) x 1.61	= kilometers/hour (km/h)
pounds force per square in (psi) x 6.89	= kilopascals (kPa)
pounds mass (lb) x 0.45	= kilograms (kg)

SUMMARY CHART
AG-CHEMICAL INJECTOR MODEL 240

RETAIL PRICE:	$1,995.00 (March, 1986, f.o.b. Lethbridge)
INSTALLATION:	- easy, in about 8 hours
OPERATION AND ADJUSTMEI	- calculations were simpler than for tank mix - no measuring of chemicals or water required - controls were adequate - chemical temperature displayed, but only for part of tank - graphs supplied for many chemicals to set flow rate - flow rate simple and easy - tank filling and draining convenient
QUALITY OF WORK:	- adequate range of chemical rate provided - chemical flow metering rate, after modifications, was constant except at very low rates - calibration curves inconsistent due to variables -- needs further investigation - accurate field speeds required for accurate application rate - sprayer pump effective in mixing chemicals with water - time lag excessive for effective spot spraying - level indicators ineffective
POWER REQUIREMENTS:	- 12 volt tractor battery
OPERATOR SAFETY:	- very good, limited contact with chemical
OPERATOR'S MANUAL:	- very good. complete
MECHANICAL PROBLEMS:	- one pressure gauge failed

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