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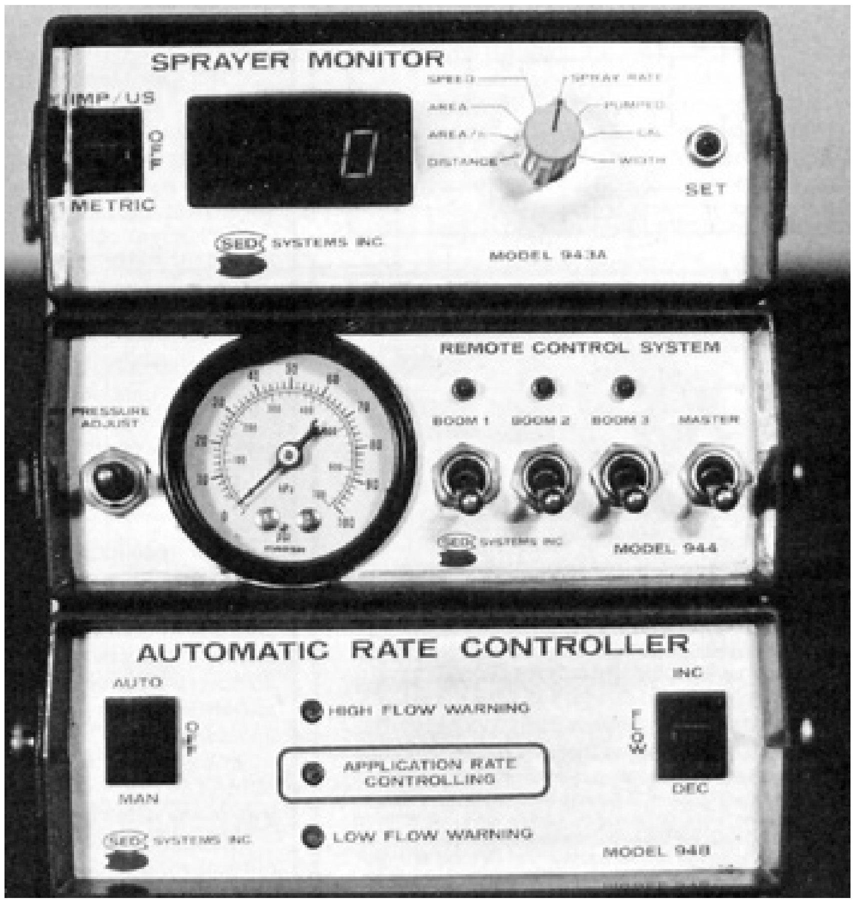

SED Automatic Sprayer Control System

(SED Model 948 Automatic Rate Controller, Model 943A Sprayer Monitor and Model 944 Remote Control)

A Co-operative Program Between

ALBERTA FARM MACHINERY RESEARCH CENTRE

PAMI
PRAIRIE AGRICULTURAL MACHINERY INSTITUTE

SED AUTOMATIC SPRAYER CONTROL SYSTEM

MANUFACTURER AND DISTRIBUTOR:

SED Systems Inc.
P.O. Box 1464
Saskatoon, Saskatchewan
S7K 3P7

RETAIL PRICE: (October, 1982, f.o.b. Lethbridge, Alberta)

(a) Model 944 Remote Control (less solenoids)	$174.00
(b) Model 943A Sprayer Monitor	$859.00
(c) Model 948-S Automatic Rate Controller	$575.00
(Model 948-H Automatic Rate Controller, not evaluated)	$775.00

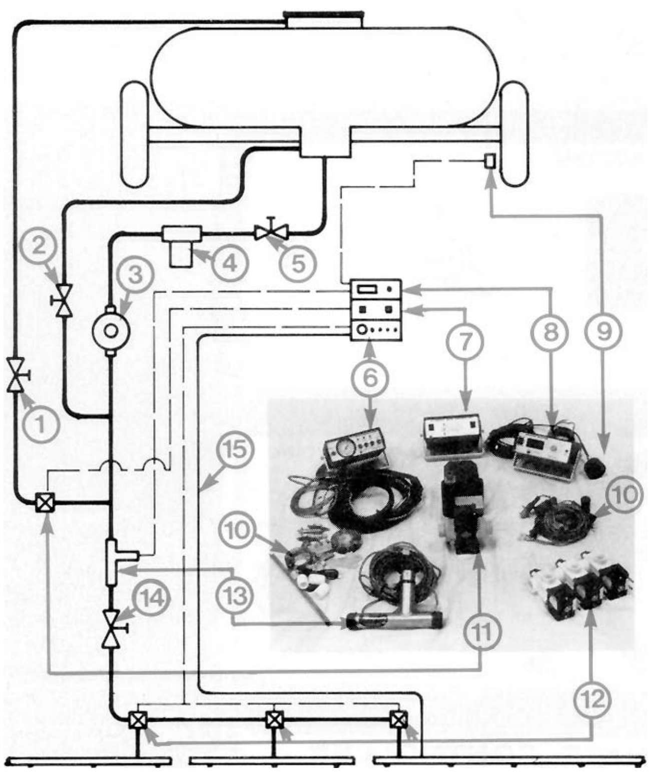

FIGURE 1. SED Automatic Sprayer Control System: (1) By-Pass Valve, (2) Agitator Valve, (3) Pump, (4) Filter, (5) Shut-Off Valve, (6) Model 944 Remote Control, (7) Model 948 Automatic Rate Controller, (8) Model 943A Sprayer Monitor, (9) Speed Sensor, (10) Cables with Puli-Apart Connectors, (11) Motorized Control Valve, (12) Solenoid Valves, (13) Flow Sensor, (14) Throttling Valve, (15) Boom Pressure Line.

SUMMARY AND CONCLUSIONS

The SED automatic sprayer control system consisted of three individual components; the SED model 944 remote control, the model 943A sprayer monitor and the model 948 automatic rate controller. These three units could be used individually or combined in a modular fashion as a system.

Functional performance of the SED 944 remote control was very good. The remote control provided the operator with the controls to manually make adjustments from the tractor seat.

Functional performance of the 943A sprayer monitor was good. The monitor provided the operator with spraying information including spraying and working rate, ground speed, total area and fluid sprayed. Performance'of the monitor was reduced by difficulty in obtaining reliable flow sensor calibration numbers, difficulty in reading numbers greater than 999 on the digital display screen, difficulty in installing the speed sensor and interference between speed sensor targets and detector.

Functional performance of the 948 automatic rate controller was fair. Performance was reduced due to the narrow range of forward speeds over which the spraying rate could be effectively controlled automatically and the large and rapid pressure changes experienced over this narrow range of forward speeds, inadequate operator's manual information for initial nozzle pressure range setting and for initial signal light and horn warning flow rate setting.

Flow sensor accuracy was good at rates between 40 and 240 Llmin (8.8 to 53 galtmin). Accuracy deteriorated when used at rates below 40 Ltmin (8.8 gal/min). Since many spray application rates common to the prairies fall below 40 L/min (8.8 gal/min), the optional flow sensor restrictor should be used. Although the flow restrictor was not submitted for test, it is designed to improve flow sensor accuracy at these lower rates. Some flow sensor repeatability problems were encountered and were felt to be characteristic of paddle wheel type flow sensors.

The speed sensor was accurate. However, speed readings fluctuated at the recommended gap setting of 12 mm (0.5 in) between the metal targets and the detector.

Of the two types of motorized control valves evaluated, the Raymond ball valve had quicker response to changes in forward speed than the Spraying Systems butterfly valve. Often the ball valve "hunted" continuously for the preset pressure and never reached a stable pressure.

The system took from 6 to 11 hours to install, depending on the sprayer plumbing system. Additional plumbing fittings, hoses, and mounting hardware were required, especially on older sprayers not using 25 mm (1 in) plumbing. Pull-apart connectors facilitated unhooking from the tractor. Screw-on polarity connectors made installing the wiring harness on the various components convenient and easy.

The control boxes were not weathertight and required covering to protect them from rain if used on tractors without cabs.

The monitor display screen and the automatic rate controller lights were visible to the operator providing the control boxes were not in direct sunlight. Readout was conveniently possible in both metric (SI) and Imperial units. The counting direction could be conveniently reversed if desired calibration numbers were overshot when entering calibration numbers. The audible alarm was loud enough to be clearly heard above tractor and pump noise.

Determining the calibration number for the flow sensor was difficult and inconvenient. The speed sensor calibration number was easily determined.

Entering the calibration numbers in the sprayer monitor, remembering to press the "Set" button and how many times to press the "Set" button was confusing until some operator experience had been gained.

Preparing the system to automatically control a preselected application rate was somewhat complex and required clarification in the operator's manual. The procedure necessitated proper nozzle selection and setting of pressure limits for proper nozzle operation.

No excessive electrical power demands were made on a normal 12 V tractor battery and charging system. A good 12 V battery was necessary to maintain the operating voltage above 11 volts.

The operator's manuals clearly outlined installation, operation and adjustment of the individual components. Information on the compatibility of the automatic rate controller, remote control and sprayer monitor was inadequate.

The few failures encountered during the evaluation included electrical circuit malfunctioning on two automatic rate controllers, a damaged speed sensor and pipe fitting failure on the Raymond motorized control valve.

RECOMMENDATIONS

It is recommended that the manufacturer consider:

1. Modifications to make numbers greater than 999 easier to read on the sprayer monitor digital display screen.
2. Modifications .to make flow sensor calibration more convenient.
3. Supplying, as standard equipment, the flow sensor restrictor for use in applying normal prairie application rates.
4. Modifications to provide more repeatable and consistent flow sensor readings.
5. Including, in the operator's manual, a detailed, step-by-step procedure to make nozzle pressure range setting and signal light and horn warning flow rate setting easier to understand.
6. Modifications to weatherproof the control boxes.
7. Providing complete information in the operator's manual on the compatibility of the remote control, sprayer monitor and automatic rate controller.
8. Improving quality control on the automatic rate controller circuitry.
9. Modifications to eliminate speed sensor metal detector and metal target interference.

Senior Engineer: E. H. Wiens

Project Technologist: L. B. Storozynsky

THE MANUFACTURER STATES THAT

With regard to recommendation number:

1. A three-digit display was selected at the time of design to provide a large, easy-to-read display. Prime consideration was given to the gallons per acre read-out which seldom exceeds three digits. Consideration will be given to providing four-digit displays with new designs.
2. Field calibration of the flow sensor is desireable to provide accurate measurement of chemical products where differing viscosities and densities are encountered. A simple calibration instruction card has been developed to provide abbreviated instructions for the calibration. SED Systems intends to include additional improvements concerning operator use in new product designs.
3. The flow sensor restrictor is now standard equipment with all 943A sprayer monitors.
4. Use of the flow sensor restrictor provides good repeatability over the flow rates discussed in this test.
5. The model 948 automatic rate controller tested was taken from a prototype run prior to completion of the operator's manual. A complete operator's manual is being provided with current production units.
6. SED Systems monitors are manufactured to perform in typical agricultural conditions of moisture and dust. SED Systems is not aware of weather related product failures.
7. As each of the remote control, sprayer monitor and automatic rate controller are sold separately, an operator's manual specific to installation of each product is provided. Consideration will be given to further improving these installation instructions.
8. The model 948 automatic rate controller tested was taken from a prototype run. Design improvements have since been incorporated to provide suitable characteristics for the two control valves currently being offered.
9. Field performance of the SED System speed sensor has been very good where properly installed. Changes to the operator's manual are being considered to clarify installation procedures of the speed sensor. The tire targets used in this test are not normally required, but are provided for use in exceptional installations.

MANUFACTURER'S ADDITIONAL COMMENTS

1. Two versions of the model 948 automatic rate controller are now available. The model 948-S is standard with a Spray-Ing Systems 314 inch butterfly valve, recommended for use in the by-pass line. The model 948-H features a 3/4 inch Hypro ball valve, replacing the Raymond ball valve prototyped in 1981 and discussed in this report. The Hypro valve may be used in the supply line as a throttling valve, or in the by-pass line as a by-pass regulator. Circuit design of the model 948-S and the model 948-H incorporate improvements to improve reliability, control stability and response time.
2. SED Systems does not promote the practice of operating a field sprayer over extreme ranges of pressure variation. Various nozzle designs are available, some of which have narrow working pressure ranges, and some of which have considerably wider working ranges. In all instances it is the responsibility of the operator to select suitable nozzles and a working pressure range for the application rate and ground speed desired. The model 944 remote control and model 943A sprayer monitor provide suitable instrumentation for the operator to make manual adjustments on-the-go from the tractor seat. The model 948 automatic rate controller provides further assistance by automatically making adjustments once suitable nozzles, ground speed and pressure have been selected.

NOTE: This report has been prepared using SI units of measurement. A conversion table is given in APPENDIX III.

GENERAL DESCRIPTION

The SED automatic sprayer control system consists of a SED model 943A sprayer monitor, a SED model 948 automatic rate controller and a SED model 944 remote control. The SED model 943A sprayer monitor measures and indicates sprayer application rate, ground speed, amount pumped, area sprayed, workrate and distance travelled, in either metric (SI) or Imperial units. The SED model 948 automatic rate controller is designed to work in conjunction with the SED model 943A sprayer monitor. The automatic rate controller automatically maintains chemical application at a preset rate. The SED model 944 remote control monitors boom pressure and controls the boom solenoid valves.

The above three control boxes mount near the operator's station. A flow sensor to measure the amount of liquid going to the booms is inserted in the sprayer plumbing circuit. A speed sensor is mounted on the tractor or sprayer wheel to measure and indicate ground speed. A motorized control valve is located in the sprayer plumbing and automatically opens or closes, to maintain the preset application rate, when changes in forward speed or flow occur. Three solenoid valves, operated by the 944 remote control, allow individual or simultaneous use of up to three boom sections.

The system is powered by the tractor electrical system and can operate on either a positive or negative ground.

Detailed specifications are given in APPENDIX I while FIGURE 1 shows major components and a schematic of their location in a typical sprayer plumbing system.

SCOPE OF TEST

The SED automatic sprayer control system was operated for 56 hours while spraying about 500 ha (1482 ac). The system was evaluated for ease of installation, ease of operation and adjustment, quality of work and suitability of the operator's manual.

RESULTS AND DISCUSSION

EASE OF INSTALLATION

Installation Time: It took from 6 to 11 hours to install the SED automatic sprayer control system on conventional field sprayers. Installation time depended on the existing sprayer plumbing system. With some older sprayers that were equipped with hoses and plumbing fittings smaller than 25 mm (1 in) and manual control valves with by-pass and agitation lines attached, virtually complete replumbing was required. Installation on sprayers already equipped with solenoid valves and 25 mm (1 in) plumbing, required considerably less time and fewer additional plumbing fittings and material.

Installation instructions were clear and adequate.

Control Boxes: Mounting brackets and cables were provided to either stack or individually mount the three control boxes on the tractor near the operator station and connect them to the tractor electrical system. The control boxes were not weathertight and had to be sheltered from rain if a tractor without a cab was used.

Flow Sensor: Installation of the 25 mm (1 in) flow sensor was easy on sprayers equipped with 25 mm (1 in) plumbing. It had to be installed so the full flow going to the booms passed through the sensor.

Sprayers with hoses and fittings less than 25 mm (1 in) usually required considerable plumbing changes and additional fittings to properly install the flow sensor.

Speed Sensor: The metal targets supplied were easily fastened to the rim of a wheel. Metal irregularities such as spokes or bolt heads on a wheel could also be used as targets. The metal detector was equipped with a flexible mount (FIGURE 2), making it difficult to secure and position to the recommended 12 mm (0.5 in) from the metal targets. In very rough fields, interference could occur between the targets and the metal detector due to movement of the detector on the flexible mount. When installing the detector on a front tractor wheel, caution was required to ensure the wheel could be turned to its extremes without target and detector interference and also that the required gap was maintained.

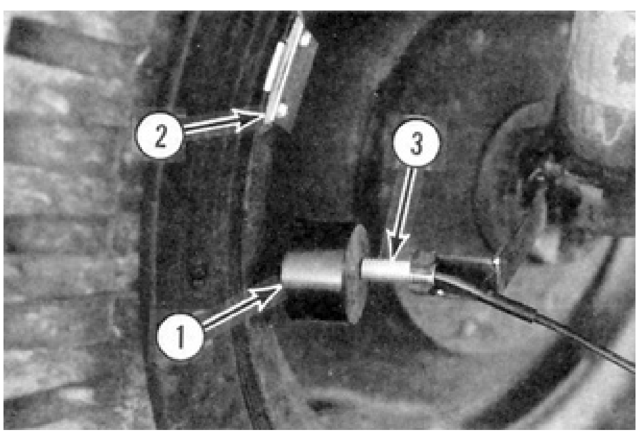

FIGURE 2. Speed Sensor: (1) Metal Detector, (2) Metal Targets, (3) Flexible Mount.

Motorized Control Valve: The motorized control valve could be installed in either the main boom supply line after the flow sensor or in the by-pass line (FIGURE 1). Installing the valve in the main boom supply line was easy and simply involved cutting the hose and inserting the valve. Installing the hose in the by-pass line was usually more difficult and required additional hose and fittings.

Two types of motorized control valves were evaluated with the SED system. One valve was the Spraying Systems 19 mm (0.75 in) butterfly valve.which did not completely shut off flow. A flow rate was selected using a manual valve and the motorized butterfly valve controlled the flow rate around this selected rate. The second valve evaluated was a Raymond 19 mm (0.75 in) ball valve which completely shut off and controlled flow. The Raymond valve was too heavy for the hose to support and required additional support. The Spraying Systems valve was light and small, requiring no additional support.

Solenoid Valves: The Spraying Systems Model 144 boom solenoid valves were easily installed and secured to the sprayer trailer frame with U-clamps. Additional hoses from the solenoid valves to the boom inlets were required.

Wiring Harness: The wiring harness included plastic hold-down clips and ties for securing cables to the sprayer. A sufficient number of screws and clips were provided but there was a shortage of cable ties. Longer cable ties were also required in some places. Pull-apart connectors between the control boxes and the various components were included to permit easy hitching to a tractor.

EASE OF OPERATION AND ADJUSTMENT

The automatic rate controller had to be used in conjunction with the sprayer monitor and remote control (FIGURE 3).

Sprayer Monitor Control Box: The sprayer monitor function selection dial allowed selecting the following functions for display on the three-digit LED display screen:

1. Width -- used for entering the actual spraying width of the sprayer.
2. Cal -- used to enter the ground speed calibration number.
3. Pumped -- displays the cumulative amount of fluid pumped.
4. Spray Rate -- displays the actual application rate.
5. Speed -- displays the actual ground speed and is also used for entering the desired application rate.
6. Area -- displays the cumulative area sprayed.
7. Area/h -- displays the area sprayed per hour at the current ground speed and is also used for entering the flow sensor calibration number.
8. Distance -- displays the cumulative distance travelled.

The display screen was easily read unless it faced directly into sunlight. Readout was conveniently possible in either Imperial or metric (SI) units by positioning the power switch. Calibration was only necessary in one set of units. Some difficulty was experienced in holding and turning the function selection dial and accidentally pressing the "Set" button in rough fields.

The "Set" button was used to enter calibration numbers into the monitor and to reset the function display screen to zero. Calibration numbers were entered by pressing the "Set" button to start the count and holding it until the desired number appeared on the display screen. The display's counting direction reversed each time the "Set" button was pressed. This was a convenient feature for use in reversing the count direction if the desired number was overshot.

The digital display screen indicated numbers directly up to 999. For numbers greater than 999, the monitor alternately displayed thousands and then hundreds. It was difficult to determine whether the monitor was displaying thousands or hundreds, even though the hundreds appeared on the screen longer than the thousands. For example, a number like 7008 was difficult to determine since the monitor alternately displayed the 7, then the 8. The zeros were not displayed, thus increasing the difficulty. It is recommended that modifications be made to make numbers greater than 999 easier to read.

Four calibration numbers had to be obtained and stored in the sprayer monitor control box in order to have the selected spraying rate automatically controlled. These numbers were stored in the control box under the following functions: "Area/h", "Speed", "Cal" and "Width".

During normal spraying the "Area/h" and "Speed" functions indicated the area being sprayed per hour and ground speed, respectively. In addition, the two functions were used to store calibration numbers that are required for the sprayer monitor and automatic rate controller to function. The calibration numbers could be viewed by turning the dial to the desired function and pressing the "Set" button once. Rressing the "Set" button twice reset the calibration number. The numbers were automatically stored by turning the function dial. Remembering when to press the "Set" button once, twice and when not to press it was confusing until some experience had been gained.

The "Area/h" function was used to store the flow sensor calibration number. Obtaining an accurate calibration number for the flow sensor was difficult and inconvenient. Initially, the flow sensor calibration number, given in the operator's manual as a starting point, was stored in the "Area/h" function. Next, a full sprayer tank was emptied at the desired spraying rate and the total volume pumped was recorded in the "Pumped" function. This number was then compared to the actual volume of the tank and a corrected flow sensor calibration number was calculated according to a formula in the operator's manual. However, it would be difficult for a farmer to establish true tank volume. Tank volumes often vary considerably from their given nominal capacities. Even if nominal capacities are accurate, tanks are seldom completely emptied during spraying. Proper calibration equipment and precise measurements were required to obtain an accurate flow sensor calibration number. It is recommended that modifications be made to make flow sensor calibration more convenient. A method which could be used to determine actual volume pumped, providing nozzles were new, would be to use the nozzle manufacturer's specified nozzle flow rate at a given pressure, multiply by the number of nozzles on the sprayer and compare to the flow rate indicated with the sprayer monitor function selector dial in the "Spray Rate" position. Then, set the calibration number so the two flow rates are the same. This method was used and found to work quite well.

The "Speed" function was used to store the desired application rate. This was the number the automatic rate controller maintained by adjusting the motorized control valve when changes in ground speed or flow occurred.

The speed calibration number was stored in the "Cai" function. Speed sensor calibration was easy. Two methods of calibration were outlined in the operator's manual. Both required that a physical measurement of distance be made. Both methods were equally accurate. It was important that both methods be done in soil conditions similar to those encountered during spraying. If the speed sensor was mounted on the sprayer wheel, calibration should be made with the sprayer tank half full in order to obtain an average calibration. Sprayer tires should be properly inflated.

The number stored in the "Width" function was the exact spraying width of the sprayer. The spraying width is the number of nozzles used times the nozzle spacing.

Automatic Rate Controller Box: The automatic rate controller functions included a flow control switch, a manual or automatic mode selector switch and a series of three signal lights.

Preparing the system to automatically control a preselected application rate required proper nozzle selection to apply the chosen application rate at the desired forward speed and at the appropriate pressures. A pressure range had to be established throughout which the nozzles would function properly. The operator's manual suggested it was only necessary to check, by using the flow control switch, to see if the motorized control could adjust nozzle pressure over the selected range. This was considered inadequate since nozzle pressures outside the desired range could result during field operation. It is recommended instructions specify that appropriate adjustment should be made so that the motorized control valve, if located in the by-pass line, be fully open at the minimum selected nozzle pressure and fully closed at the maximum pressure. This would eliminate field operation at nozzle pressures outside the selected range. Setting this pressure range was accomplished by adjusting the sprayer throttling valve, pressure relief valve or by-pass valve.

The operator's manual used an example indicating a nozzle pressure range between 140 and 380 kPa (20 and 55 psi) could be used. The Machinery Institute recommends that, when using standard flat fan TeeJet nozzles, minimum pressure, for proper nozzle distribution patterns, not be set below 200 kPa (29 psi) and that maximum pressure, to avoid spray drift, not be set above 300 kPa (45 psi).

The desired pressure limits were established with the pump operating at rated speed, the boom control valves open and the automatic rate controller in the "Man" position. Care had to be used when adjusting the pressure limits using positive displacement pumps to avoid excessive pressure that might damage solenoid valves and other plumbing components. A pressure relief valve should be installed in the by-pass line to protect against component damage.

Having established the minimum and maximum nozzle pressure as discussed above, the flow rate was set, using the flow control switch, to spray at the average or nominal pressure and sprayer forward speed was adjusted until the desired application rate was displayed on the monitor. At this point, the "Set" button was pressed. This identified to the system, the flow rate that that the signal light and horn warning system was based on. Setting the "Set" button at this point was usually overlooked since the procedure in the operator's manual lacked sufficient information on the purpose of this step. It is recommended that a detailed step-by-step procedure be included in the operator's manual to make both the nozzle pressure range setting and signal light and horn warning flow rate setting easier to understand.

Having established the pressure range and flow rate, the automatic rate controller was set to "Auto", placing it in the operating mode to maintain the preselected application rate by automatic adjustment of the motorized control valve when changes in forward speed or flow occurred.

The above, somewhat complex, procedure for setting the preselected application rate was only required to initially set up the sprayer for automatic operation and no changes were required unless the desired application rate was changed. A new application rate could easily be entered in the monitor. However, it was important to determine if the new application rate could be achieved with the same nozzles. Changing the application rate by more than 20% usually required different sized nozzles. Changing the application rate less than 20% required the operator to change to a new nominal speed in order to operate at the desired nominal pressure. For example, at a nominal pressure of 250 kPa (35 psi), changing the application rate from 100 to 80 L/ha (9 to 7.2 gal/ac) required the speed to be increased from 8 to 10 km/hr (5 to 6.2 mph).

The signal light and horn warning system worked well. The green "Application Rate Controlling" light was illuminated during normal automatic operation and flashed intermittently when the control valve was being adjusted. The "High" and "Low" warning lights came on and a horn sounded when the flow rate was 30% above or below the flow rate required to maintain the preselected application rate. This provided a convenient warning of extreme changes in pressure due to such things as large changes in tractor speed, leaking hoses, plugged nozzles or plugged filters. The lights were readily visible unless exposed to direct sunlight. The warning horn was clearly audible above tractor and pump noise.

The automatic rate controller could be set to apply lighter and heavier application rates in areas that required it. The application rate could be decreased or increased using the flow control switch with the controller positioned in either "Auto" or "Man". In the "Auto" position the application rate returned to normal automatically when the flow switch was released. In the "Man" position the new application rate remained until the flow switch was adjusted again or the controller was returned to the "Auto" position.

QUALITY OF WORK

Flow Sensor: The flow sensor was capable of measuring flow rates up to 240 L/rain (53 gal/min). Normal application rates in the prairie provinces are usually less than 100 L/ha (9 gal/ac) which, using an 18 m (60 ft) field sprayer at 10 km/h (6.2 mph), required a flow rate of 30 L/min (6.6 gal/min). Consequently, only the very bottom end of the flow sensor's range was used for normal prairie spraying conditions. Flow sensor accuracy and reliability was generally poor throughout this normal range. The sensor had to be recalibrated each time the application rate was changed. For example, at a flow rate of 15 L/min (3.3 gal/min) the calibration number used was 92.2. Increasing the flow rate to 30 L/min (6.6 gal/min) resulted in the correct calibration number being 86.8. The above flow rates, when using an 18 m (60 ft) sprayer at 10 km/h (6.2 mph), represented application rates of 50 and 100 L/ha (4.5 and 9.0 gal/ac), respectively. The operator's manual indicated a restrictor was available for flow rates between 4.5 and 32 L/min (1 and 7 gal/min). The restrictor was not supplied for evaluation and consequently its effectiveness was not determined. It is recommended that the restrictor be supplied as standard equipment. At flow rates between 40 and 240 L/min (8.8 and 53 gal/min) the flow sensor was accurate with little difference in the measured and actual flow rates. The calibration number remained constant throughout this entire range.

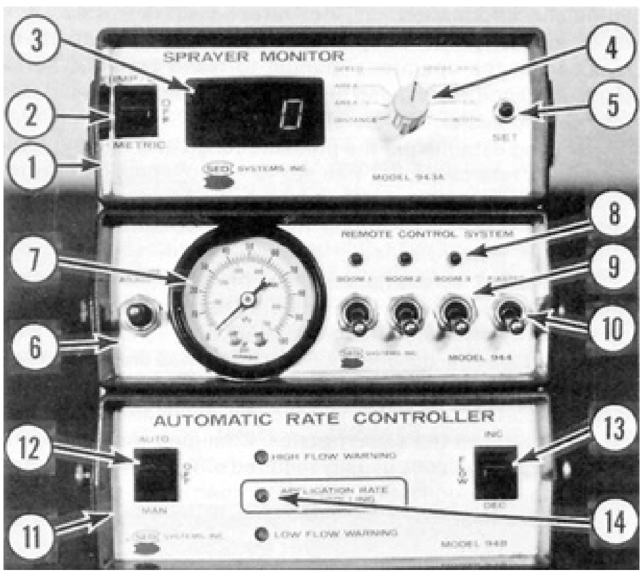

FIGURE 3. SED Control Boxes: (1) Sprayer Monitor Control Box, (2) IMP/US-METRIC-OFF Power Switch, (3) Function Display Screen, (4) Function Selection Dial, (5) SET Button, (6) Remote Control Box, (7) Pressure Gauge, (8) Boom Lights, (9) Boom Solenoid Switches, (10) Master Boom Switch, (11) Automatic Rate Controller Box, (12) AUTO-MAN-OFF Power Switch, (13) Flow Switch, (14) Application Rate Warning Lights.

Flow sensor accuracy depended on sprayer plumbing. It was important that the flow sensor be installed in a 25 mm (1 in) line and at least 308 mm (15 in) downstream from the nearest elbow, tee or plumbing connection. Placing the sensor closer to plumbing fixtures affected its accuracy and a different calibration number had to be determined for each application rate. Density and viscosity of the chemical mixture being sprayed could also affect flow sensor-accuracy.

Repeatibility is a measure of how consistently the flow sensor gives the same reading repeatedly, using the same calibration number and flow rate. Some repeatability problems were encountered, which, for example, required a change in the calibration number from 78.8 to 82.6. This was felt to be characteristic of the paddle wheel type flow sensor used. It is recommended that modifications be made to obtain more repeatable and consistent flow sensor readings.

The pressure loss created by installing the flow sensor in the sprayer plumbing system was negligible and was not a problem.

Speed Sensor: The speed sensor was accurate. However, with the gap between the metal targets and metal detector set at the recommended 12 mm (0.5 in), speed readings fluctuated. For example, at a ground speed of 10 km/h (6.2 mph), speed readings fluctuated between 9.8 and 10.4 km/h (6.1 and 6.5 mph). If the gap was reduced to 5 mm (0.2 in), speed readings were constant, with no fluctuation.

Effect of Forward Speed: The SED automatic sprayer control system only effectively controlled application rate over a narrow range of forward speeds. For example, the controller was set to apply 100 L/ha (9 gal/ac) at 8 km/h (5 mph) at a nozzle pressure of 250 kPa (36 psi). The minimum and maximum pressures were set at 200 and 300 kPa (29 and 45 psi), respectively. Under these conditions, the automatic rate controller maintained the application rate at the desired rate from 7.1 to 8.7 km/h (4.4 to 5.4 mph) (FIGURE 4). FIGURE 5 indicates how rapidly the nozzle pressure varied throughout this small range of forward speeds between the set pressure limits. At 7.1 km/h (4.4 mph) nozzle pressure was 200 kPa (29 psi) which, if installed in the by-pass line, would result in the motorized control valve being in its fully-open position and at 8.7 km/h (5.4 mph) the nozzle pressure increased to 300 kPa (45 psi) which would result in the motorized control valve being in its fully closed position.

Forward speeds outside this range would result in sprayer performance similar to that without a controller. For example, as indicated in FIGURE 4 with the controller set in the manual mode, the application rate would decrease as forward speed was increased.

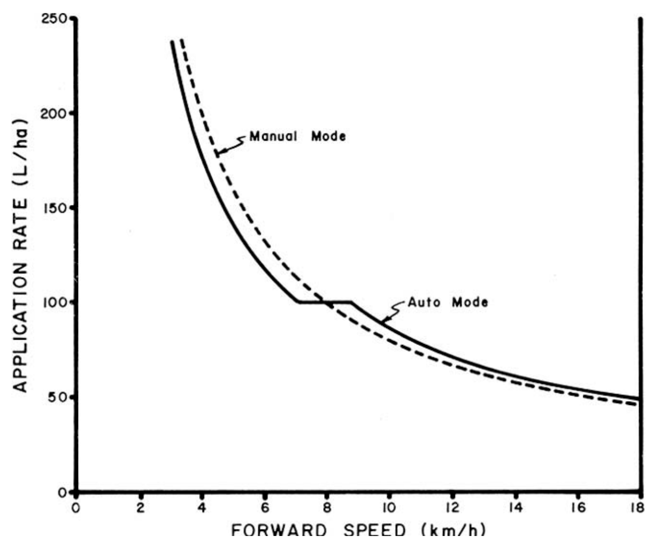

FIGURE 4. Application Rate at Various Forward Speeds with the Automatic Sprayer Control System in the Automatic and Manual Modes.

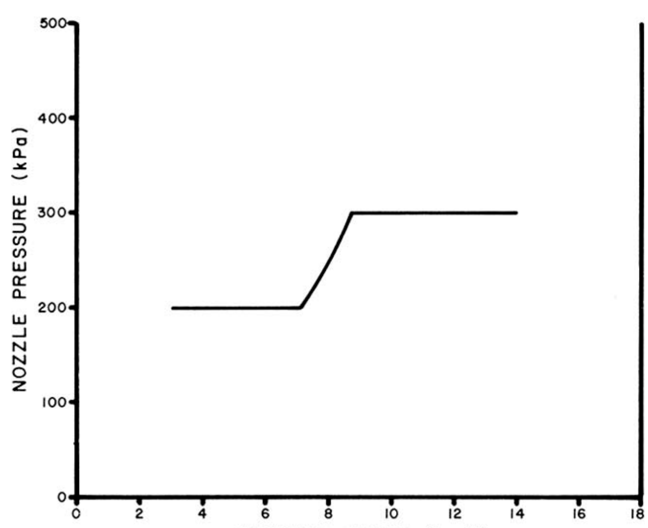

FIGURE 5. Nozzle Pressure at Various Forward Speeds with the Automatic Sprayer Control System.

Increasing the nozzle pressure range resulted in the application rate being controlled over a larger forward speed range. Increasing the minimum and maximum pressures to 100 and 400 kPa (15 and 58 psi), respectively, the automatic sprayer control system controlled the application rate from 5.2 to 10 km/h (3.2 to 6.2 mph) (FIGURE 6). FIGURE 7 indicates the rapid increase in nozzle pressure over this range of speeds. Operating at pressures above 300 kPa (45 psi) is not recommended, due to excessive spray drift. Pressures lower than 200 kPa (29 psi) are not recommended, with standard flat fan nozzles, due to poor nozzle distribution patterns. Nozzle pressures throughout this expanded forward speed range greatly exceeded these pressure limitations, in essence reducing the effective controllable speed range.

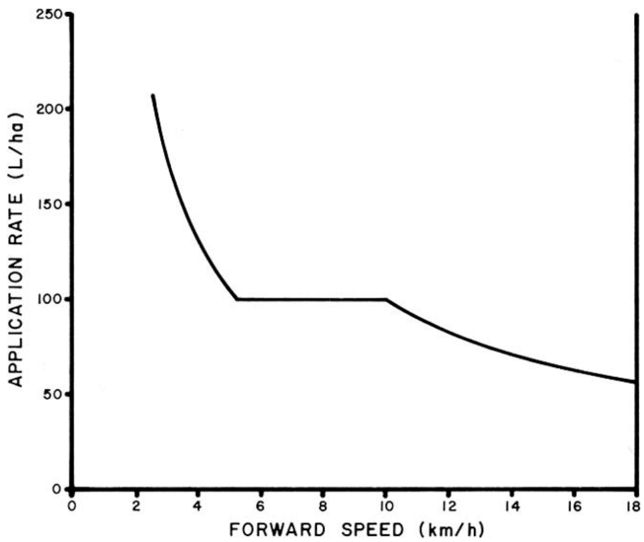

FIGURE 6. Applicate Rate at Various Forward Speeds with Automatic Sprayer Control System with an Increased Preset Pressure Range.

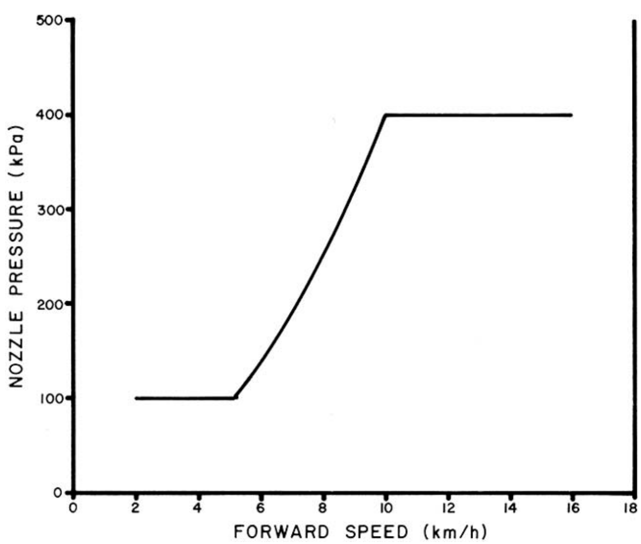

FIGURE 7. Nozzle Pressure at Various Forward Speeds with the Automatic Sprayer Control System with an Increased Preset Pressure Range.

Motorized Control Valves: Two different types of motorized control valves were evaluated; a Raymond ball valve and a Spraying Systems butterfly valve. Both could be used as either a throttling valve in the boom supply line or as a flow control valve in the by-pass line.

With the automatic rate controller in the manual mode, pressure settings could be easily obtained with the Spraying Systems valve when used as either a throttling valve or installed in the by-pass line. Pressures were more difficult to set with the Raymond valve, since large changes in pressure occurred for very short periods of flow control switch operation. Correct pressure adjustment was a trial and error procedure and was more difficult to set when the Raymond valve was used as a throttling valve than as a flow control valve positioned in the by-pass line.

The Raymond valve responded more quickly than the Spraying Systems valve. For example, in the manual mode, it took the Raymond and Spraying Systems valves about 14 and 30 seconds, respectively to fully open from the closed position or vise versa.

FIGURE 8 shows typical response curves for changes in forward speed for the Raymond valve, when operating in the automatic mode. Response times varied from 15 to 30 seconds, six seconds of which were as a result of slack in the mechanical linkage between the motor and the valve. A more direct linkage would reduce response time accordingly. The 15 second response time only occurred under ideal operating conditions. Longer response times were encountered when the valve was operating at or near its fully open or closed position. This was normally the case, since as shown in FIGURE 5, small changes in forward speed called for relatively large changes in pressure and consequently flow, which resulted in the valve frequently operating at or near its fully open or closed position. Often, continuous "hunting" for the preset pressure occurred and the pressure never did stabilize. Continuous pressure variations up to 30 kPa (4 psi) were encountered. The Raymond valve would sometimes stick in the fully open or closed position. It was then necessary to start the valve moving from these positions in the manual mode and then switch to the automatic mode. This was inconvenient.

FIGURE 9 shows typical response curves for changes in forward speed for the Spraying Systems valve, when operating in the automatic mode. Although response time, under ideal conditions, was as low as 20 seconds, more normal response times up to 80 seconds were encountered when the valve was operating near or at its fully open or closed position. Some "hunting" for the preset pressure occurred and it took about 80 seconds before the pressure stabilized.

When operating the Spraying Systems motorized control valve in the by-pass line, an additional 18 L/min (4 gal/min) of flow was required before it could effectively adjust the pressure. It was therefore important to have a pump with adequate capacity.

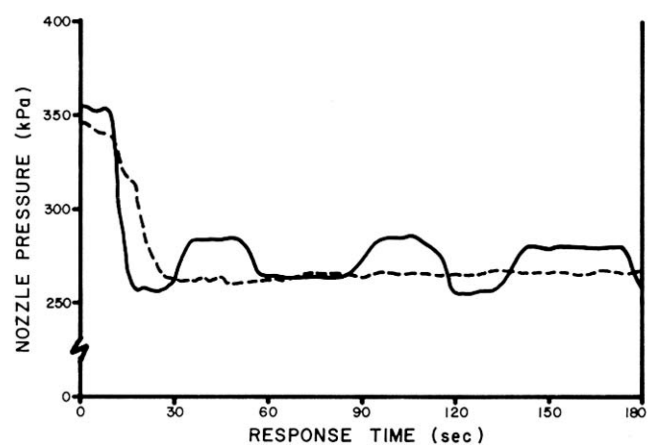

FIGURE 8. Response Curves for Raymond Motorized Control Valve to a Change in Forward Speed.

Effect of Tractor Engine Speed: Momentary changes in tractor engine speed, and consequently pump speed, in hilly fields could result in application rate changes up to 10%. Due to the slow response time of the motorized control valve, the automatic rate controller usually was unable to compensate for these brief variations in pump speed.

Effect of Plugged Nozzles: When operating in the automatic mode, each plugged nozzle resulted in an increase in pressure. This pressure increase was used as a convenient indicator of plugged nozzles. The automatic sprayer control system kept the application rate at the desired rate for each plugged nozzle until the preset maximum pressure was reached.

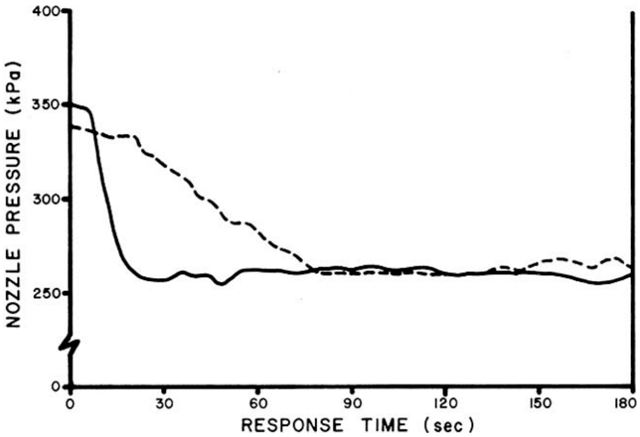

FIGURE 9. Response Curves for Spraying Systems Motorized Control Valve to a Change in Forward Speed.

Effect of Boom Width: Shutting off part of the boom during spot spraying required setting the automatic rate controller on "Man" and adjusting to normal spraying pressure. If left on "Auto", the controller adjusted the motorized control valve to increase the flow, since the monitor did not compensate for the change in spraying width. As a result, the pressure increased and the monitor indicated the application rate for the total width of the sprayer and not the reduced width. The reduced spraying width had to be entered into the monitor before the correct application rate would be indicated.

Environmental Effects: The control boxes were not sealed and therefore had to be covered from rain if installed on a tractor without a cab. The dust common to normal spraying operations did not affect the monitor's performance. It is recommended that the control boxes be weatherproofed to avoid the inconvenience of having to cover them.

Effect of Voltage: The monitor functioned well between 11 and 17 volts. Damage to the unit could result when subjected to voltages greater than 18. The monitor did not indicate the correct application rate below 11 volts. It was therefore important that a good battery be used to supply 12 volts to the system at all times.

Starting the tractor lowered the battery voltage supply. If the voltage decreased below 6 volts, the calibration numbers stored in the monitor had to be re-entered unless the monitor was in the off position during starting.

COMPARISON OF SPRAYER MONITOR AND REMOTE CONTROL VERSUS AUTOMATIC RATE CONTROLLER

The use of the sprayer monitor to provide the operator with a readout of spraying performance (i.e. spraying rate, speed and all other displayed functions) was considered very beneficial. This provided the operator with the information required to make necessary changes in pressure or tractor speed. The remote control, allowing pressure to be adjusted and various sections of the boom to be controlled from the operator's position on the tractor was also considered beneficial. The use of the automatic rate controller to automatically maintain a preselected application rate when changes in forward speed or flow occurred was considered to be of considerably less importance, particularly since effective automatic control was only possible over a narrow range of forward speeds and resulted in such rapid changes in nozzle pressure.

ELECTRICAL POWER REQUIREMENTS

No excessive demands were made on the tractor battery or electrical charging system. The SED sprayer monitor and automatic rate controller drew a maximum of 0 6 A when attached to a 12-volt electrical system. In the off position the monitor and controller drew a maximum of 0.1 A. The remote boom control with two solenoid valves drew a maximum of 3.6 A. The Raymond and Spraying Systems motorized control valves drew a maximum current of 0.7 A and 0.1 A, respectively.

OPERATOR'S MANUAL

Separate operator's manuals were supplied for each of the three control boxes. The manuals presented comprehensive installation, operating and adjustment instructions for each control box. It has already been recommended that a detailed, step-by-step procedure be added to make nozzle pressure range setting and signal light and horn warning flow rate setting easier to understand. Information was also lacking on the compatibility of the Model 944 remote control with the Model 943A sprayer monitor and Model 948 automatic rate controller. It is recommended that the manufacturer provide complete information on the compatibility of the remote control, sprayer monitor and automatic rate controller.

DURABILITY RESULTS

The SED automatic sprayer control system was operated in the field for 56 hours. The intent of the test was functional evaluation and an extended durability evaluation was not conducted. TABLE 1 outlines the failures that occurred during functional testing.

TABLE 1. Mechanical History

ITEM	OPERATING HOURS
- The automatic rate controller circuitry failed and the control box was replaced at	beginning of test and at 2 hours
- The Raymond motorized control valve 19 mm (3/4 in) NPT connections failed at	end of test
- The speed sensor was damaged at	end of test

DISCUSSION OF MECHANICAL PROBLEMS

Circuit Malfunction: Two power transistors attached to the heat sink in the automatic rate controller overheated, causing the circuit to malfunction. A new automatic rate controller was obtained. An insulating washer was missing in the second automatic rate controller which caused a short in the circuitry. It is recommended that the manufacturer improve quality control.

Speed Sensor: In rough fields, with the metal detector positioned 12 mm (0.5 in) from the metal targets, the detector face interfered with the metal targets due to movement of the detector on the flexible mount. This interference resulted in detector damage (FIGURE 10). Modifications are required to eliminate this interference.

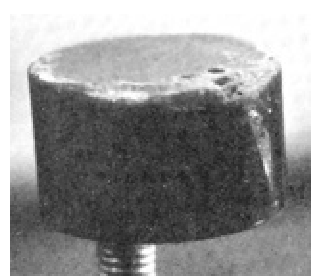

FIGURE 10. Damaged Speed Sensor.

APPENDIX I
SPECIFICATIONS

MAKE:	SED Sprayer Monitor	SED Automatic Rate Controller	SED Remote Control
MODEL:	943A	948	944
SERIAL NO.:	PS 113814A	RA 1100004	RE 2100219
CONTROL BOX:			
- size	70 x 130 x 168 mm	70 x 130 x 168 mm	67 x 130 x 168 mm
- controls	METRIC-IMP-OFF power switch, number range button and function select dali.	AUTO-MAN-OFF power switch and flow adjustment switch	MASTER on-off power switch, pressure adjustment switch and three boom switches
- alarm		buzzer and warning lights	--
- display	three digit LED display screen	--	0-600 kPa pressure gauge
CONNECTORS:	pull-apart connections at control box and between tractor and sprayer	screw-on polarity connectors at control box, pull-apart polarity connectors between tractor and sprayer and crimp-on end connection for battery	pull-apart connectors between tractor and sprayer and crimp-on connection for battery and solenoid valve

SENSORS:

- speed	
- metal irregularity detector	54 mm diameter x 32 mm long molded cylinder
- targets	6, 50 x 50 x 1 mm tin plate
- flow	
- type	paddle wheel
- size	25.4 mm I.D., 203 mm long and 140 mm high

MOTORIZED CONTROL VALVES:

- make		
- motor	Raymond Control Systems	Spraying Systems
valve	Plastic Systems Inc.	
- model		
- motor	MAR-8-8-4	244
- valve	157	--
- serial no.		
- motor	56621 K84	--
- valve	108 532	
- power	12 V DC	12 V DC
- size	19 mm NPT (F)	19 mm NPT (F)
- type	ball	butterfly

BOOM SOLENOID VALVES:

- make	Spraying Systems Co.
- model	144
- power	12 V DC, 30 watt
- size	19 mm NPT (F)
- no.	3

WEIGHT:

Sprayer monitor control box	0.551 kg
Automatic rate controller box	0.485 kg
Remote boom controller box	0.835 kg
Raymond motorized control valve	3.182 kg
Spraying Systems motorized control valve	0.350 kg
Flow sensor and cable	1.150 kg
Speed sensor and cable	0.453 kg
Speed sensor metal targets	0.398 kg
Cables	0.446 kg
Solenoid valves	0.740 kg
Hose clamps, ties, mounting hardware, nipples, screws, etc.	0.444 kg
Total	9.034 kg

APPENDIX II

MACHINE RATINGS

The following rating scale is used in Machinery Institute Evaluation Reports:

(a) excellent
(b) very good
(c) good
(d) fair
(e) poor
(f) unsatisfactory

APPENDIX III

CONVERSION TABLE

1 kilometre/hour (km/h)	= 0.6 miles/hour (mph)
1 hectare (ha)	= 2.5 acres (ac)
1 litre per hectare (L/ha)	= 0.09 Imperial gallons per acre (gal/ac)
1 kilopascal (kPa)	= 0.15 pounds per square inch (psi)
1 kilogram (kg)	= 2.2 pounds mass (lb)
1 litre per second (L/s)	= 13.2 Imperial gallons per minute (gal/min)
1 litre (L)	= 0.22 Imperial gallons (gal)
1 meter (m)	= 3.3 feet (ft)
1 millimetre (mm)	= 0.04 inches (in)
1 hp	= 0.75 kW

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