TEST REPORT

of the

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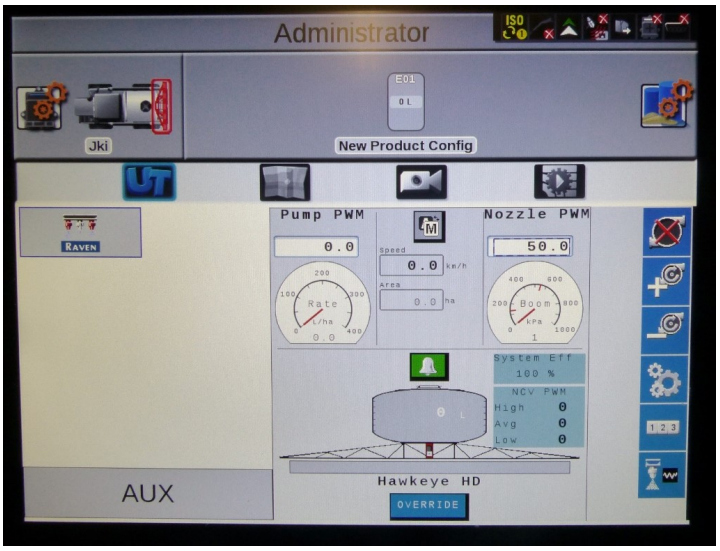
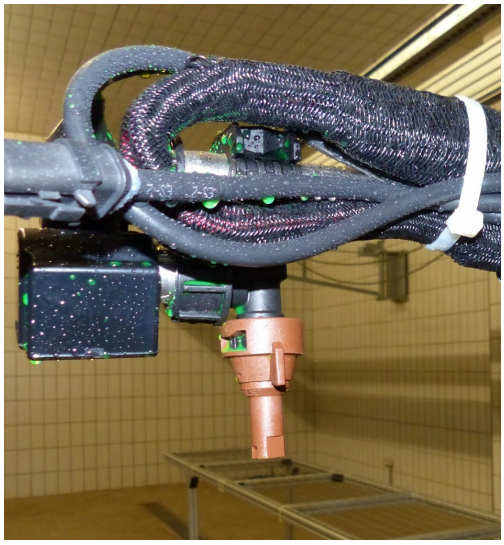
Federal Research Institute
for Cultivated Plants, Braunschweig





Electronic nozzle control with pulse width modulation

Raven „Hawk Eye“

Approved for the use with sprayers for field crops (tested with duty cycle of 50% to 100% and frequency of 20 Hz)

Applicant and Manufacturer
Raven Industries
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USA

Approved on
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Equipment and dimensions

Electronic nozzle control with pulse width modulation Raven „Hawk Eye" consisting of the solenoid valves mounted on the respective spray boom with single nozzle bodies and a solenoid valve in the nozzle body (switching frequency 20 Hz), the connection lines and the nozzle control via the ISO bus universal terminal („UT") for setting of the pulse width modulation "PWM".

Fig. 3: PWM control mudule on sprayer boom.

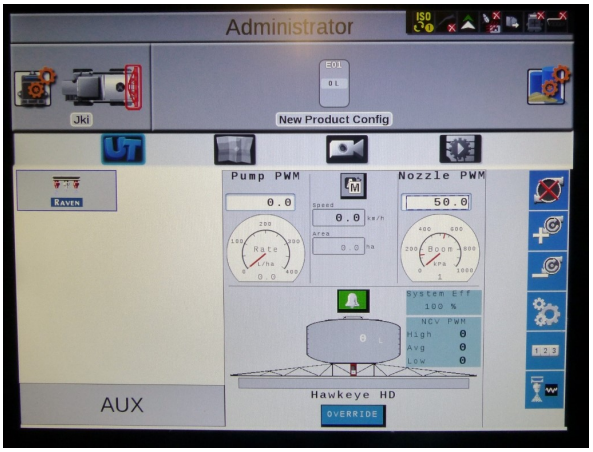

Fig. 3: Display on Universal Terminal („UT") for manual entry of the PWM.

Method of operation: The nozzle control system controls the injection times and the closing times of the nozzle via the Raven universal terminal, the so-called "Duty Cycle" ("DC" on the monitor). The switching cycles are designed for 20 Hz. Ohter switching frequencies are theoretically possible and can be set via the system setup. The frequency of 20 Hz proved ist worthe during the test. By means of pulse width modulation and the setting of the "duty cycle", the application rate of the nozzles used is thus regulated between 50% and 100%, without the pressure in front of the nozzles and thus also the droplet spectrum changing. The pulse width can also be set very easily via the terminal with touchscreen from 0 to 100% (0% = nozzles completely closed, 100% nozzle completely open). In the case of a duty cycle of less than 50%, care must be taken because gaps in the longitudinal direction can be produced by switching the nozzles on and off.

In order to effectively prevent such gaps, adjacent nozzles are always alternately switched through the system. With a double overlap of the nozzle spray thus gaps in the direction of travel are reduced.

In automatic mode, the system regulates the „duty cycle" (opening times) of the nozzles according to the preset application rate and driving speed. Manual operation with a fixed duty cycle is possible. The application rate is then only regulated via the volume flow controller of the sprayer. The optimal choice of the nozzle size - based on the usual operating ranges for application rate and driving speeds - in almost completely open state („DC" about 85 to 100%), requires that a DC of less than 50% can occur only at reduced travel speed.

Assessment

During the technical inspection and also in practical use the system worked without errors or failures. The cross distribution results on the test bench with different nozzles and different pulse width modulations were in the range of the permissible tolerances (maximum 7% - 9% coefficient of variation, see table 1 to 4). The deviations of the individual nozzle volume flows from the common average were within the permissible range (+/- 5%) both before and after practical use.

In 2019 and 2020, a sprayer from the Horsch company was equipped with the system. The distribution uniformity in the cross distribution is both before and after the practical application in the required range.

The longitudinal distribution of the system was tested on the laboratory spraying track at different pressures, duty cycle („DC") and travel speeds. The results of the longitudinal distribution determined under dynamic conditions show with coefficients of variation of max. 9% comparable results in relation to the static cross distribution measurements. The accuracy of the longitudinal distribution is rated as good on the basis of the measured values.

Practical application: The electronic nozzle control system was used in 2019 on 325 hectares with the nozzles TeeJet AIC 110 05 VP and Lechler IDKN 120-03 POM and in 2020 on 726 hectares with the nozzle Lechler AD 120-03 POM. A sufficient effect of the plant protection measures was confirmed. Phytotoxic damage did not occur.

Basics for testing
The tests were carried out on basis of the Regulations for Testing Plant Protection Equipment (JKI-Guideline 2-1.1:2013) and of ISO 5682-1:1999. The requirements of ISO 16119-2:2013 and of JKI-Guideline 1-2.1:2013 were fulfilled.

Table 1: Results in cross distribution with nozzle TeeJet AIC 110 05 VP

Pressure (bar)	PWM Duty Cycle (%)	Max. deviation of the individual nozzle volume flows from the mean (%)	Cross distribution at 40 / 50 / 60 (cm) (Vk %)
2.0	50	1.55	- / 8.7 / -
2.0	100	1.61	- / 8.1 / -
3.0	30		- / 5.7 / -
4.0	50	-1.75	- / 3.6 / -
4.0	100	1.56	- / 4.7 / -
6.0	30	2.70	- / 7.4 / -
6.0	50	2.03	- / 4.9 / -
6.0	100	1.83	- / 4.0 / -

Table 2: Results in cross distribution with nozzle Lechler IDKN 120-03 POM

Pressure (bar)	PWM Duty Cycle (%)	Max. deviation of the individual nozzle volume flows from the mean (%)	Cross distribution at 40 / 50 / 60 (cm) (Vk %)
1.0	50	-2.48	- / 7.9 / -
5.0	30	-	- / 3.8 / -
5.0	50	-	- / 4.4 / -
1.0	100	1.29	- / - / -
3.0	50	5.10	- / - / -
3.0	100	-1.30	- / - / -

Table 3: Results in cross distribution with nozzle Lechler IDKT 120-03 POM

Pressure (bar)	PWM Duty Cycle (%)	Max. deviation of the individual nozzle volume flows from the mean (%)	Cross distribution at 40 / 50 / 60 (cm) (Vk %)
1.5	30	5.17	- / 7.4 / -
1.5	50	-3.90	- / 5.8 / -
1.5	100	-	- / 4.0 / -
3.0	30	4.08	- / 3.3 / -
3.0	50	3.76	- / 2.9 / -
3.0	100	-	- / 2.2 / -
5.0	50	-3.43	- / - / -

Table 4: Results with nozzle Lechler AD 120-03 POM (after field test)

Pressure (bar)	PWM Duty Cycle (%)	Max. deviation of the individual nozzle volume flows from the mean (%)	Cross distribution at 40 / 50 / 60 (cm) (Vk %)
1.0	50		- / 6.9 / -
1.0	100		- / 5.9 / -
1.0	30	-4.10	-
1.0	50	2.16	-
1.0	100	-	-
3.0	30	-3.15	-
3.0	50	-5.30	-
3.0	100	4.98	-
5.0	50	-2.29	-

Table 5: Dynamic longitudinal distribution with different puls width modulation „Duty Cycle“ (DC)

PWM (Duty Cycle %)	Pressure (bar)	Driving speed (km/h)	Coeffizient of Variation CV (%)
TeeJet AIC 110 05 VP			
50	2.5	8	8.62
100	2.5	8	4.95
50	4.0	8	5.19
100	4.0	8	3.48
Lechler IDKN 120-03 POM			
50	3.0	8	7.80
100	1.0	8	7.70
100	3.0	8	5.17
Lechler IDKT 120-03 POM			
50	1.5	8	9.93
100	1.5	8	6.20
50	3.0	8	6.52
100	3.0	8	4.14

Field testing:

Landwirtschaftskammer Niedersachsen
Pflanzenschutzamt
Wunstorfer Landstraße 9
30453 Hannover

Technical testing:

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