Periodic inspection of AX-1

Kilter

14. november 2025

Introduction

This document is based on ISO 16122-1:2024 and ISO 16122-2:2024, and it describes how Kilter's precision sprayer AX-1 can be tested during mandatory inspection. The document presents the user interface necessary for testing, discusses differences and similarities in how the machine can be tested compared to a traditional field sprayer (horizontal boom sprayer), and proposes relevant criteria to be applied to the machine.

Sprayer information

- **Make:** Kilter
- **Type:** Self-propelled (self-driving)
- **Sprayer type:** Horizontal boom sprayer
- **Category:**
- **Tank capacity:** 50L
- **Pump make:** Flojet
- **Pump type:** R3B21-501A
- **Pump capacity:** Flow @ 30 PSI (~ 2 bar) 8.70 LPM
- **Stirring:** Hydraulic
- **Spray boom working height:** Standard height: 0.15 m, allowed interval: 0.1-0.5 m
- **Spray boom number of sections:** 1
- **Nozzle spacing:** Center distance: 265 mm

- **Number of nozzles:** Standard: 5-6
- **Maximum capacity of one nozzle:** ≈0.05 Litre per minute.

User interface

The user interface on the AX-1 is primarily a software application available on mobile devices. Within this software, there is a dedicated control panel that provides the tester with all necessary information, settings, and sensor values. It is possible to grant a tester access to the machine for 24 hours in Kilter Farm.

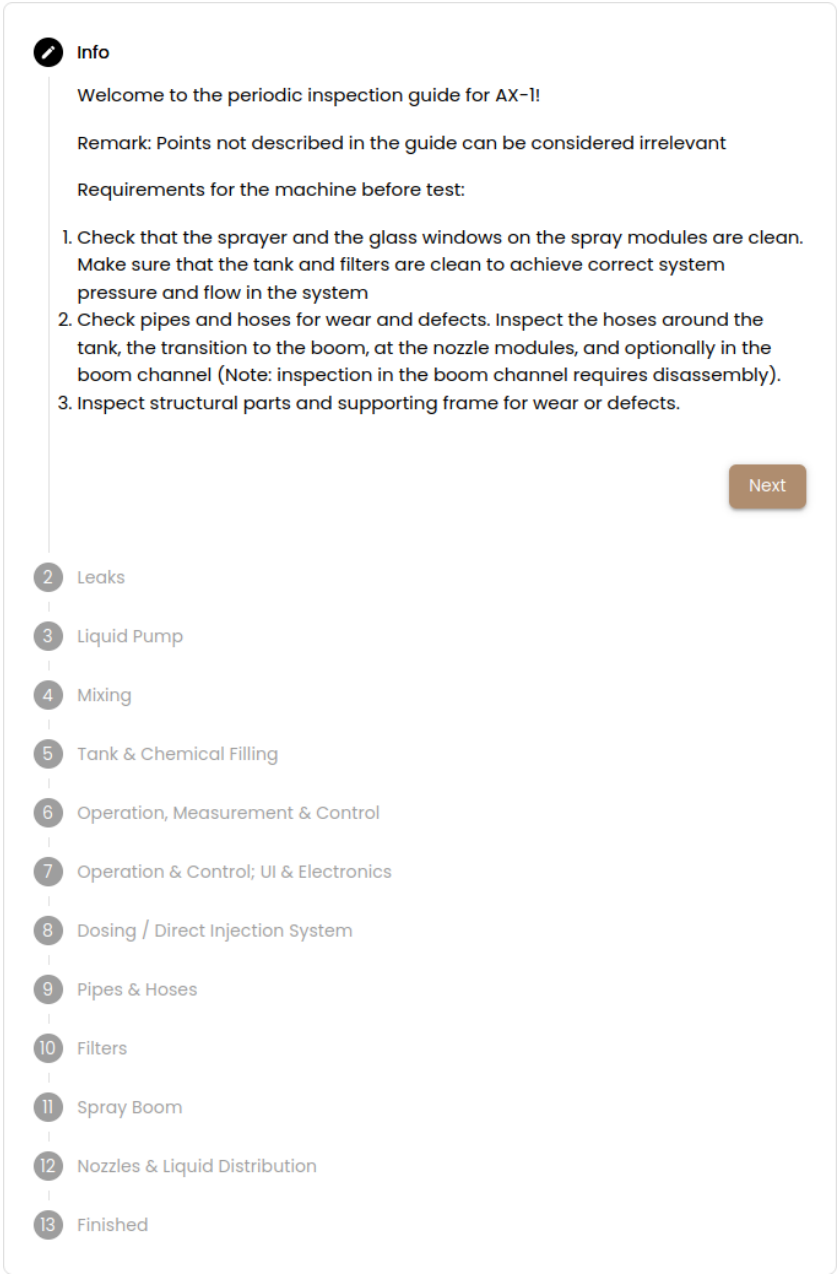


Fig. 1: User interface for periodic inspection of AX-1

1 Requirements for the Sprayer Before Testing

1.1. **The sprayer must be clean:** In addition to the common practice, it is very important that the filters are cleaned to ensure correct system pressure and flow. Check if the camera glasses are clean.

1.2. **Power transmission and shielding:** Not relevant.

1.3. **Moving parts – shielding and safety:** There are 3 wheels, boom, and 5 hinged covers among the moving parts.

1.4. **Pipes and hoses – wear or defects:** Hoses that are easily accessible/visible on the AX-1 are illustrated in Figure 2. Inspect the hoses around the tank, at the transition to the boom, at the nozzle modules, and possibly in the boom channel (cover must be removed).

1.5. **Structural components and load-bearing frame:** All load-bearing elements are easily visible. Two transverse beams, truss connecting them, boom lift, and wheel suspension.

1.6. **Safety valve is functional:** Check if installed. As of today, there is no mechanical safety valve on the machines.

1.7. **Foldable parts:** Not relevant.

1.8. **Fan – intact and functional:** Not relevant.

Fig. 2: Hoses visible on AX-1

2 Leaks

2.1. **Static leaks:** Fill the tank with water, open relevant covers to check for leaks.

2.2. Leakage (no spraying): Set valves to NORMAL OPERATION (there is a desctiption of valve positions inder the left cover, see figure 8b), turn on the pump, and press the MAXIMUM SYSTEM PRESSURE button (Figure 3) to set maximum system pressure. Wait until the pressure stabilizes. If there is no dripping underneath the machine, proceed to the next step.

2.3. Leakage (during spraying): Press NORMAL SYSTEM PRESSURE (Figure 3) to set the pump to working pressure. Then run NOZZLE PURGE, this will initiate a procedure that prepares all nozzle outlets. If this procedure is not run, it will affect droplet quality and precision. Monitor that all nozzle outlets are functioning. Make sure that they don't have leakages during or after the cleaning procedure has been completed. It is common for hanging droplets to occur on the nozzle outlets during the cleaning procedure. If the machine has been idle for a long time, it may be necessary to run the NOZZLE PURGE procedure multiple times.

2.4. Liquid spray and dripping on components: With the pump set to working pressure, press START SPRAYING. All nozzle outlets will now start generating droplets simultaneously. Perform a visual check of the spray. None of the machine's components should be hit by the liquid.
Note: some users might have poor water quality, and some additives might be necessary in order to obtain good droplet properties. If in doubt, continue until the last stage of the inspection, where the spray modules are tested thoroughly.

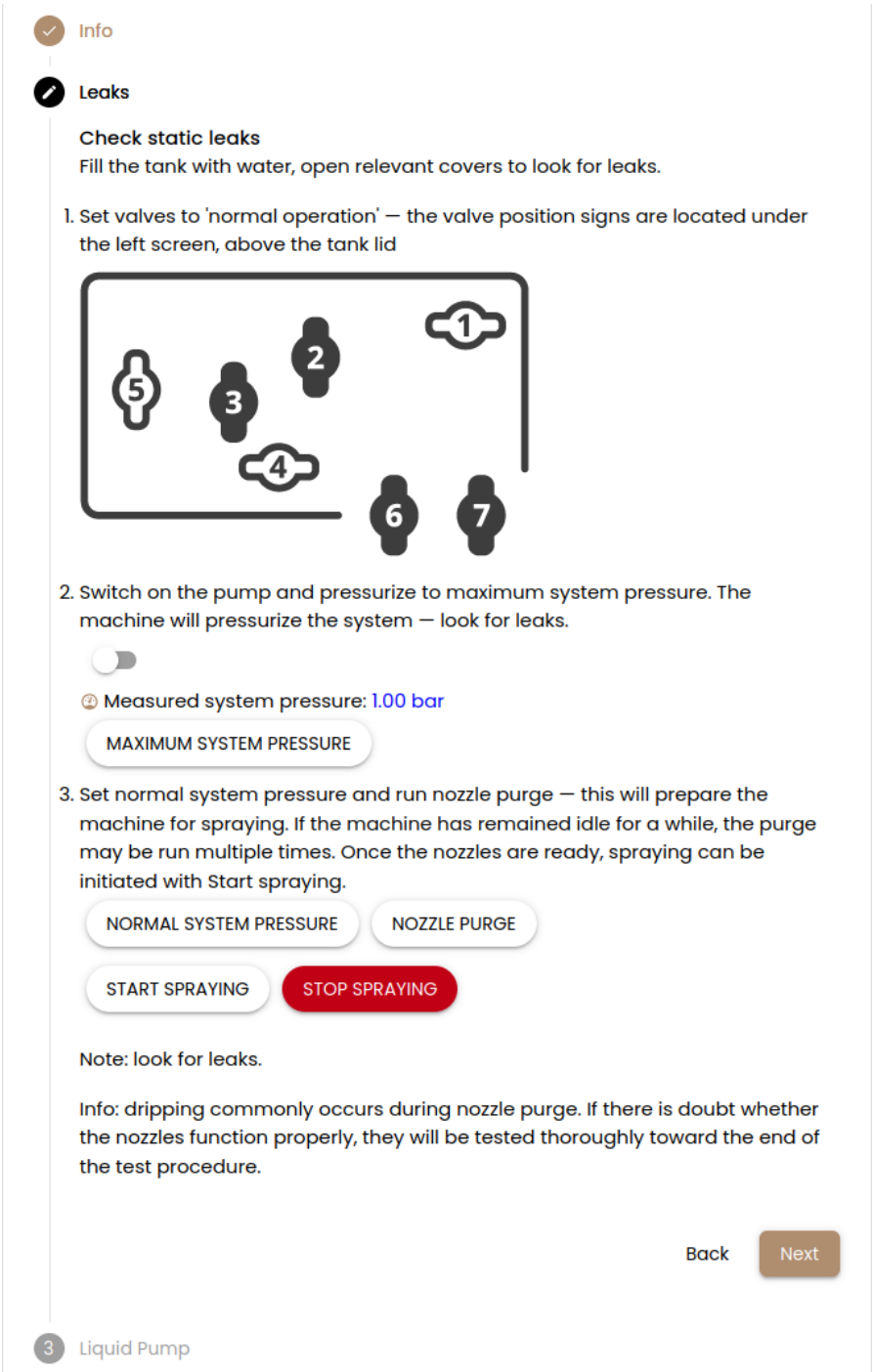


Fig. 3: User interface for testing leaks. The user interface allows the user to set the system pressure to its maximum allowed value, standard working pressure, and start spraying.

3 Liquid Pump

3.1. Pump Capacity: The recommendation is that the pump capacity should be at least 90% of the capacity when the pump was new. The AX-1 is designed in such a way that all liquid flows through the nozzles, only a small part is ejected, and most of it returns through the return hose.

- **Pump Capacity Required for Nozzles:** Not relevant, only the pumps remaining capacity is of relevance for the machine.
- **Measured Pump Capacity:** The pump is equipped with a quick coupling. Disconnect it on the high-pressure side of the pump and connect measurement equipment. When testing the pump, press the START FULL PUMP OUTPUT button to run the pump at maximum power (Figure 4), measure the pump capacity as usual. It is important that the machine is connected to electricity (The generator is on, or a 230V power outlet might be used) for the pump to operate at maximum power.
- **Maximum Capacity for a Nozzle:** Not relevant.
- **Minimum Agitation:** If the system is clean, the pump is functioning properly, and there have been no clogging/damage in the system, the flow in the return hose should be approximately 3.5-4 L/min at 1 bar working pressure. The minimum requirement is 2.5 L/min, and it should be satisfied in the whole working pressure range. If the pump capacity is checked, a criterion for pump operation and system pressure is implemented in the graphical interface which can check if the flow rate is sufficient (figure 5). Alternatively, the flow in the return hose can be measured.
- **Available Agitation Capacity:** Not relevant.

3.2. Pulsation: Pulsation should not exceed 10% of the working pressure.

3.3. Air Chamber: Not relevant.

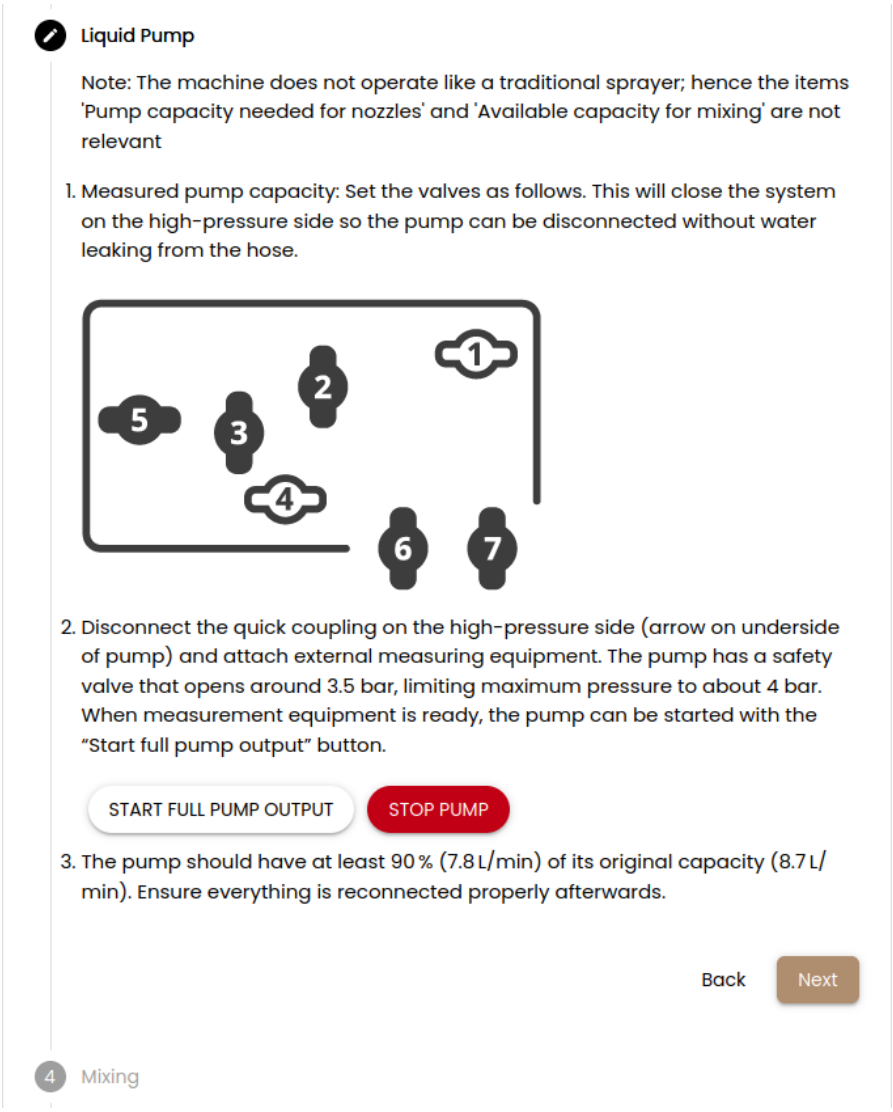


Fig. 4: User interface for liquid pump. The user interface explains how to connect the pump to the measurement equipment, and allows to run the pump at maximum power in order to assess its performance.

4 Agitation

4.1. Agitation: This is discussed in point **3.1.** since there is a connection between system pressure and agitation. In principle, the flow in the return hose should be between 2.5-4 L/min throughout the working pressure interval, relatively unaffected by the number of shots from the nozzles.

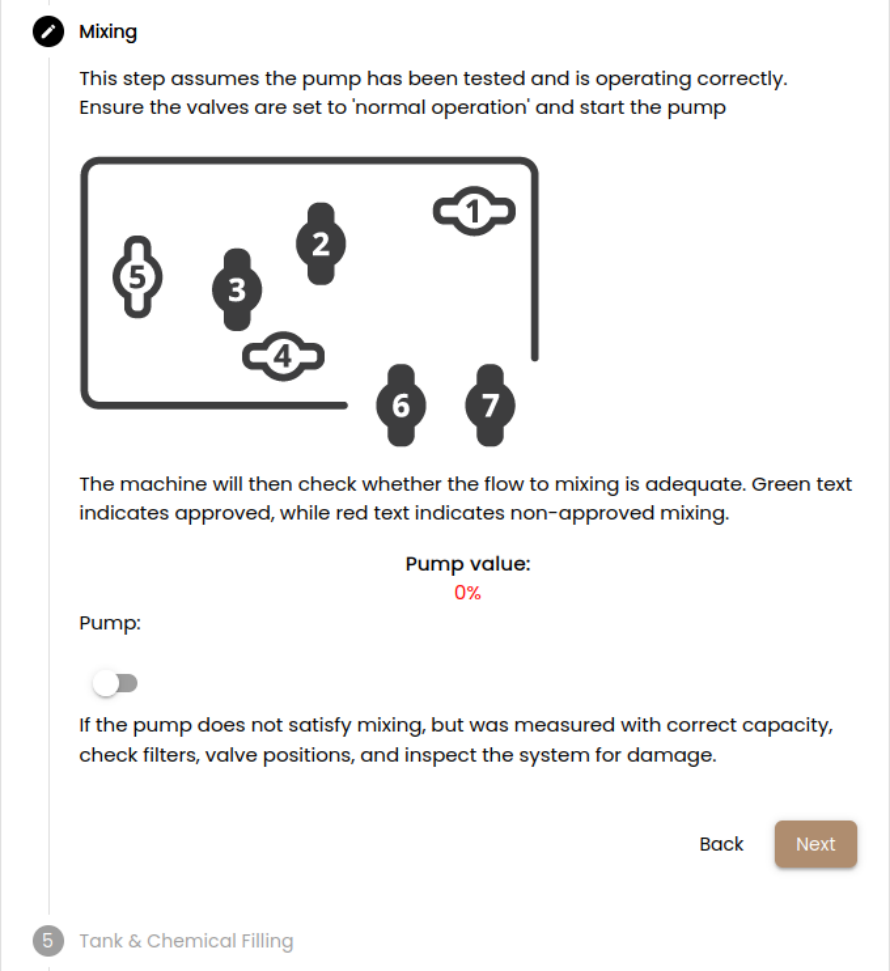


Fig. 5: User interface for agitation. After the pump is tested, the machine can run a self test to verify if the circulation is sufficient.

5 Spray Tank

5.1. Lid: Remove the lid and inspect the gasket on the tank. The lid is equipped with a breather valve.

5.2. Filling port: The strainer is located under the lid. It can be removed for inspection if necessary.

5.3. Induction hopper: Not applicable.

5.4. Pressure compensation: Visually inspect the breather valve located in the lid.

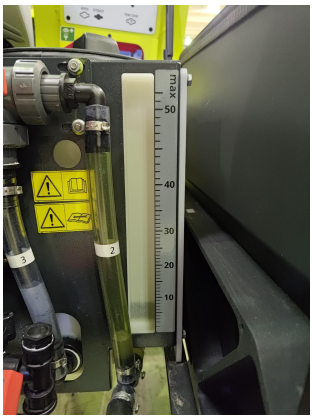
5.5. Tank content indicator: The machine is equipped with two liquid level indicators, a physical scale on the side of the tank (Figure 6a), and a digital variant where the value is read in the user interface (Figure 7).

5.6. **Tank emptying:** There are primarily two ways to drain the system. The first is valve number 7 (to the right in Figure 6b) which opens a hose from the drain on the pesticide tank. This valve only drains the tank, and there may be liquid in the system. The other way is to open valve no. 6 (to the left in Figure 6b) which opens the high-pressure side of the system. If the pump is running, it will pump the liquid from the tank, through the system, and out through the drainage point. When the tank is empty, the pump will pump air into the system, allowing most of the liquid to be removed from the system.

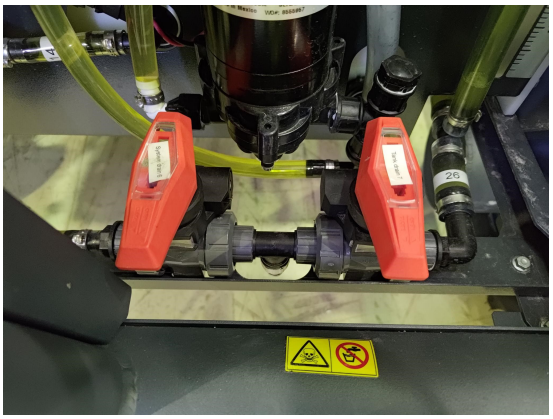
5.7. **Non-return valve:** Not applicable.

5.8. **Cleaning equipment for chemical filler:** Not relevant.

5.9. **Cleaning equipment and tank rinsing:** There is a washing nozzle installed in the tank. This can be inspected by removing the lid and the strainer. It should spin freely and not be clogged.



(a) Visual liquid level indicator



(b) Valves for emptying of the tank

Fig. 6

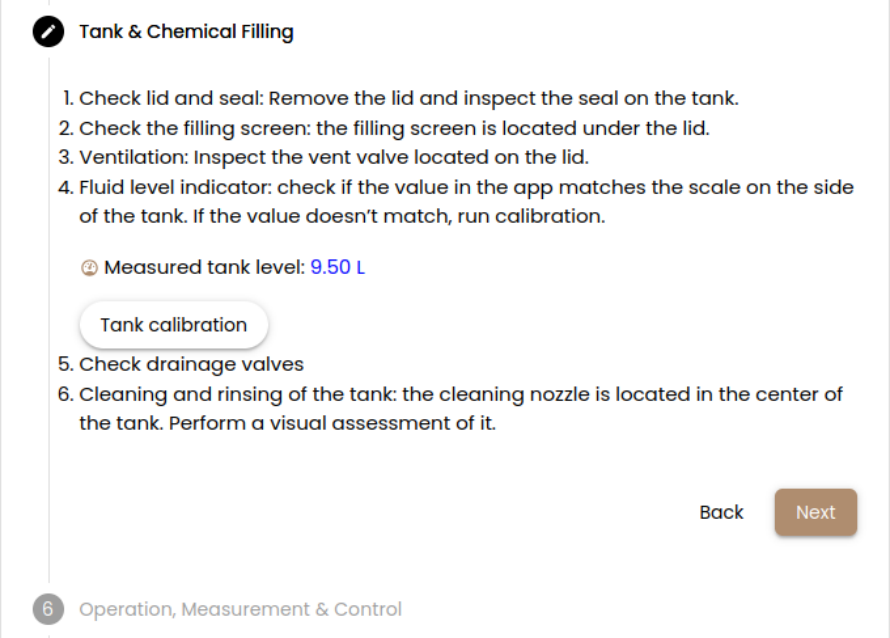


Fig. 7: User interface for herbicide tank. It describes information necessary to check the tank, and allows for calibration of the digital level measurement.

6 Measuring Systems, Controls and Regulation Systems

6.1. Pressure gauge – readability, size, and scale: The main instrument for pressure measurement is a digital pressure sensor. This is the basis for the machine, and the values can be read in the user interface (figure 9).

6.2. Pressure gauge – accuracy and stability: See point **6.1.**. The accuracy for field sprayers is 0.2 bar for pressures under 2 bar. We suggest having stricter requirements, as the working pressure is relatively low, and propose a limit of 0.1 bar for AX-1.

6.3. Control valves and operation: The machine is equipped with control valves on the front of the pesticide tank, see Figure 8a. The left panel of the machine contains a diagram showing the position of the various valves depending on the operation the user wants to perform (Figure 8b).

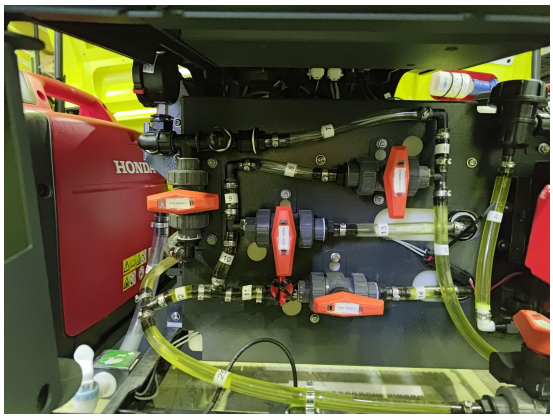
6.4. Pressure regulating valve: Not applicable. The machine regulate their pressure through pump power.

6.5. Injection system: Not relevant.

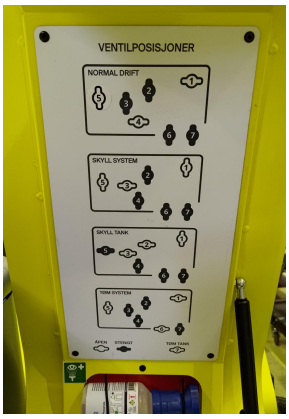
6.6. Flow meter – accuracy: Not relevant.

6.7. Speed sensor – accuracy: The machine needs 2 meters of space to perform this test. There must be liquid in the system. Press the START VELOCITY TEST procedure (Figure 9). The machine will start by running the nozzle preparation procedure, once completed, it will start moving forward. As it reaches the correct speed, it will eject 200 droplets from

all nozzle outlets. The centre distance between the first and last row of droplets should then be 120 cm with an allowable error margin of 2.5% (3 cm).



(a) Control valves



(b) Control valve positions

Fig. 8: Control valves and operation

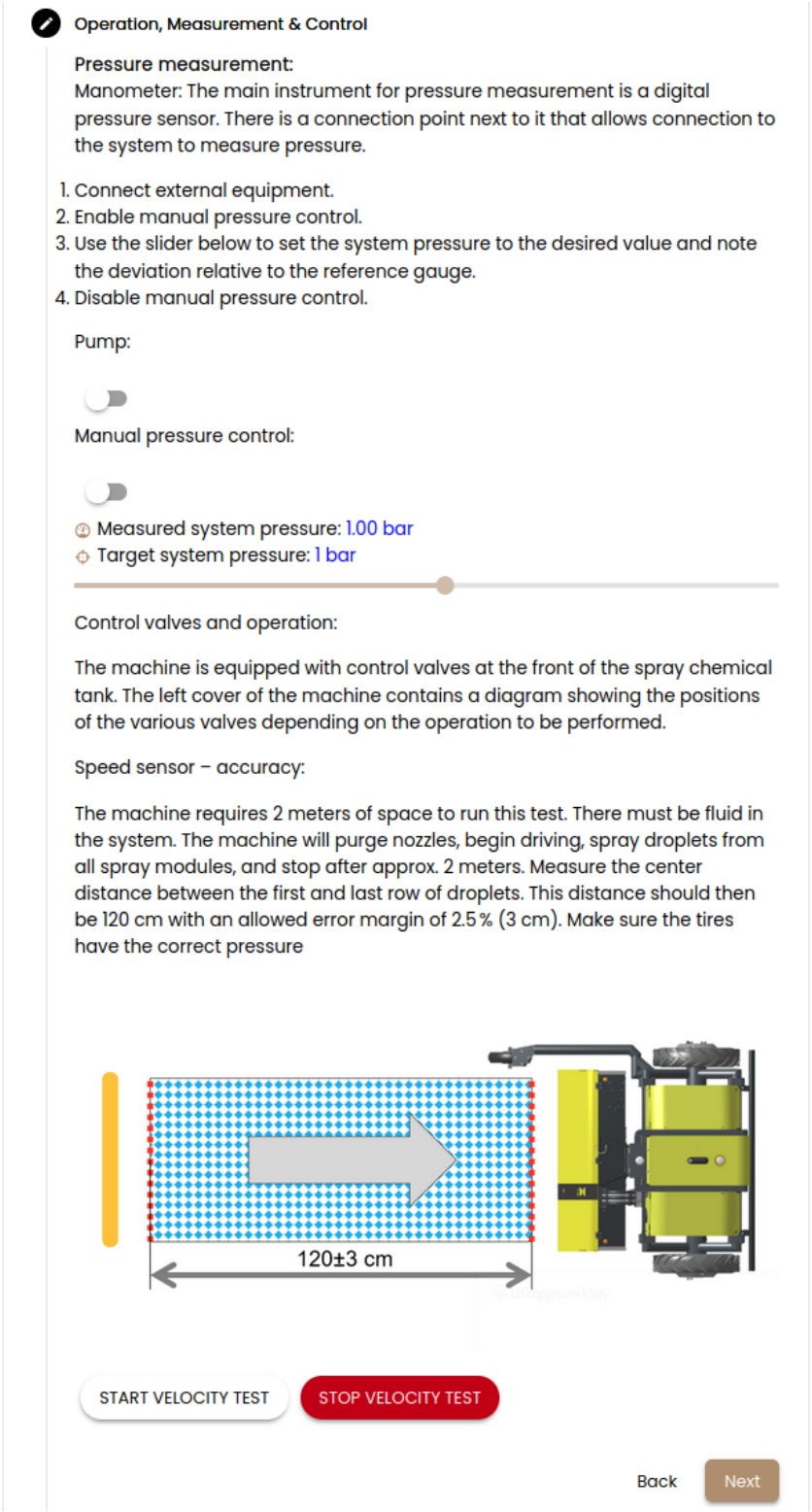


Fig. 9: User interface for Measuring Systems, Controls and Regulation Systems. It is described how to check the pressure sensor, and velocity sensor.

7 Operation and Control; User Interface and Electronics

Electronics considered most relevant for testing with the aim of achieving the best possible spraying result includes the image capture system, pressure sensors, height sensors, machine speed, and nozzle performance. Most of these are tested in other parts of this document, except for the image capture system, hence, it is described here.

7.1. Test camera system: Check if the camera glass covers are clean. The image from the nozzle modules can be evaluated in the software (see Figure 10). Check if the flash works when taking pictures.

7.2. User interface: The user's hardware running the user interface software (mobile phone/tablet, etc.) should be in good condition.

7.3. Self-check, error messages: The machine returns error messages if something is not working correctly. Check if any error messages have occurred and if they are of relevance. They are listed in the control panel of the user interface.

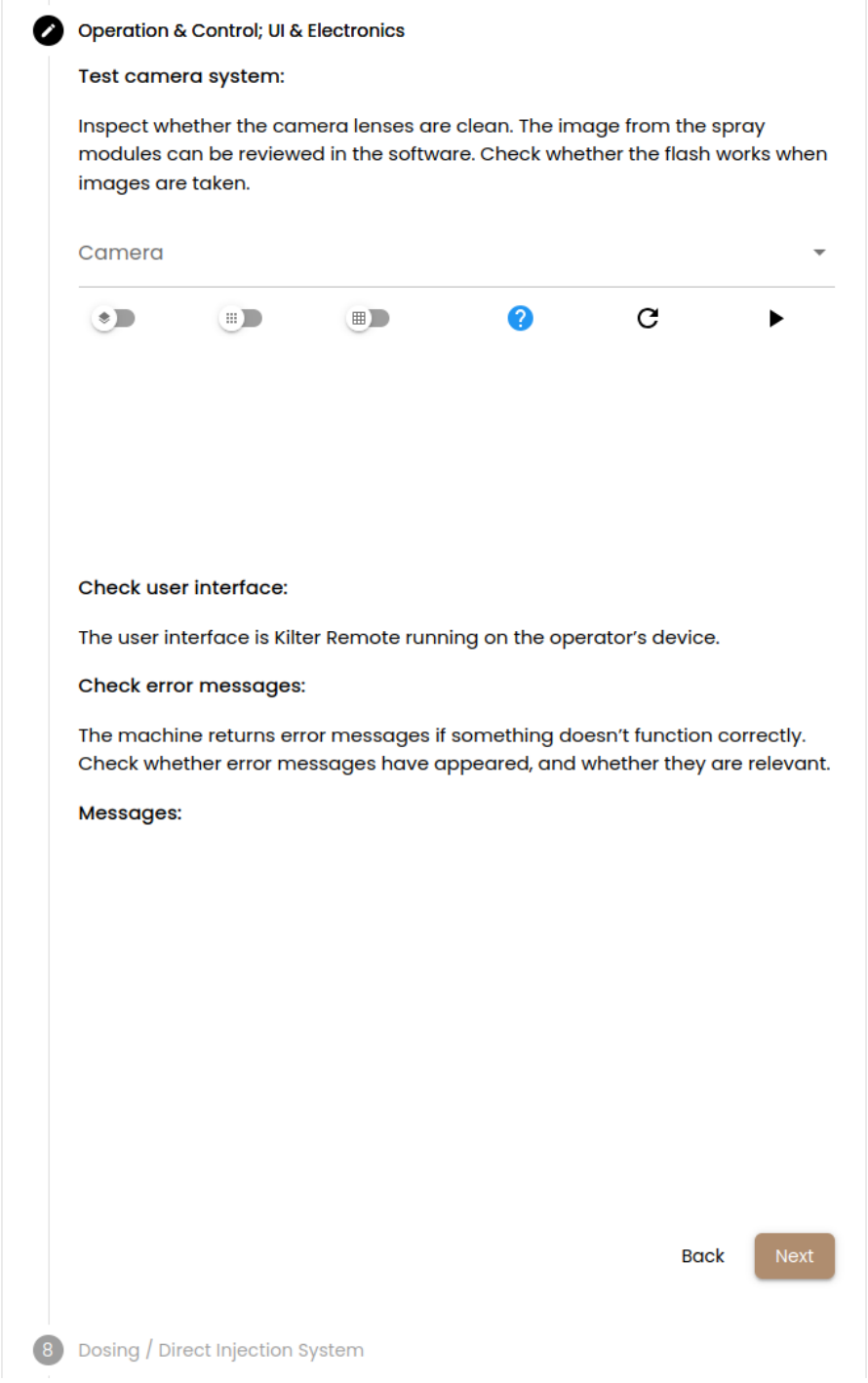


Fig. 10: User interface for Operation and Control.

8 Dosage / Direct Injection System

8.1. Leakage of water or chemicals: Not applicable.

8.2. Backflow of water or chemicals: Not applicable.

8.3. Mixing function: Not applicable.

8.4. Accuracy: Not applicable.

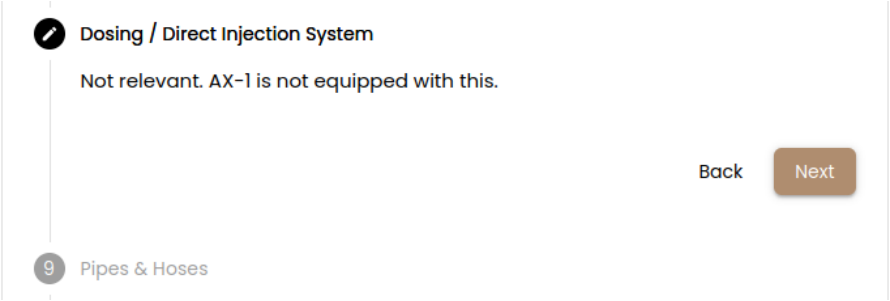


Fig. 11: User interface for control of dosage systems. Not relevant as automatic dosing systems are not present on AX-1.

9 Pipes and Hoses

- **Wear, damage, bending/kinking, and assembly:** Inspect hoses in front and on the side of the tank, the transition to the spray boom, and the spray modules. If necessary, the cover on the side of the boom can be removed to inspect the hoses hidden in the boom channel. See Figure 2.

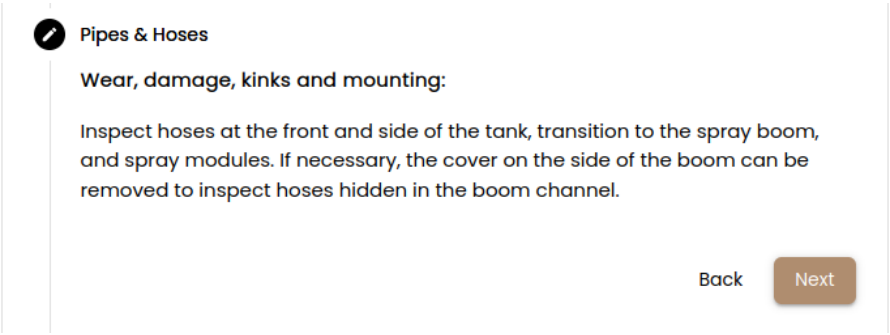


Fig. 12: User interface for checking hoses and pipes.

10 Filters (condition, relevant mesh size, function)

10.1. Filter on suction side: AX-1 is equipped with a main filter on the suction side, which also has a magnet to capture metallic particles. See Figure 13a.

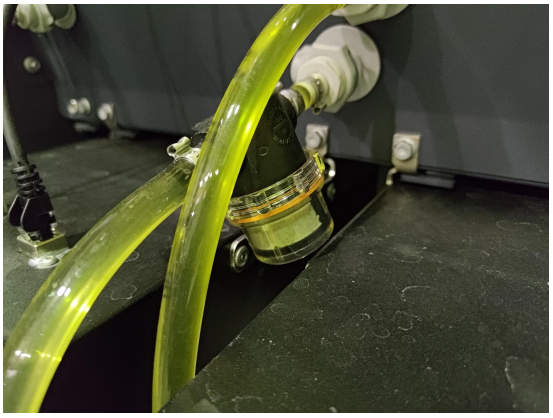
10.2. Self-cleaning filter: Not relevant.

10.3. **Central pressure filter:** Not relevant.

10.4. **Section filters:** Each nozzle module has its own filter on the high-pressure side. These are mounted after the last connector before the nozzle outlets. It is possible to disassemble the filter while there is liquid in the system, but both hoses to the nozzle module must be disconnected, in order to stop the fluid from leaking. Be aware that some liquid may come out when the filter cup is opened. Ensure that no liquid comes into contact with the cable connectors on the top of the spray modules.

10.5. **Nozzle filters:** Not relevant.

(a) Main filter on the suction side



(b) Nozzle module filters on the high pressure side

Fig. 13: Filters on AX-1

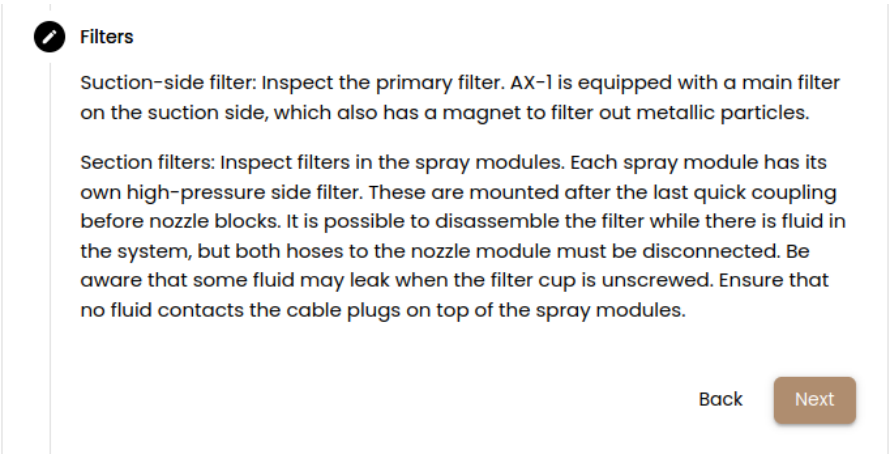


Fig. 14: User interface for inspection of filters.

11 Spray Boom

11.1. **Stability and symmetry:** Evaluated visually. Have there been any significant changes to the boom? Inspect the boom for mechanical damages that may affect its integrity. Does

the lift function as it should? Lift control is available in the user interface (see Figure 15).

11.2. Automatic resetting: Not applicable.

11.3. Nozzle positioning – spacing and direction: The nozzles are mounted with a center-to-center distance of 265 mm (error margin for classical sprayers is 5%). There are no adjustment options, only some slack in the mounting holes, but the positioning is fixed. The nozzle modules should be aligned unless mechanical damage has occurred.

11.4. Boom deformation – vertical and horizontal plane: If the ground is plane and levelled, and the tire pressure is correct, a spirit level can be placed on the boom to examine its vertical deformation. Criteria for classical field sprayers are not sufficient here (maximum value of 0.5% of the working width or 10 cm when measuring between nozzles and a horizontal reference). Due to the low working width, we suggest a criterion of 2 cm as an allowable margin.

11.5. Nozzle protection: Inspect the protection plates on the nozzle modules for mechanical damage.

11.6. Boom height adjustment: Each nozzle module is equipped with a height sensor. The boom takes the average of the measurements and adjusts the height to the reference value. The sensor is calibrated for 15 cm from the nozzle outlet to the ground/weeds. Place the machine on a flat surface, turn on automatic boom height adjustment (Figure 15), and measure the distance from a nozzle outlet in the centre of the boom to the ground. Since it is impractical to measure the distance between the ground and the nozzle outlets, the distance to the top of the spray module can be measured instead, as illustrated in Figure 16b. The distance measured to the top is 25.5 cm greater than the value measured to the nozzle outlets. Compare this with the value shown in the app. On a flat surface, the distance should be within 1 cm of the desired value (Figure 16). If this is not the case, a calibration must be performed.

11.7. Damping and tilt compensation: Not applicable.

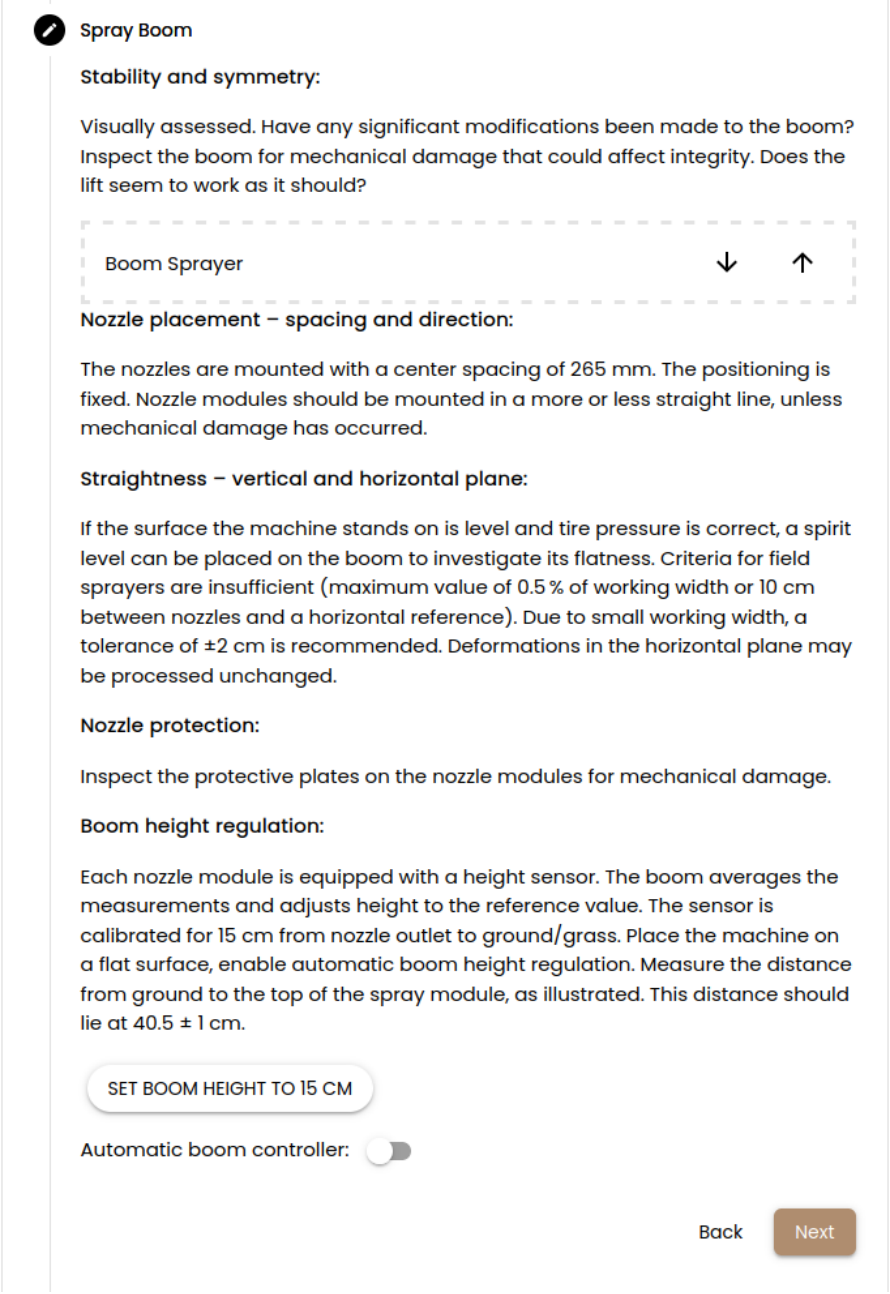


Fig. 15: User interface for the boom. It allows the user to set the boom height and perform calibration of height sensors.

(a) Distance to nozzle outlets

(b) Distance to the top of the nozzle module

Fig. 16: Assessment of boom height

12 Nozzles and Liquid Distribution

At this stage in the test, in order to properly asses the performance of the nozzles, proper adjuvants or herbicides which are typically used with the machine, should be used. 4 liters should be sufficient.

12.1. Nozzle types and nozzle filters identical: Each nozzle is marked with a product number. All nozzles should have the same number, unless otherwise specified by the manufacturer.

12.2. Nozzle fixation: Nozzle modules have a non-adjustable fixation, and unless there are mechanical damages, it should not be possible to mount them incorrectly.

12.3. Drip protection: Press the START SPRAYING (see Figure 17), and let it run for 10-20 seconds. After it stops, there should be no dripping or leakage.

12.4. Pressure distribution: There is only one section on AX-1, but the pressure between nozzles can be checked if nozzles are malfunctioning. Set the boom height to 15 cm and connect a control pressure gauge between the boom and the connector on the hose with a filter. If the nozzles are equipped with pressure sensors, they can be checked against the control pressure gauge. Measure the pressure in each of the nozzle modules and compare it with the working pressure; the nozzle pressure should be within 10% of the pressure measured by the main pressure sensor, even if all nozzles are shooting at full capacity (with automatic pressure regulation activated).

12.5. Pressure drop – Use a control nozzle when measuring pressure drop: Not applicable.

12.6. Visual check of spray patterns: Run NOZZLE PURGE, wait until the machine is ready, start spraying with START SPRAYING, check if all nozzle outlets are spraying, if there are no hanging droplets, assess the spray pattern for anomalies.

12.7. **Condition:** Perform visual inspection.

12.8. **Functionality:** Perform visual inspection.

12.9. **Adjustment options:** Controlled by the software.

12.10. **Liquid distribution:** Kilter's specially designed measuring beaker (Figure 18) is a 2-in-1 tool.

The lower section (figure 18a) consists of 42 measuring cups. The dashed line in the middle of the scale marks a volume of 1 mL. Each solid line represents a deviation of 50% from the reference value. This section is used to assess the distribution of a spray module. Each nozzle outlet typically fires 1 000 shots, so a volume of 1 mL corresponds to a droplet volume of 0.001 mL or 1µL.

The upper section (figure 18b) of the tool is used to measure the nozzle module's average droplet size and thereby the area dosage. Normally, each outlet fires 3,000 droplets, and the dashed line corresponds to a droplet size of 1 µL, with allowed deviation of 15% (solid lines).

Procedure:

- Place the machine on a flat surface and set the boom height to 40 cm.
- Run NOZZLE PURGE.
- Attach the measuring beakers to all nozzle modules. See Figure 18a.
- Start the RUN VARIANCE COEFFICIENT TEST.
- Once the machine finishes firing, check if all values are within the two solid lines.
- Without emptying the beaker, run the RUN AREA DOSAGE TEST.
- Once again check if the fluid level is within the two upper solid lines.
- DROPLET CALIBRATION allows to adjust the ejected volume.

12.11. **Camera-nozzle calibration:** There are no specific requirements or guidelines for calibrating precision sprayers, but Kilter strongly recommends testing camera-nozzle calibration to assess whether the droplets hit the intended target. This can be done by pressing the NOZZLE CALIBRATION button.

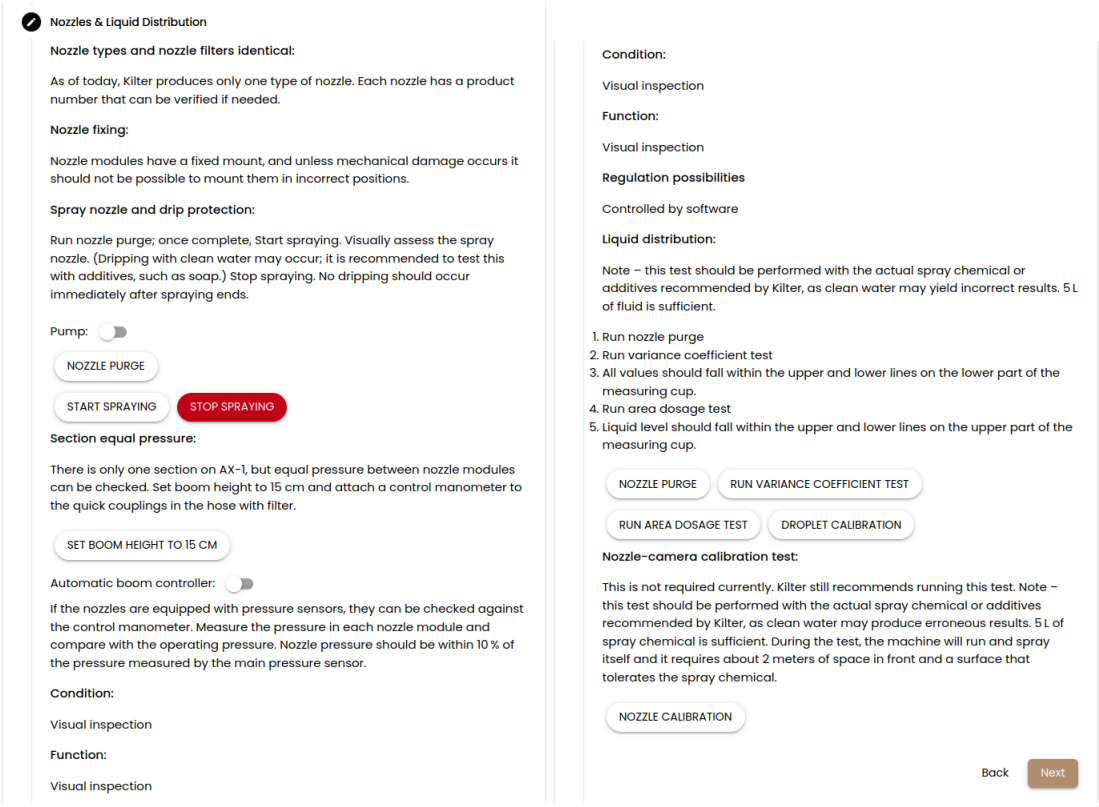
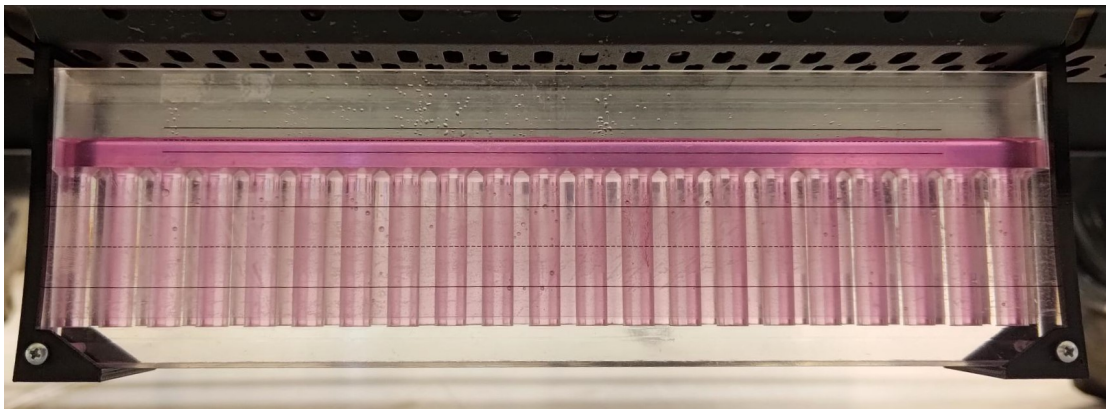


Fig. 17: User interface for nozzle testing

(a) Test of the coefficient of variation



(b) Test of areal dosage

Fig. 18: Spray distribution test