# MICROMISER 12 & 16 ATOMISERS FOR USE ON UAVs

## Operator's Handbook

## and

## Parts Catalogue

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# 1. INTRODUCTION

Micronair Micromiser atomisers can be installed on Unmanned Aerial Vehicles (UAVs) to spray a wide range of liquids in droplets of precisely controlled size. Applications include spraying of agricultural crops, migrant pests (locusts etc) and mosquito control using adulticides or liquid larvicides.

Micromiser atomisers are intended for Ultra Low Volume (ULV) and Low Volume (LV) applications.

Spray droplets are produced by a rotating toothed disc. Droplet size is determined by the rotational speed of the disc, which is driven by a 24 V DC brushless motor for maximum reliability.

Unlike hydraulic spray nozzles, the atomiser does not require a high liquid pressure to operate and there are no small internal orifices to block. This allows the atomiser to handle viscous materials and liquids with a high solids content.

Each atomiser can operate at flow rates of up to 300 ml/min, with the minimum flow rate determined only by the liquid delivery system used.

The brushless motor has integrated drive electronics and requires only a 24 V DC supply to operate. A pulse output is provided for the measurement of disc speed or for monitoring of atomiser performance.

The atomiser is available in two versions:

**Micromiser 12** with rotational speed variable over the range of 1,500 – 12,000 RPM to produce spray droplets of 60 – 300 µm VMD. This atomiser should be used for application on crops and ground targets. The atomiser motor incorporates closed-loop speed control to ensure constant rotational speed regardless of liquid flow rate. The rotational speed is set by means of an external potentiometer or voltage input. This allows the spray droplet size to be pre-set or varied by a customer provided control system.

**Micromiser 16** with a fixed rotational speed of 15,000 – 16,000 RPM to produce small spray droplets of 45 – 60 µm VMD. This atomiser should be used for space spraying application of insecticides to control flying insects such as mosquitoes

## 2. SPECIFICATION

| | |
|---|---|
| Dimensions: | Length 105 mm (including atomiser disc but excluding connector), diameter 58 mm (max), 32 mm (motor housing) |
| Weight: | 240 g |
| Mounting: | By two M4 tapped holes |
| Liquid feed connection: | Push-in fitting for 6 mm O/D rigid plastic tube |
| Vent connection: | Push-in fitting for 3 mm O/D rigid plastic tube |
| Electrical connection: | 4 pin M12 sealed connector (A-coding) |
| Environmental protection: | IP65 (with motor vent tube connected) |
| Ambient temperature: | -10 – +40 ºC nominal (minimum temperature must not be below freezing point of liquid being sprayed) |
| Input voltage: | 24 V DC |
| Power consumption: | 1.5 – 10 W (dependant upon disc speed and liquid flow rate) |
| Motor rating: | Continuous |
| Disc speed: | Micromiser 12: adjustable 1,500 – 12,000 RPM<br>Micromiser 16: fixed 15,000 – 16,000 RPM |
| Speed output: | 5 V pulse output (one pulse/disc revolution) |
| Spray droplet size: | Micromiser 12: 60 – 300 µm VMD<br>Micromiser 16: 45 – 60 µm VMD<br>(dependant upon disc speed & liquid properties) |
| Liquid flow rate: | 0 – 300 ml/minute |

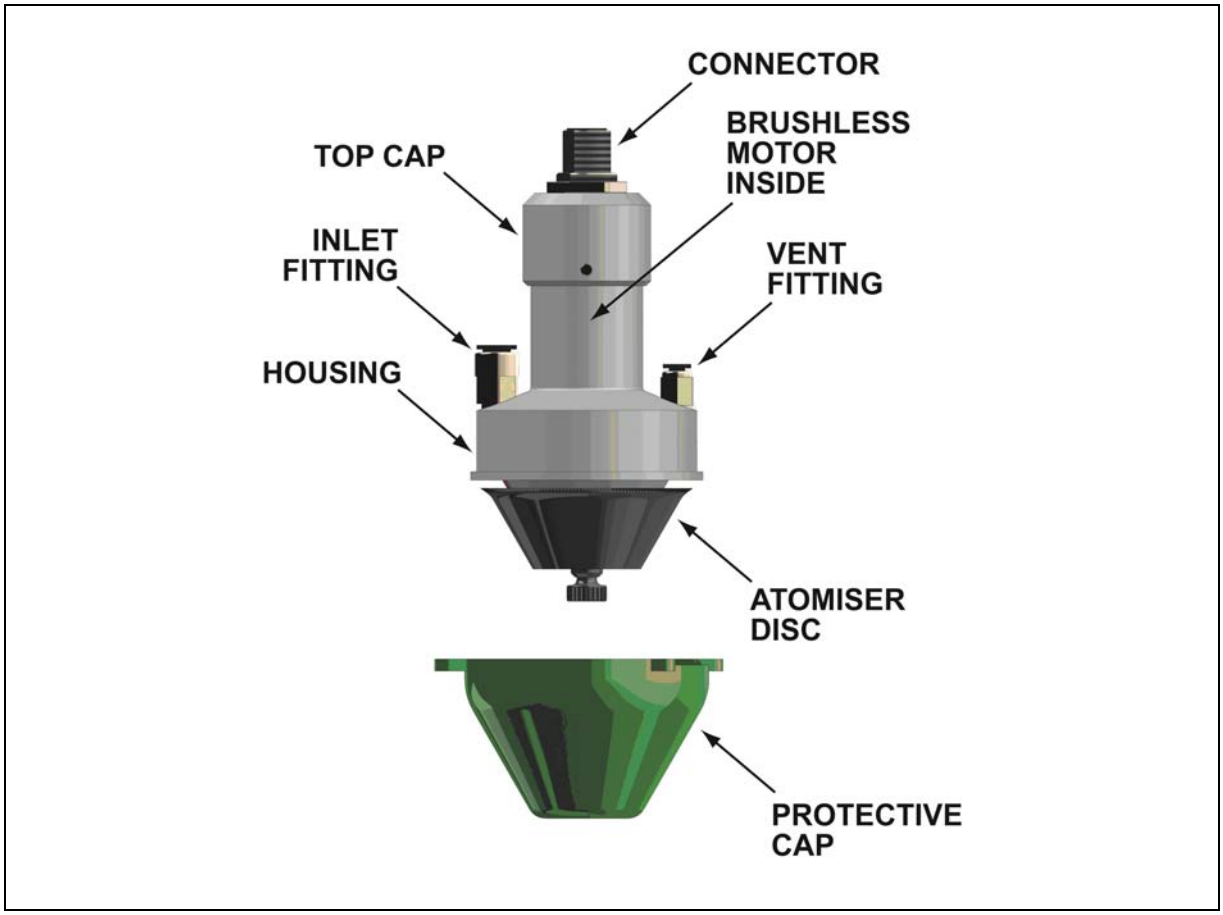



*Fig 1. – Micromiser Atomiser*

*Fig 2. – Micromiser Atomisers on Multi-rotor UAV*

# 3. INSTALLATION

## 3.1. Atomiser

Many different configurations of UAV (multi-rotor, fixed-wing etc) can be used for aerial spraying. The following points provide general guidance on the installation of Micromiser atomisers but are not intended to make specific recommendations. It is the responsibility of the installer to establish the optimum placement of atomisers and to carry out trials to assess the spray distribution on the target.

- Atomisers are normally mounted on booms extending laterally from the structure of a multi-rotor UAV or below and slightly behind the trailing edge of a fixed-wing UAV.
- Each atomiser should be attached to a mounting bracket on the boom with two M4 screws in the tapped holes in the side of the atomiser housing (25 mm between hole centres) as shown in Fig. 3. M4 x 12 mm stainless steel cap head screws are supplied with the atomiser and these are suitable for a bracket with a thickness of 2 – 6 mm. If alternative screws are used these should also be stainless steel.
- The boom structure and bracket must be sufficiently rigid to avoid excessive vibration in flight.
- The booms must be positioned to provide adequate clearance under the atomisers whilst the UAV is resting on the ground or manoeuvring during take-off or landing. If necessary, the booms should have sufficient dihedral angle to maintain ground clearance.
- The orientation of the atomisers depends upon the direction and speed of flight of the UAV. In the case of a fixed-wing UAV or a multi-rotor UAV that flies in only one direction and sprays at a relatively high airspeed (>10 km/hr) the atomisers should be mounted with the axis of the motor horizontal with the disc at the rear. This is similar to the installation of rotary atomisers on conventional agricultural aircraft and helicopters. In the case of a UAV that reverses its direction of flight (relative to the airframe) at the end of each spray run or a UAV that will spray at low airspeeds the atomisers should be mounted with the axis of the motor vertical with the disc downwards.

## 3.2. Liquid Feed

The liquid feed to the atomiser is by a tube connected to the inlet fitting on the face of the housing as shown in Fig. 3. The standard fitting supplied with the atomiser is a push-fit type that accepts a 6 mm outside diameter flexible tube. If required, this fitting can be replaced with an alternative type with a M5 male thread to screw into the atomiser housing.

Spray liquid is fed to the atomiser by means of a pump provided by the installer. This can either be a positive displacement type (eg a gear pump) with a speed controller to adjust the output to provide the required total flow rate or a centrifugal or diaphragm type with a flow control valve. It is recommended that the flow control valve should be fitted in a by-pass line to return excess flow from the pump to the tank.

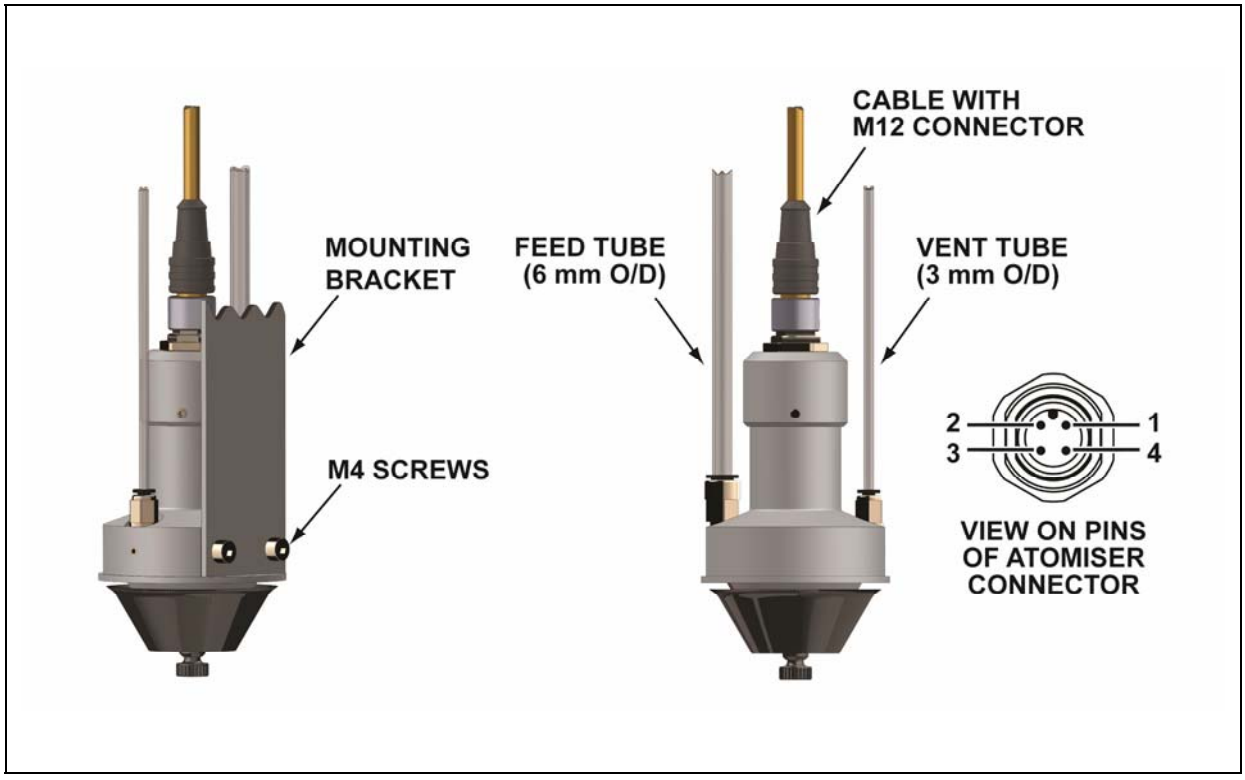
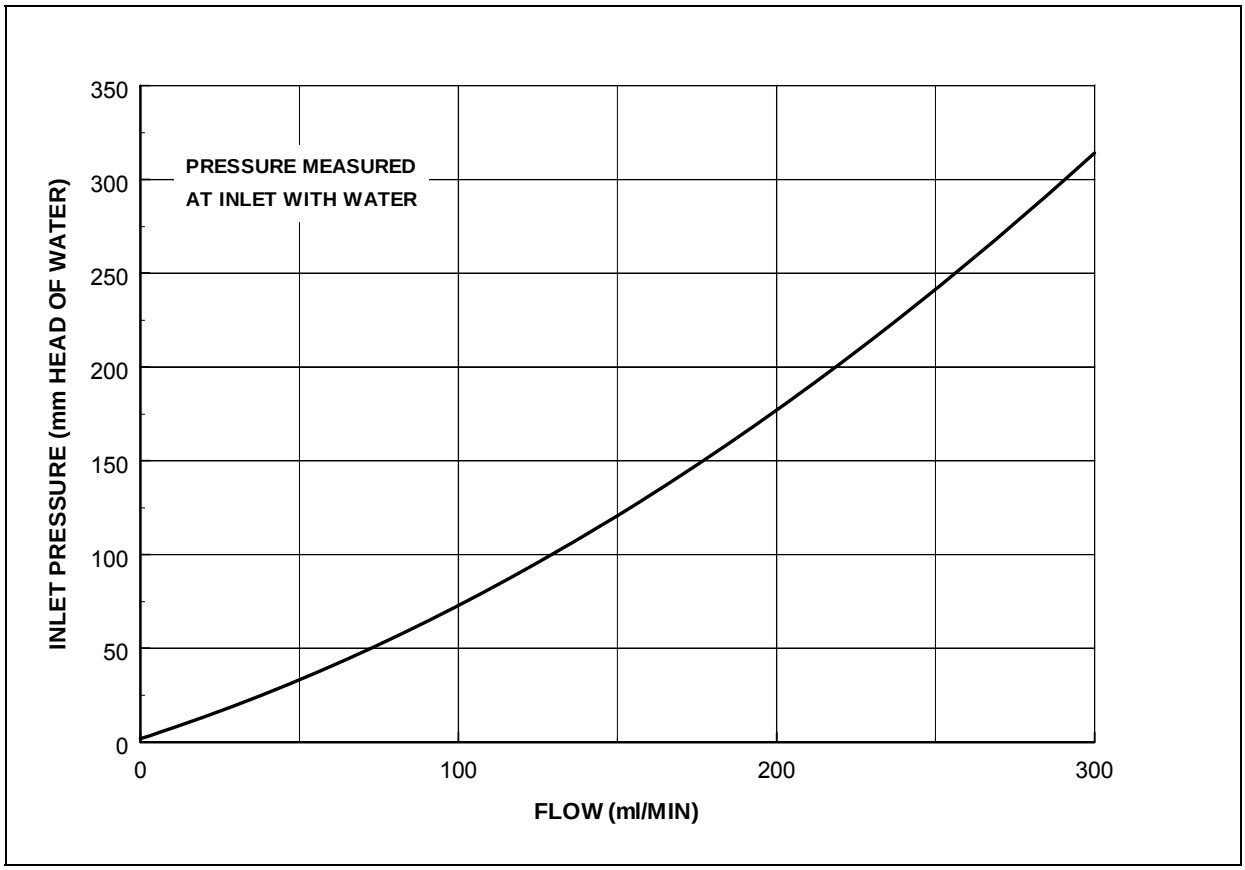



*Fig. 3 – Mounting of Atomiser and Connections*




*Graph 1 – Inlet Pressure vs Flow Rate*

As there are no small orifices in the atomiser, the liquid pressure required at the atomiser inlet is very low – see Graph 1. If multiple atomisers are installed It is recommended that a restrictor orifice should be fitted in the feed line to each to create some back-pressure and to balance the flow between atomisers.

The system should incorporate a filter before the inlet to the pump to reduce the risk of blockages, particularly if restrictor orifices are installed.

## 3.3. Motor Venting

In order to avoid condensation inside the motor, the atomiser is fitted with a vent port that must be connected to a tube that can supply air from an area away from spray droplets – see Fig. 3. The standard vent fitting supplied with the atomiser is a push-fit type that accepts a 3 mm outside diameter flexible tube. If required, this fitting can be replaced with an alternative type with a M5 male thread to screw into the atomiser housing.

The rotation of the atomiser disc creates a small negative pressure inside the motor housing and this is sufficient to draw air into the vent port. The tube must run upwards throughout its length so as to avoid any loops that could trap moisture – see Fig. 4. On a multi-rotor UAV the vent tubes should be run to a point towards the top of the airframe. On a fixed-wing UAV the tubes should run forwards to a point clear of the spray boom. If necessary, the open ends of the tubes should be under a cover to prevent ingress of water from rain or washing.

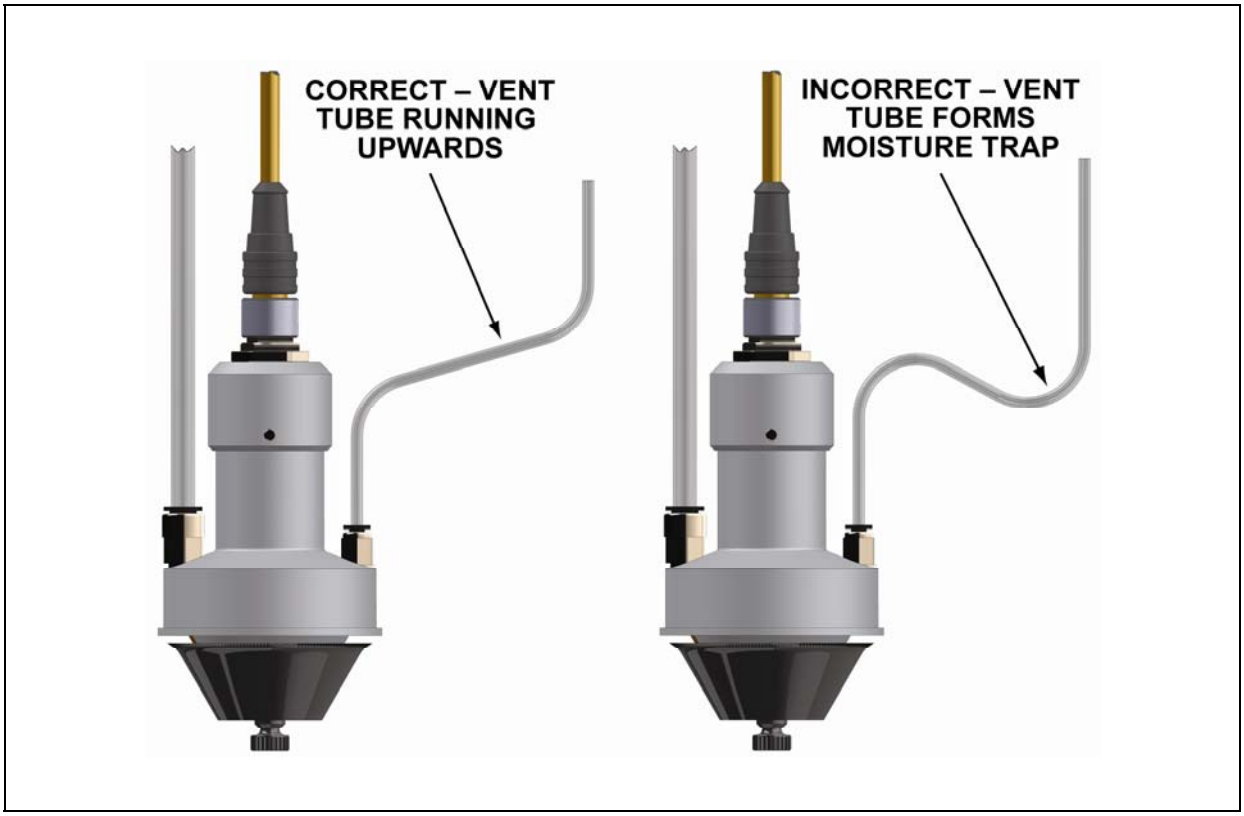



*Fig. 4 – Orientation of Atomiser Vent Tube*

## 3.4. Electrical Connections

The atomiser is fitted with a sealed 4 pin male M12 connector (A-coding). Pin numbers are as shown in Fig. 3 and pin assignments are as follows:

| Pin Number | Wire Colour* | Function |
|---|---|---|
| 1 | Brown | +24 V DC supply |
| 2 | White | Tacho (RPM) pulse output |
| 3 | Blue | Ground |
| 4 | Black | Speed control input (Micromiser 12 only) |

*When using standard moulded cable

It is recommended that the cable with moulded connector supplied with the atomiser should be used to prevent moisture ingress. If an alternative re-wireable connector is used it must be filled with non-corrosive silicone rubber compound.

The cable used to connect the atomiser to the power supply or controller should have a minimum conductor size of 0.33 $mm^2$ (22 AWG).

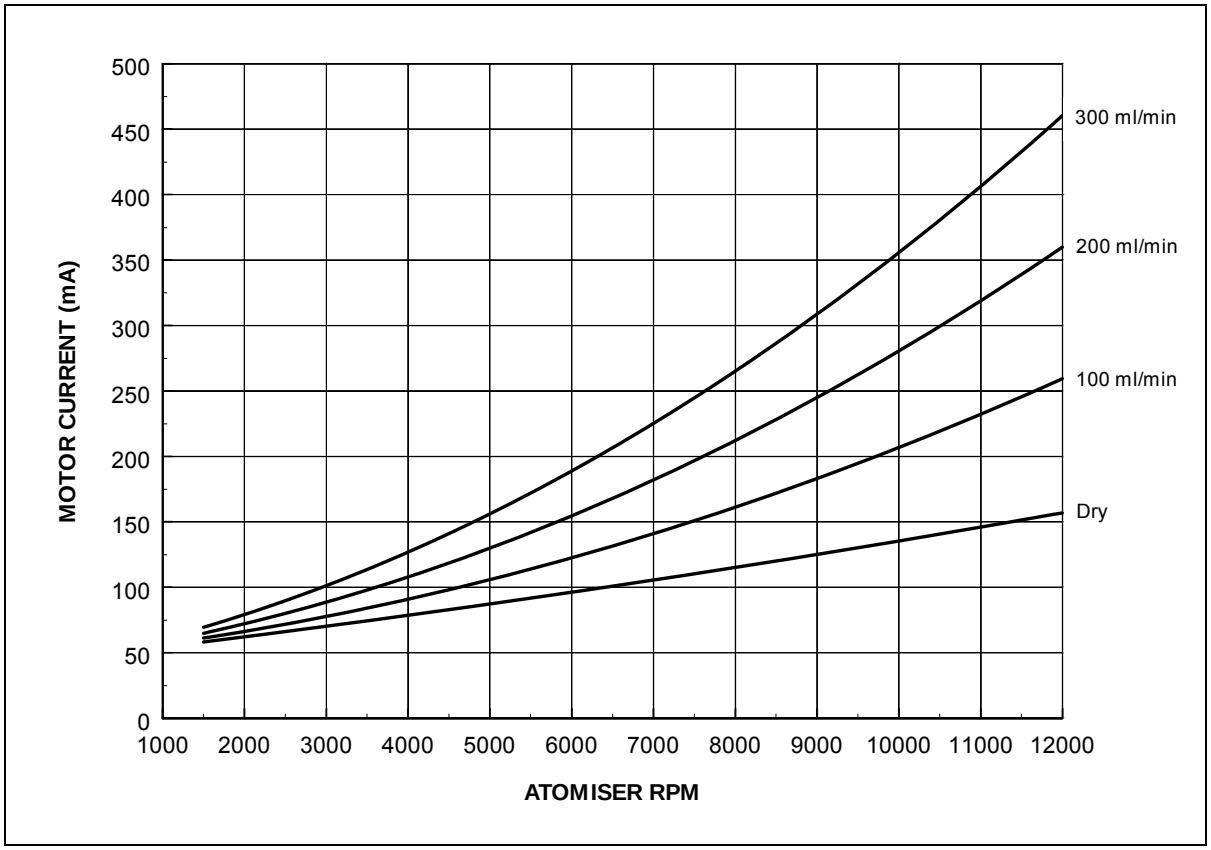
### 3.4.1. Power Supply

Both the Micromiser 12 and Micromiser 16 atomisers require a 24 V DC power supply. This will normally be provided by the main battery of an electrically powered UAV. If the available supply is greater than 24 V it will be necessary to install a step-down (buck) voltage converter. If the available supply is less than 24 V it will be necessary to install a step-up (boost) voltage converter. One converter can be used to supply several atomisers connected in parallel provided that its output current rating is at least 0.5 A per atomiser. Small buck and boost converter modules are readily available from electronic equipment suppliers and internet sellers.

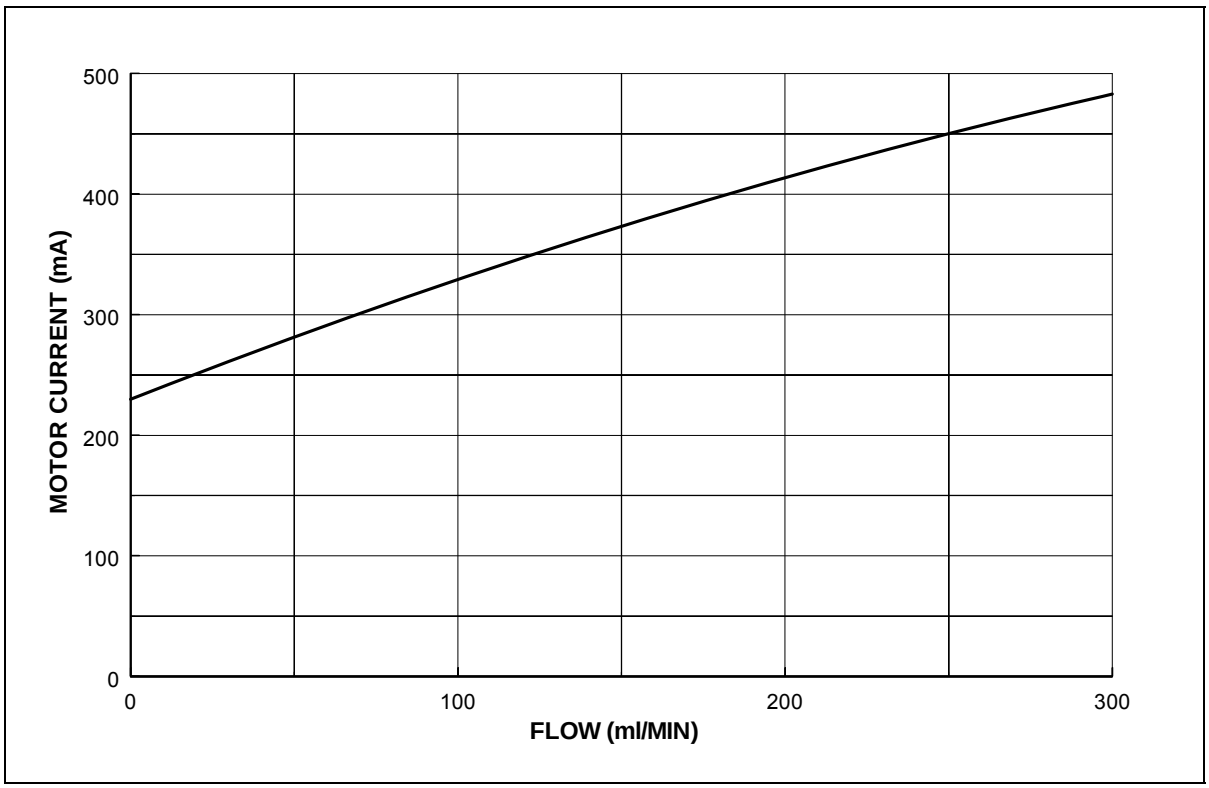
**IMPORTANT:** Micromiser atomisers must be operated with a smooth DC power supply. Under no circumstances should a pulsed (PWM) power supply or voltage converter (eg a PWM motor speed controller) be used. A pulsed power supply will damage the internal motor controller and its use will void all warranties.

The supply to the voltage converter (if fitted) or atomisers must be protected by a fuse or circuit breaker. The recommended rating is 1 A per atomiser. Each atomiser motor incorporates a controller with a slow-start ramp, so there is no significant current surge when the motor starts.

Graph 2 shows the relationship between current consumption, atomiser rotational speed and liquid flow rate for the Micromiser 12. Graph 3 shows the relationship between current consumption and liquid flow rate for the Micromiser 16 when operated from a 24 V supply.




*Graph 2 – Current Consumption of Micromiser 12 vs Atomiser RPM and Flow Rate*




*Graph 3 – Current Consumption of Micromiser 16 vs Flow Rate at 24 V Input*

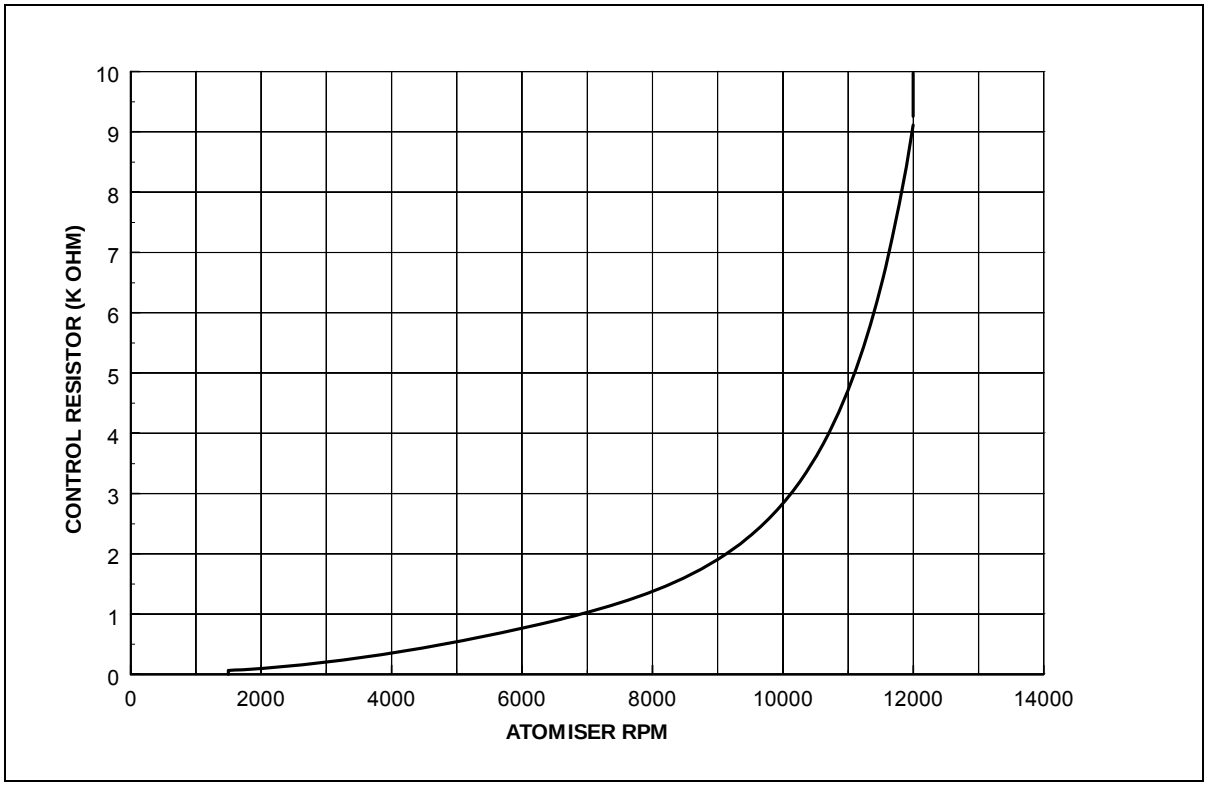
## 3.4.2. Atomiser Speed Control (Micromiser 12 Only)

The speed of the Micromiser 12 atomiser is determined by the voltage on pin 4 of the motor connector. This pin is pulled up to the internal +5 V supply of the motor controller by a 1 K Ohm resistor and an external resistor between pin 4 and ground forms a potential divider to set the control voltage. Fig. 5 shows a simplified schematic of the control input.

The external speed control resistor can be either an adjustable potentiometer or a fixed resistor if the atomiser is always to operate at a set speed. Graph 4 shows the relationship between atomiser RPM and the external speed control resistor value. It is recommended that a 10 K Ohm potentiometer is used if the atomiser is to be operated over its entire speed range.

The minimum speed of the Micromiser 12 is 1,500 RPM. This will be achieved with a control resistor value of 47 Ohms. The atomiser will not rotate if the control resistor is below 47 Ohms. It is recommended that a 47 Ohm resistor should be fitted between the lower side of the potentiometer and ground – see Fig. 5. This ensures that the atomiser runs at its minimum speed with the potentiometer set fully anti-clockwise.

The internal motor controller of the Micromiser 12 atomiser operates in closed loop mode and compensates automatically for the load of liquid on the disc. The disc speed therefore remains constant over the full range of flow rates. The disc speed can be adjusted with the atomiser running dry and will not change under load.




*Graph 4 – Micromiser 12 Atomiser RPM vs Control Resistor Value*

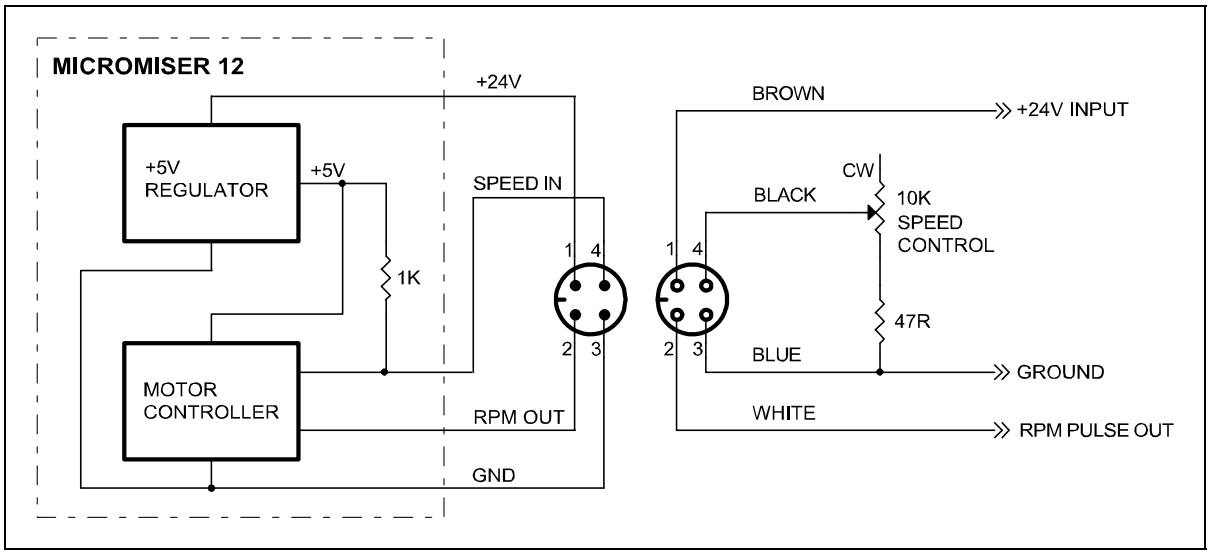



*Fig. 5 – Schematic of Speed Control for Micromiser 12*

## 3.4.3. Atomiser Speed Output

A pulse output is provided to enable the rotational speed of the atomiser to be measured without the use of an external tachometer or stroboscope on the disc.

The atomiser speed can be measured either with a portable instrument (eg a laboratory frequency counter or multimeter with a frequency function) or by a permanently installed indicator calibrated to read RPM directly.

The speed output is provided on pin 2 of the atomiser connector (white wire in standard moulded M12 connector). The specification of this output is:

| | |
|---|---|
| Scaling: | One pulse per revolution |
| Pulse amplitude: | +5 V relative to ground (pin 3) |
| Minimum load impedance: | 50 K ohm |
| Maximum load capacitance: | 0.01 µF |

**IMPORTANT:** connecting an instrument with a lower impedance or higher capacitance loading will impair the efficiency of the integrated motor drive circuit and could cause permanent damage.

If a multimeter or other frequency measuring instrument is used to measure the motor speed in Hz the atomiser speed (RPM) is given by:

Motor speed (RPM) = Frequency (Hz) x 60

### 3.4.4. Interface with Flight Control System

It is possible to interface Micromiser atomisers with a suitable UAV flight control system so that the atomiser motors can be started and stopped in flight and (if required) the atomiser rotational speed can be changed to produce the required spray droplet size. The control of the atomisers will normally be in conjunction with switching of the pump or flow to the atomisers.

The configuration of the interface will depend upon the flight control system and operational requirements. The following points are provided for general guidance only:

- The atomiser motors can be turned on and off by switching the 24 V DC power supply with a relay or semiconductor device (eg a suitably rated MOSFET).
- The atomiser motors must be turned on at least 2 seconds before starting the pump and turned off after the pump has been stopped and liquid flow has ceased – see Section 4.
- It is not normally necessary to stop the rotation of the atomisers during turns within the spray area.
- When possible, it is recommended that the atomisers are not rotating during take-off or landing to minimise the risk of damage to the discs from contact with foliage on the ground etc.
- In normal operation there should be an interlock to ensure that there cannot be flow to the atomisers unless they are rotating. However, the control system should incorporate a function or switch to enable the pump whilst the atomisers are not rotating for calibration on the ground – see Section 5.1.
- If using a Micromiser 12 atomiser its rotational speed can be set by varying the voltage on the control input (pin 4). This can be achieved by means of a transistor and voltage feedback as shown in the example schematic in Appendix I. Note that this arrangement requires a DC control voltage from the flight control system (typically provided by a D/A converter). Under no circumstances should the control voltage be provided directly from a pulsed output (eg a PWM motor controller). Should the control system provide a pulsed output this must be filtered to provide a DC voltage with a maximum of 10 mV P/P ripple.
- If required, the atomiser speed output (pin 2) can be fed to the flight control system. This can be used either for closed-loop speed control or as an indication that the atomiser is rotating. The absence of pulses on this output whilst the atomiser is powered can be used to indicate a fault. The input to the flight control system must have a high impedance and low capacitance – see Section 3.4.3. If necessary, a buffer or level converter must be used between the atomiser output and the control system input as shown in Appendix I.

## 4. OPERATION

The atomiser is provided with a clip-on plastic protective cap. This must be removed before operation and should be re-fitted if the atomiser is not to be used for a prolonged time or before the UAV is transported.

The atomiser disc must be running at its required speed before the liquid flow commences. The atomiser motor can take up to two seconds to reach its final speed so there should be a delay of a minimum of two seconds between starting the motor and starting the liquid feed to the atomiser.

The liquid flow to the atomiser must be stopped before the motor is stopped. The time for the liquid flow to cease will depend upon the diameter, length and orientation of the feed tube. There must be a sufficient delay between stopping the liquid flow and stopping the atomiser to allow the feed tube to empty completely.

**IMPORTANT:** the liquid flow to each atomiser must not exceed 300 ml/min. Operation at a higher flow rate could result in damage to the atomiser motor.

## 5. HEALTH & SAFETY

Legislation regarding the application of chemicals which are potentially harmful to individuals or the environment varies considerably between countries. Operators using chemicals and equipment must ensure they are working within the regulations applicable to their area.

Irrespective of legislation, Micronair advise the users of their equipment that all possible care must be taken to ensure the health and safety of the user and personnel in the vicinity of the spraying operation.

The following recommendations are for guidance only and do not exclude any statutory requirement:

1. The application of each chemical should follow the recommendations of the manufacturer. Extreme care should be taken to prevent chemical reaching the operator or any other people, animals or neighbouring crops where contamination could have an adverse effect.
2. Ensure that the equipment is correctly calibrated for the chemical being used.
3. Suitable clothing, gloves, eye protection and masks must be worn when working with or near toxic chemicals and operators must adhere to all relevant handling precautions and regulations.
4. The entire spray system and all ancillary equipment must be thoroughly washed out after use or before maintenance.
5. All chemical residues must be safely stored or disposed of.
6. All used chemical containers must be safely disposed of in accordance with local regulations and requirements.
7. First aid and washing facilities must always be available and personnel must be trained in their use.

# 6. CALIBRATION

For correct operation, both the liquid flow rate and the spray droplet size must be adjusted according the requirements of the application.

## 6.1. Flow rate

The flow of liquid to the atomisers is controlled by a valve, metering pump etc provided by the installer. See Section 3.2 for further details.

The total flow rate (l/minute) from the UAV is determined by the area treated per minute (ha/min) and the required application rate of the product (l/ha).

The area treated per minute depends upon the spraying speed (km/hr) and the distance between successive spray tracks (track spacing in m):

$$\text{Area treated/min (ha/min)} = \frac{\text{spraying speed (km/hr)} \times \text{track spacing (m)}}{600}$$

The total flow from the UAV is given by the area treated/minute (ha/min) multiplied by the application rate on each hectare (l/ha), so:

$$\text{Flow (l/min)} = \frac{\text{spraying speed (km/hr)} \times \text{track spacing (m)} \times \text{application rate (l/ha)}}{600}$$

Example:

A UAV fitted with four Micromiser 12 atomisers is to apply 10 l/ha using a spraying speed of 12 km/hr and a track spacing of 5 m, so:

$$\text{Total flow from UAV} = \frac{12 \text{ km/hr} \times 5 \text{ m} \times 10 \text{ l/ha}}{600} = 1.0 \text{ l/min}$$

$$\text{Flow per atomiser} = \text{total flow} \div \text{number of atomisers} = 1.0 \div 4 = 0.25 \text{ l/min}$$

The flow rate from each atomiser can be measured as follows:

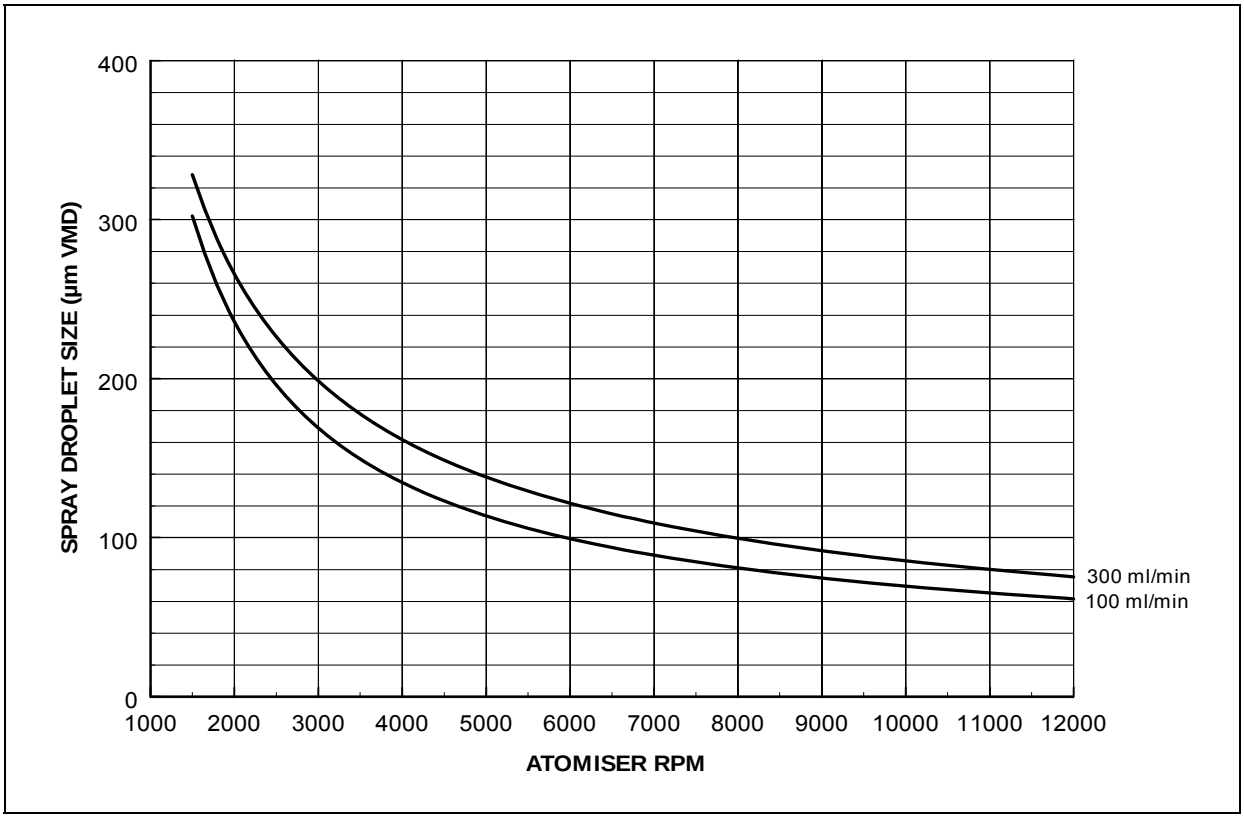
1. Remove the discs from all atomisers as described in Section 6.
2. Place a bucket or other suitable receptacle under each atomiser.
3. Fill the spray tank with the actual product to be sprayed (note that the flow rate may change according to the viscosity of the product).
4. Turn on the pump and wait for a steady stream of liquid to flow from each atomiser.
5. Place an empty container under each atomiser to collect liquid for a measured time (typically 1 minute, but two minutes can be used for low flow rates).
6. Turn off the pump.

7. Measure the volume collected from each atomiser by pouring the liquid into a calibrated measuring cylinder or jug.
8. Calculate the flow rate from each atomiser (l/min) by dividing the volume collected (l) by the time (min).
9. Add the flow rates (l/min) from all atomisers together to obtain the total flow rate from the UAV.
10. Adjust the flow rate as necessary and repeat steps 4 – 9 to obtain the required total flow rate as calculated above.

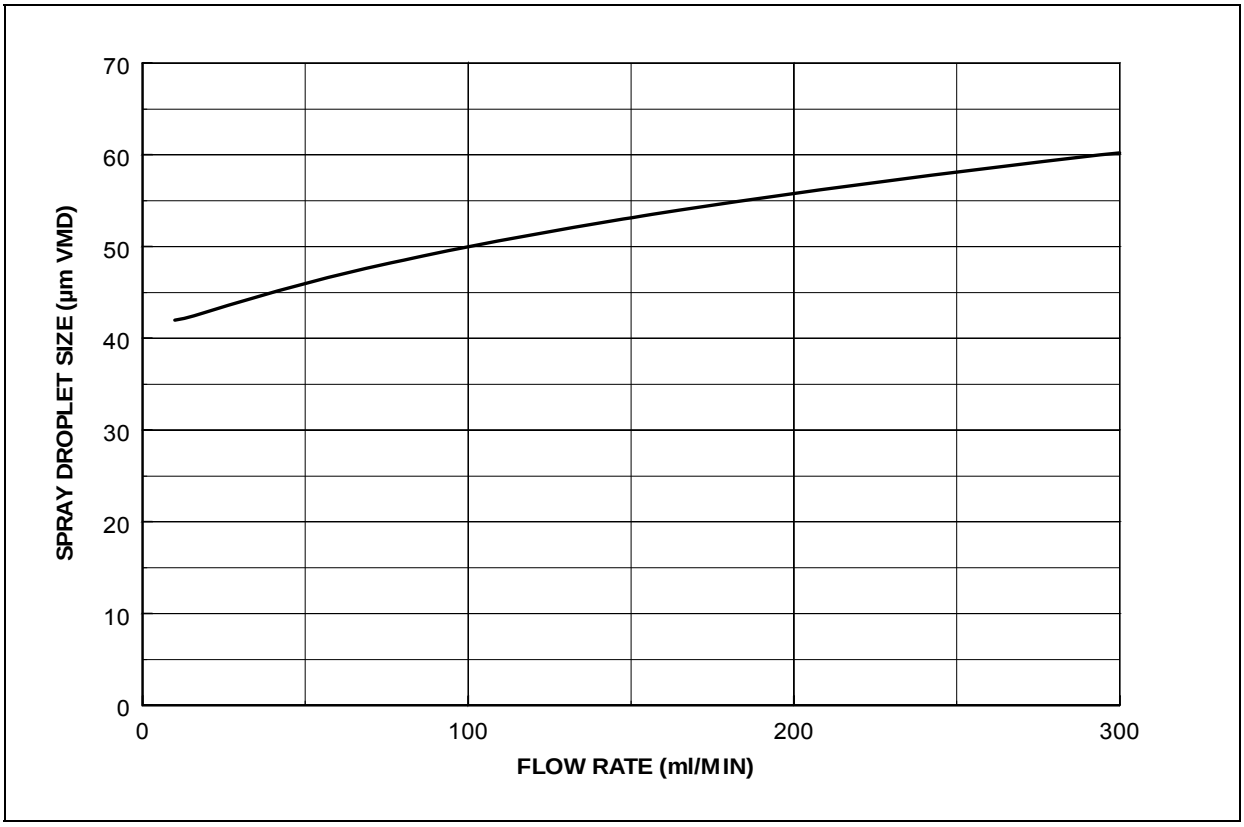
## 6.2. Spray Droplet Size

The diameter of the spray droplets produced by the atomiser disc is determined by the rotational speed of the disc, the liquid flow rate and the physical properties of the spray liquid.

Graph 5 shows the measured VMD (Volume Median Diameter) of spray droplets from the Micromiser 12 at rotational speeds of 1,500 – 16,000 RPM when spraying plain water. Graph 5 shows the relationship between measured VMD (Volume Median Diameter) of spray droplets and liquid flow rate from the Micromiser 16 when operated from a 24 V supply. These graphs are intended as a guide only as the droplet size is influenced by the physical properties of the liquid being sprayed. In general the addition of a surfactant to reduce surface tension will reduce droplet size by up to 15%. The droplet size when spraying formulations based on light oils will be about 15 – 20% smaller than shown.




*Graph 5 – Spray Droplet Size vs Atomiser RPM for Micromiser 12*




*Graph 6 – Spray Droplet Size vs Flow Rate for Micromiser 16 with 24 V Supply*

When using a Micromiser 12 atomiser the atomiser speed must be set either by an external control resistor or a potentiometer as described in Section 3.4.2 or by the UAV flight control system as described in Section 3.4.4.

The Micromiser 16 atomiser is intended to operate only at its maximum speed to produce the smallest possible spray droplets. It must be used with a 24 V DC power supply and the droplet size will be as shown in Graph 6.

## 7. MAINTENANCE

The rotating disc of the atomiser must be kept clean at all times. Contamination of the grooves on the inner surface of the disc or of the teeth on the periphery will result in poorly controlled spray droplet size and can cause vibration.

The procedure to clean the atomiser disc is as follows:

1. Disconnect power from the atomiser.
2. Whilst holding the disc with one hand, use the other to unscrew the knurled knob of the locking collet at the bottom of the disc by about four turns.
3. Pull on the knurled knob to slide the disc off the motor shaft.
4. Immerse the disc in water or a suitable solvent for the liquid that had been sprayed and remove any residue by brushing along the grooves and between the teeth with a soft brush. Do not use a metal or other hard brush as this could damage the disc.

5. Dry the disc with a soft lint-free cloth or compressed air.
6. Inspect the teeth of the disc. If these are worn or damaged the disc should be replaced. The disc is a consumable item and replacements are available from Micron Sprayers Ltd, part number CBP3324.
7. Replace the disc on the motor shaft and slide it on as far as possible.
8. Hold the disc in one hand whilst simultaneously pushing it towards the atomiser body and tightening the knurled knob with the other. The knob should be finger tight, but do not over-tighten with pliers etc.
9. If the atomiser is not to be used immediately, fit the plastic protective cap over the disc.

Liquid is fed to the atomiser disc through a feed nozzle. If this nozzle should become blocked, the procedure to clean it is as follows:

1. Disconnect power from the atomiser.
2. Remove the atomiser disc as described above.
3. Using a 5 mm A/F socket or box spanner (wrench), unscrew the feed nozzle from the housing.
4. Immerse the nozzle in water or a suitable solvent for the liquid that had been sprayed and remove any blockage or residue by inserting a piece of wire into the bore of the nozzle
5. Dry the nozzle with a soft cloth or compressed air.
6. If necessary, remove the liquid feed tube from the atomiser and remove any residue or blockage from the inside of the tube and the hole through the housing.
7. Replace the feed nozzle in the housing.
8. Replace the atomiser disc as described above

The outside surfaces of the atomiser can be cleaned with a cloth moistened with water or a suitable solvent for the liquid that had been sprayed.

## 7.1. Fault Finding

| Problem | Possible Cause | Action |
|---|---|---|
| No liquid flow from atomiser | Blocked feed nozzle | Remove feed nozzle and clean |
| | Blocked or defective flow control valve or pump | Remove feed tube from fitting on atomiser and check flow rate; clean or repair valve or pump |
| Liquid drips from flange of atomiser feed body | Excessive flow rate | Reduce the liquid flow rate to 300 ml/min or less |
| | Contaminated or damaged disc | Clean disc or replace if damaged |
| Disc does not rotate | Faulty power supply, cable or connector | Remove connector from atomiser and check voltage between pins 1 & 3 of cable connector; locate external fault and repair |
| | Debris between edge of disc and feed body or alongside feed nozzle | Check disc for free rotation, remove disc and clean as necessary |
| | Low voltage on speed control input | Check voltage between pins 3 & 4 of cable connector (atomiser will not rotate when <0.25 V), locate external fault and repair |
| | Defective atomiser motor | Replace motor assembly or return atomiser to Micron Sprayers Ltd for repair |
| Atomiser vibrates whilst operating | Contaminated or damaged atomiser disc | Clean disc or replace if damaged |

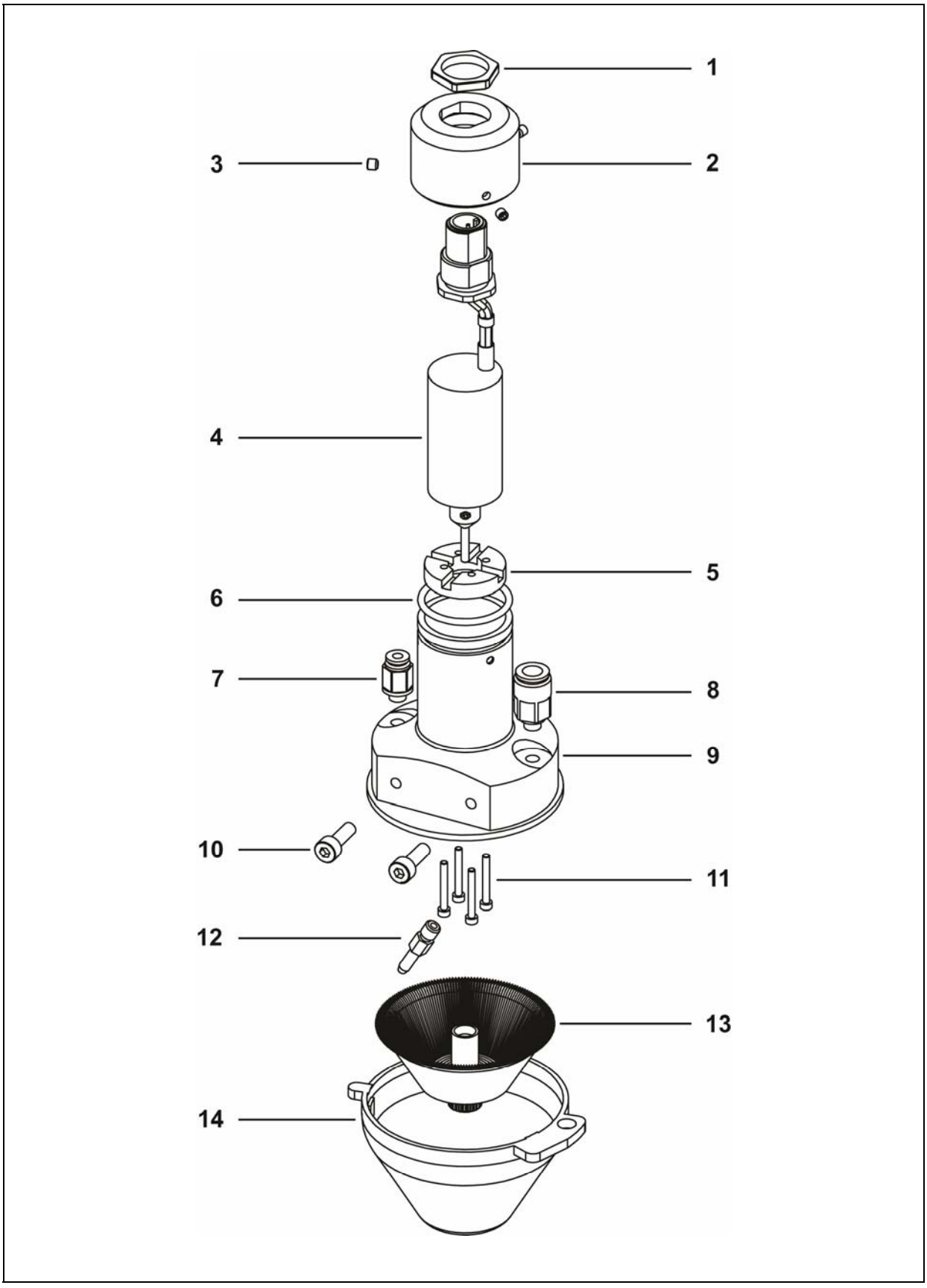



*Fig. 6 – Components of Micromiser Atomiser*

# 8. PARTS LIST

## 8.1. Micromiser Atomiser

| | | |
|---|---|---|
| Complete atomiser: | Micromiser 12: | EX7464 |
| | Micromiser 16: | EX7465 |
| Atomiser with cable: | Micromiser 12 | PC1212 |
| | Micromiser 16 | PC1216 |

| Item | Part No | Description | Qty | Notes |
|---|---|---|---|---|
| 1 | | Nut, connector retaining | 1 | Supplied with item 4 |
| 2 | EX7167 | Top cap | 1 | |
| 3 | CBP3319 | Grub screw, M3 x 3 | 4 | |
| 4 | EX7466 | Motor assy, Micromiser 12 | 1 | Includes connector |
| 4 | EX7467 | Motor asy, Micromiser 16 | 1 | Includes connector |
| 5 | EX7168 | Spacer disc | 1 | |
| 6 | CBP3320 | O-ring | 1 | |
| 7 | CBP3321 | Tube fitting, 3mm | 1 | |
| 8 | CBP3322 | Tube fitting, 6 mm | 1 | |
| 9 | EX7166 | Housing | 1 | |
| 10 | CBP3323 | Cap screw, M4 x 12 | 2 | |
| 11 | CBP3316 | Cap screw, M2 x 16 | 4 | |
| 12 | CBP3325 | Feed nozzle | 1 | 2 mm bore |
| 13 | CBP3324 | Atomiser disc | 1 | |
| 14 | EX7199 | Protective cap | 1 | |

## 8.2. Cable Assembly with Moulded M12 Connector

Cable, 22 AWG x 2 m: CBP3430

## 9. CONVERSION FACTORS

| | | |
|---|---|---|
| 1 yard | = 3 feet | = 0.91 metre |
| 1 metre | = 39.37 inches | = 1.09 yards |
| 1 statute mile | = 0.87 nautical mile | = 1.61 kilometres |
| 1 nautical mile | = 1.15 statute mile | = 1.85 kilometres |
| 1 kilometre | = 0.62 statute mile | = 0.54 nautical mile |
| 1 statute mile | = 1760 yards | = 5280 feet |
| 1 nautical mile | = 2027 yards | = 6081 feet |
| 1 kilometre | = 1094 yards | = 3282 feet |
| 1 metre/sec | = 2.237 miles per hr | = 196.9 ft/min |
| | | |
| 1 acre | = 43560 sq feet | = 4840 sq yards |
| 1 acre | = 4047 sq metres | = 0.40 hectare |
| 1 hectare | = 107600 sq feet | = 11955 sq yards |
| 1 hectare | = 10000 sq metres | = 2.47 acres |
| 1 sq mile | = 640 acres | = 259 hectares |
| 1 sq kilometre | = 247 acres | = 100 hectares |
| | | |
| 1 US gal | = 0.83 Imp gal | = 3.78 litres |
| 1 Imp gal | = 1.20 US gals | = 4.54 litres |
| 1 litre | = 0.26 US gal | = 0.22 Imp gal |
| 1 US pint | = 16 US fl ounces | = 0.47 litres |
| 1 Imp pint | = 20 Imp fl ounces | = 0.57 litre |
| | | |
| 1 US fl ounce/acre | = 1.04 Imp fl ounce/acre | = 73.04 ml/hectare |
| 1 ml/hectare | = 0.0137 US fl oz/acre | = 0.0142 Imp fl oz/acre |
| 1 US gal/acre | = 8 US pint/acre | = 9.45 litres/hectare |
| 1 Imp gal/acre | = 8 Imp pints/acre | = 11.35 litres/hectare |
| 1 litre/hectare | = 0.11 US gal/acre | = 0.081 Imp gal/acre |
| | | |
| 1 pound | = 16 ounces | = 0.45 kilogram |
| 1 kilogram | = 2.20 pounds | = 35.3 ounces |
| 1 ounce | = 28.35 grams | |
| | | |
| 1 pound/sq inch | = 0.068 atmosphere | = 0.067 bar |
| 1 atmosphere | = 14.70 pounds/sq in | = 1.01 bar |
| 1 bar | = 14.50 pounds/sq in | = 0.98 atmosphere |
| 1 kilopascal | = 0.01 bar | = 0.145 pounds/sq in |

# APPENDIX I

## Interface with Flight Control System

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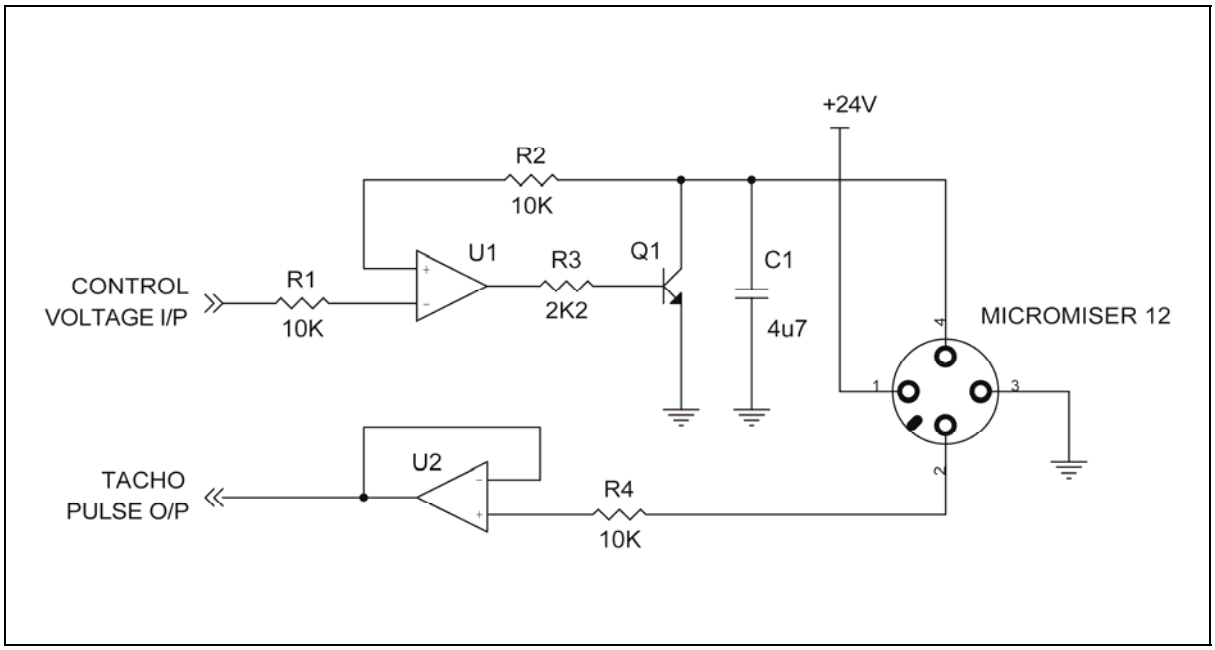


*Schematic of Controller Interface*

The schematic above shows an example of an interface to a flight control system providing a DC voltage output to control the rotational speed of a Micromiser 12 atomiser.

- Op amp U1 and transistor Q1 mirror the control voltage input on the speed control input of the Micromiser 12 atomiser (pin 4).
- The rotational speed of the atomiser is proportional to the control voltage input, with the atomiser reaching its maximum speed at 4.5 V input. The rotational speed is therefore 12000/4.5 = 2667 RPM/volt.
- The control input must be a smooth DC voltage, for example from the output of a D/A converter. A pulsed output must not be used. If the controller provides a PWM output this must be filtered to provide a DC voltage with a maximum of 10 mV P/P ripple.
- Op amp U2 is a high impedance buffer for the speed (tacho) output pulse output of the Micromiser 12 (pin 2). This is required only if the output is to drive a low impedance or capacitive load.

## Notes