MicroFab Technologies, Inc.

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MJ-SF User's Manual

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Warranty

The MJ-SF jetting device is warranted against defects in material and workmanship for a period of thirty days from date of shipment. During the warranty period, MicroFab will, at its option, either repair or replace devices which prove to be defective.

Limitation of Warranty

The foregoing warranty shall not apply to defects resulting from improper or inadequate maintenance by Buyer, Buyer-supplied software or interfacing, unauthorized modification or misuse, or operation outside of the environmental specifications for the product. MicroFab makes no claim that the jetting device will perform with all fluids introduced to the device, or that the device will work at all frequencies and operating parameters selected by the Buyer.

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Equipment Series: MJ-SF Jetting Device

Mfg Date: Indicated by device Serial No.

General Safety Considerations

Warning	**The jetting device itself presents no general chemical hazard. However, when fluids are selected to be dispensed by the operator, appropriate safety measures should be followed as outlined in the selected material's MSDS.**
Warning	**If this product is not used as specified, the protection provided by the equipment could be impaired. This product must be used in a normal condition (in which all means for protection are intact) only.**

Table of Contents

Section 1 - General Information

Introduction

MicroFab's MJ-SF jetting device has been developed to dispense single drops of solvents, polymers, solder, water-based fluids, and inks. With proper fluid preparation and device maintenance, the jetting device will provide reliable delivery of fluid micro-drops.

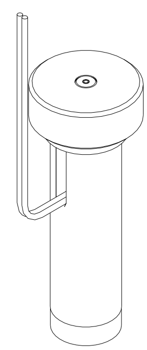

Figure 1 - MJ-SF-01 Jetting Device

Technical Specification

The MJ-SF jetting device design has successfully jetted a wide variety of fluids. Performance of the jetting device is closely tied to the characteristics of the fluid in use. Typical fluids successfully jetted in this device have viscosities less than 40 centipoise and surface tensions in the range of 0.02-0.07 N/m. Fluids with properties outside these limits can be jetted if changes to the properties can be achieved with solvents or changes in temperature.

The jetting device can be provided with orifice sizes ranging from 30-60 microns. Depending on the operating parameters and the fluid, these devices can produce drops ranging from 50-200 picoliters in volume.

Operating Range

- Operating temperature between 20 and 250°C.

Physical Dimensions

- Physical dimensions are shown in Figure 2.

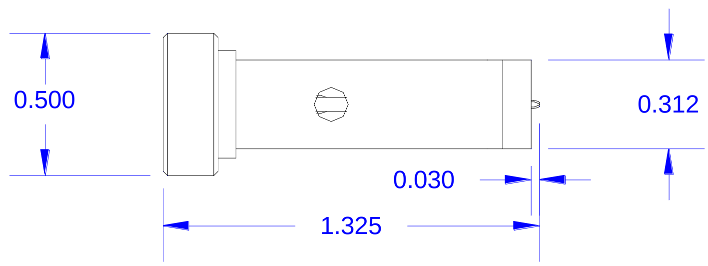

Figure 2 - Device Dimensions

Power Requirements

- Required power - 115VAC/2A max; 50/60 Hz (for JetDrive electronics; JetDrive can also be configured for 240V installation)

Facility Requirements

The jetting device, by itself, requires no connection to lab or machine power. However, the support equipment for the jet does require some typical lab support.

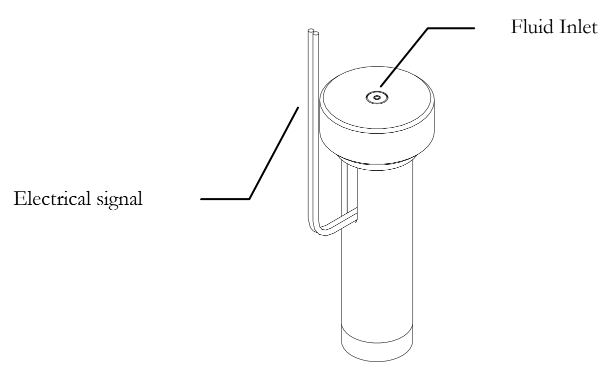

Figure 3 - Fluid & Electrical

Pneumatics

Depending on the viscosity and contact angle of the fluid, the jetting device can require either positive or negative pressure at the fluid inlet. There are two typical ways to provide this back pressure. First, the back pressure can be provided by either a positive or negative pressure head provided by positioning the fluid reservoir. If the reservoir is mounted a few inches above the jetting device, a constant positive pressure will be provided. If it is mounted a few inches below, the orifice will realize a negative pressure.

The second approach is to regulate existing compressed air or vacuum sources. By inserting a pressure or vacuum regulator between the source and the jetting device, the pressure can be adjusted. MicroFab provides such capability in it's CT-PT-01 pneumatics panel. In this case, the lab facilities must provide a +15 PSIG source, either through an air compressor or through a compressed gas tank. For negative pressure, the regulator should be connected to a vacuum source of –24 in. Hg.

An unheated cartridge, used as a subassembly in the PH-04 print head, is shown in Figure 4. In this instance, pneumatic back pressure is plumbed to the top of the cartridge lid.

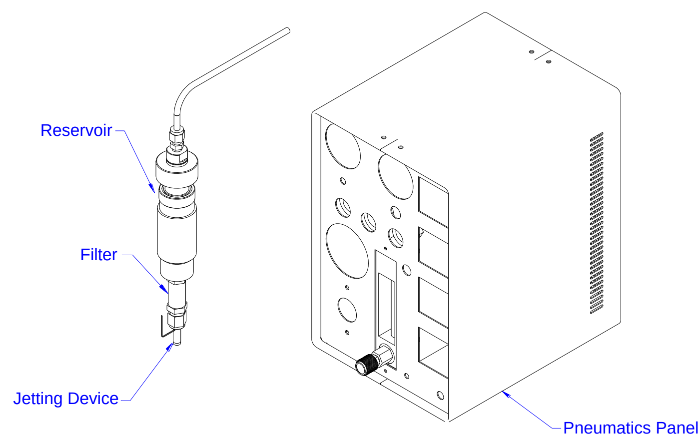

Figure 4 - Back Pressure Control

Electrical

In order to generate drops, a pulse is sent to the PZT surrounding the glass capillary. The shape of this waveform is shown in Figure 5. Acceptable ranges for the jetting device are listed in Table 1.

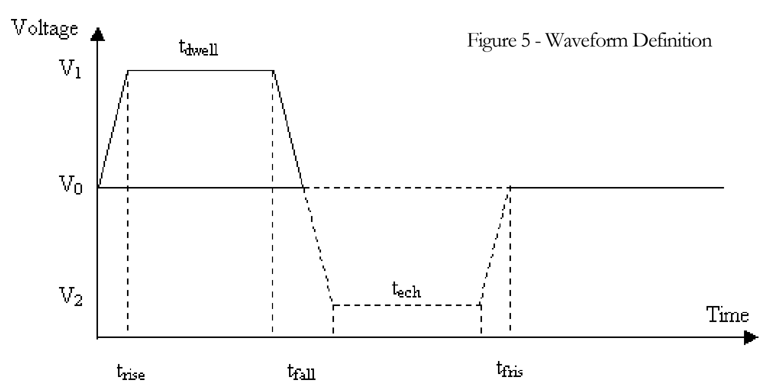

Figure 5 - Waveform Definition

Table 1 - Voltage Pulse Parameters

Voltage level 1	0 to 100 V
Voltage level 2	-100 to 0 V
t_{rise}	1 – 300 µs
t_{dwell}	3 – 800 µs
t_{fall}	1 – 150 µs
t_{ech}	3 – 800 µs
t_{fris}	1 – 300 µs
Frequency	1 Hz to 20 kHz

MicroFab offers a controller (part no. CT-M3-01) that has been designed to meet or exceed these parameters. However the same function can be accomplished by properly implementing a wave form generator and a voltage amplifier from qualified manufacturers. It is important in either arrangement, however, to make sure that the output connector from the voltage source mates with the connector provided on the jetting device.

Section 2 - Equipment Ratings

Supply Voltage

Consult the manufacturer's data sheet for supply voltage requirements of the pulse generator used for operation.

Range of environmental conditions

The MJ-SF device has been successfully operated in the temperature range of 20° to 250° C. It is intended for use in a normal laboratory environment.

Equipment Installation

Unpacking and Inspection

When received, the MJ-SF device will be individually packaged in a plastic box and a bag. The glass tip of the jetting device will be covered by a protective shell. After verifying that the box is labeled with the desired orifice diameter, the device can be removed from its bag and inspected.

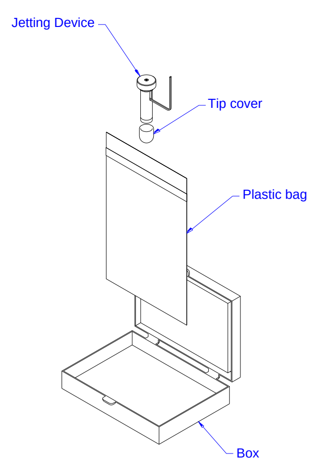

Figure 6 - MJ-SF Packing

While removing the protective cap, be sure to pull straight away from the device. The glass tip can be broken or damaged if the cap is pulled to the side during removal.

Assembly

The jetting device will be securely held in place by threading the nut which clamps the face seal surface of the device to the mating gland. No attempt should be made to hold the jetting device by the glass tip. In order to place the nut around the fitting of the device, the connector and wires must first be threaded through the nut as shown inf Figure 7 .

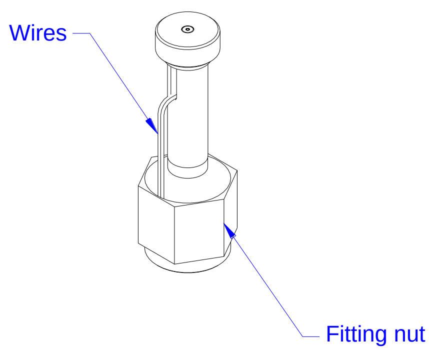

Figure 7 - Device and Mounting Nut

In many cases it is advisable to use a filter compatible with the fluid to be jetted. Orifice sizes for a MicroFab jetting device typically range from 30 to 60 μm. Filter sizes of 7 μm and smaller will reduce the risk of contaminants clogging the orifices. It is important that the selected filter is compatible with the fluid to be jetted and that adequate flow through the filter can be maintained. A list of compatible mounting nuts and filters are included at the end of this manual.

Instructions for Protective Earthing

Protective earthing for the JetDrive III controller is provided through the ground terminal of the plug providing power. Source power to the controller, or to a wave form generator selected as an alternate, must provide protective earthing to this terminal in order to minimize the hazard of a possible shock.

Ventilation

The MJ-SF jetting device itself requires no special ventilation for operation. However it is possible that the fluid being dispensed will require a unique environment for reliable operation. As an example, fluids which quickly dry in contact with air may need an elevated humidity to slow this process. Additionally, the dispensed fluid may emit volatile fumes which must be captured and disposed of. Both of these situations are the responsibility of the user of the device and beyond MicroFab's control.

Equipment Operation

Hardware Overview

Figure 8 shows a typical set-up for a jetting test station. The key components are:

1. Jetting device (in this case, shown in a PH-04 print head)
2. Fluid reservoir (shown with static pressure control)
3. Drive electronics with strobe interface
4. Drop observation camera and monitor

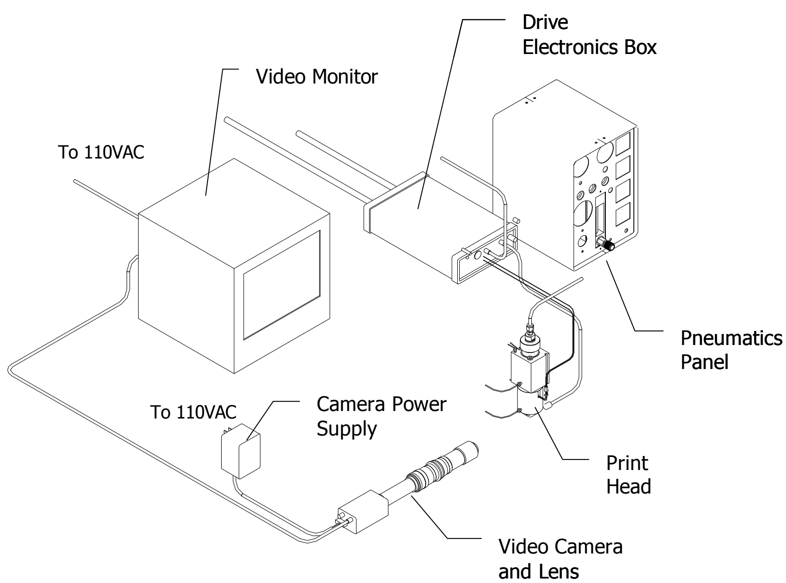

Figure 8 - Typical Set-up

Not shown in the figure is a personal computer. A PC is required in order to serve as the user interface to download operating parameters to the drive electronics box. The software required to perform this interface is included with the drive electronics (JetDrive III). For systems where the voltage pulse is supplied by other equipment, variations on the figure will occur, although the same components are required.

Principles of Operation

The MJ-SF device consists of an annular piezoelectric actuator bonded to a glass capillary that is connected at one end to the fluid supply and at the other end has an orifice generally in the range of 30-60um. By applying a voltage to the PZT actuator, the cross-section of the tube capillary is reduced/increased producing pressure variations of the fluid enclosed in the tube. These pressure variations propagate in the glass tube towards the orifice. The sudden change in cross-section (acoustic impedance) at the orifice, causes a drop to be formed. This mode of producing drops is called drop on demand (DOD).

The same device can be used for continuous drop generation when the fluid is pressurized and a sinusoidal signal is applied to the actuator. A Rayleigh type instability results in the break-off of the fluid column into droplets. The continuous jetting results in a higher throughput.

A wide range of fluids can be dispensed with the requirement that the viscosity has to be lower than 40 centipoise. Drop volume is a function of the fluid, orifice diameter, and actuator driving parameters (voltage and timings) usually ranging from 50 picoliters to 200 picoliters. The operating frequency is limited by the total driving time of the actuator and on the dispensed fluid.

Initializing Jetting Hardware

Hardware

The jetting device is the key element of the dispensing system. Each device is polished and extensively cleaned prior to shipment. Maintaining this cleanliness is extremely important to the successful operation of the device. In many systems provided by MicroFab, a filter is supplied prior to the inlet fitting of the jet. The fluid line or fittings between the filter and the device, and between the filter and the reservoir, should be flushed and cleaned to assure that no particulates are accumulated in the plumbing. In addition, compatibility of the fluid under test and each plumbing element should be understood by the user. If the fluid to be dispensed chemically attacks any of the plumbing components, the resulting contamination may result in a "clog" at the orifice.

Final testing of the jetting device prior to shipment is done using Isopropyl Alcohol. During initial testing of the MJ-SF device, this fluid is recommended to help demonstrate that all parts of the system are operating normally. After new operators are comfortable with dispensing IPA, the actual fluid to be tested can be loaded into the reservoir.

Observation system

To observe the drop formation, a CCD camera can be used to observe the jet tip. MicroFab offers a suitable system (model no. CM-VS-01). The camera can also be replaced by an appropriate microscope.

The total magnification to the display should be in the range of 50 to 100 times. An LED synchronized with the PZT pulse provides lighting. The delay between the PZT pulse and LED pulse is adjustable, allowing the capture of the drop formation at different stages of development.

Drive electronics

To use the device as a drop on demand dispenser the waveform presented in Figure 8 has to be supplied to the red wire of the piezoelectric actuator with the black/blue wire connected to the ground of the drive electronics unit. The driving signal can be unipolar or bipolar, depending on the fluid used. The parameters are t_{rise} = initial rise time; t_{dwell} = time at high voltage (V1); t_{fall} = transition time from high voltage to low voltage; t_{echo} = time at low voltage (V2); t_{frise} = final rise time. The voltage V_0 is normally set to zero and $V_1 = -V_2$. The piezoelectric actuator has a capacitance of about 1 nanoFarad.

The timings are dictated by the length of device and the jetted fluid. To minimize the driving voltage the rise and fall times should be short (2-3µs). An optimum value for the dwell time is approximated as:

$$t_{dwell}=2\ L/c \qquad (1)$$

where L is the distance between the middle of the piezoelectric element to the device end and c is the speed of sound in the dispensed fluid. For the MJ-SF device, the value of L is approximately 0.434" (11 mm). Typical dwell time values are between 15 to 35µs. The echo time t_{echo} (if using a bipolar waveform) should be adjusted for a clean break-off of the drop (generally about twice the dwell time).

To achieve larger drop volumes with the same device (drop volume is also a function of the orifice diameter) longer rise and dwell time values can be used (which also results in an increase in the voltages V_1 and V_2).

The LED signal should be synchronized with the driving signal and have an adjustable delay from the beginning of the pulse. By adjusting the delay the drop formation will be "frozen" at that time from the beginning of the PZT pulse.

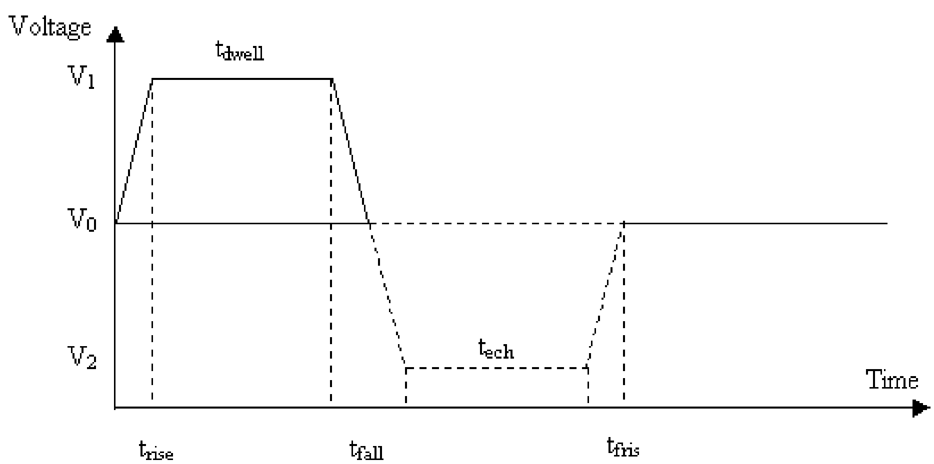

Figure 9 - Waveform Set-up

Setup and operation

> ***Important:*** The glass tip of device is very fragile! Care should be taken to remove the protective cap along the device axis otherwise the glass capillary outside the device will break. A gentle twist is usually required to pull the cap directly off the device. Also use care not to touch the fluid end of the device possibly contaminating it.

Setup steps:

1. Verify that the tip of the jetting device is visible when the camera is on. Check focus and camera calibration.

2. Verify that the device is full of fluid by purging under positive pressure. This is accomplished by turning the purge knob on the pneumatics panel. Alternately, positive pressure can be applied to a syringe body by making a pneumatic connection to the syringe, or pressing the plunger to achieve roughly 10-15 psig. After a few seconds, turn the pressure off.

3. Switch the pneumatics panel from Purge to On to transfer control to the fine adjust pressure regulator. Adjust the large, fine adjust, regulator until the fluid meniscus is flush with the device frontal face. Often a lint free swab is useful in cleaning the front face of the orifice in order to verify the pressure level. Figure 9 shows possible situations that arise at the orifice.

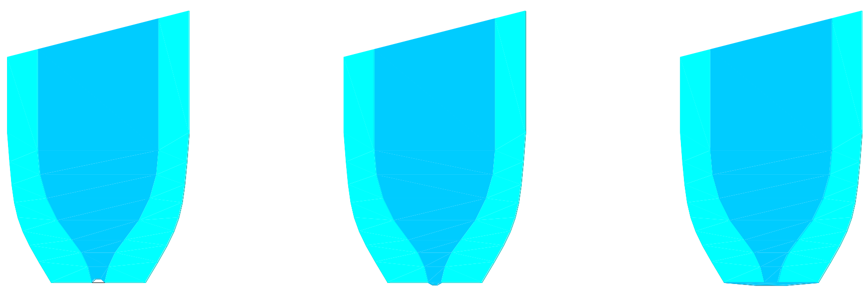

Figure 10 - Meniscus variations

4. Initialize the pulse to the jetting device. Set the signal frequency between 60 and 100 Hz. Set V_1 to 20 V and t_1 between 25 and 30μs. The rise and fall times are adjustable and should be set to 2-3 μs. If an echo pulse is used, set V_1 to 15 V and V_2 to –15 V and t_2 to 50 μs (twice t_1). The echo pulse is used to optimize the drop break-off, so for initial studies, using a unipolar pulse is recommended. An oscilloscope is often useful in order to verify or observe the voltage pulse.

5. Be sure the output of the drive electronics box or high voltage amplifier is OFF. Connect the output from the drive electronics to the device (ground to the device black/blue wire and signal to the red wire). Turn the output to the electronics unit or amplifier to on. ***CAUTION:*** High voltage is present at the cable ends to the device.

6. After initiating the jetting pulses in their baseline values, adjust the delay control of the strobe interface, and you should be able to observe the meniscus moving. If this is not observed, pressurize the reservoir to 5-15 psi, and you should observe radial perturbations on the cylindrical fluid column exiting the device. The perturbations will move along the column when changing the delay. This demonstrates that the

PZT actuator is seeing a voltage pulse and it's motion disturbs the fluid column. Adjusting this "stimulation" pulse is the next step.

7. If the meniscus is moving at the device orifice but no drop is formed, position the delay so you can see the meniscus at the maximum position outside the glass. Increase the applied voltage in 2 V increments. This should produce an increase of the meniscus excursion and, at a certain voltage level, should produce a drop.

8. Adjust the t_1 interval at constant voltage (change t_1 up and down from the previous set value) for the maximum velocity. If satellites (smaller drops) are formed, the voltage should be decreased.

9. Perform fine-tuning (for stable drop formation and no satellite operation) by adjusting the timings and voltage around the values determined above.

Notes:

- An increase of the voltage produces an increase in velocity.
- Beyond a certain voltage level satellites start forming. Also, high voltage results in air ingestion.
- Drops are formed at a certain range for t_{dwell}. Increasing t_{dwell} results in no drops. Increasing t_1 further will produce again drops (of larger volume).
- Changing the operating frequency might require additional tuning.

Basic Drop Formation Troubleshooting

No drops formed

- Set the delay to zero then increase to about 3 times t_1.
- Check (visualize with an oscilloscope) that the drive waveform is the same waveform you wanted.
- Inspect the tip. Turning the LED strobe off and lighting constantly (with a white background) will show you a change in the light reflection when no fluid is present in the nozzle. Purge to recover the meniscus or to eliminate any large air bubbles observed in the nozzle area.
- Pressurize the reservoir. If no fluid is purged, the device is clogged. Several possible techniques exist for removing a clog from the orifice. Contact MicroFab for determining the best solution for your system.
- Repeat steps 3 to 9 in the setup procedure

No drops are formed with a fluid puddle formed on the device tip

- Wipe of the front surface with a cotton swab until dry and readjust the reservoir back pressure if necessary.

- Air may have been ingested through the orifice – Purge the device, or decrease the voltage to the device

- Satellites are formed in addition to the main drop – Decrease the voltage to the device or adjust the dwell time.

Jet is not straight

- Could be produced by a low velocity drop. In this case increase the velocity (increase the voltage or adjust the t_{dwell})

- Could be produced by non-uniform wetting. Wipe off the device face until dry and readjust the syringe level if necessary.

- Could be a foreign particle at, or in the orifice, use cleaning procedures.

Supplemental Parts

In many instances, the MJ-SF jetting device is purchased as a "stand-alone" component of a larger subsystem. In order to make both fluid and electrical connections, details regarding the electrical connector, tubing, etc., is required. Below is a partial listing of some of these items that are known to interface correctly with the supplied device. *This is, in no way, an endorsement of these products, or does it attempt to address questions of fluid / material compatibility.*

- Electrical connector
    - The default connector is Molex P.N. 50-57-9402
        - The appropriate mating connector is Molex P.N. 70107-0001, with two Molex male crimp terminals, P.N. 16-02-0115
- Fluid connection
    - The nut that mounts the device is a Swagelok SS-4-VCO-4.
    - For PH-04 print heads, the filter used in line is a Swagelok SS-4F-V03-7. Filter element replacements are available for this item from the Swagelok Corporation.

Factory Support

For any questions regarding the MJ-SF-01 jetting device, or ink jet technology, contact

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