Fanavaran Nano-Meghyas

Lab-scale Dual Pump Electrospinning Unit (Side by Side Electroris) user mannual 2018

electroris.com

Chapter 1 Information

1.1 General information

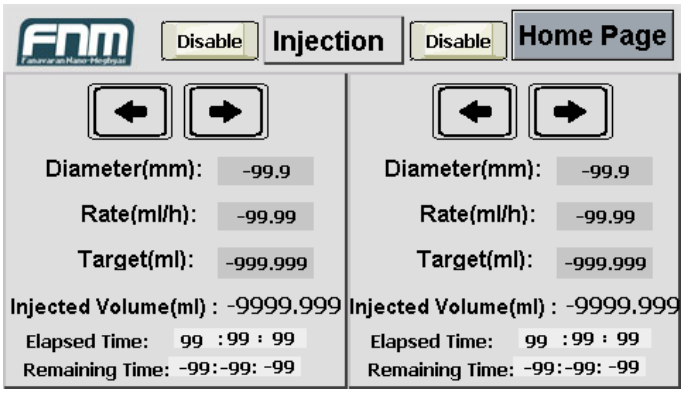
1.1.1 Serial Number

All inquiries concerning our product should refer to the serial number of the machine. Serial numbers are located on the rear of the case.

Electroris® serial number label

1.1.2 Calibration

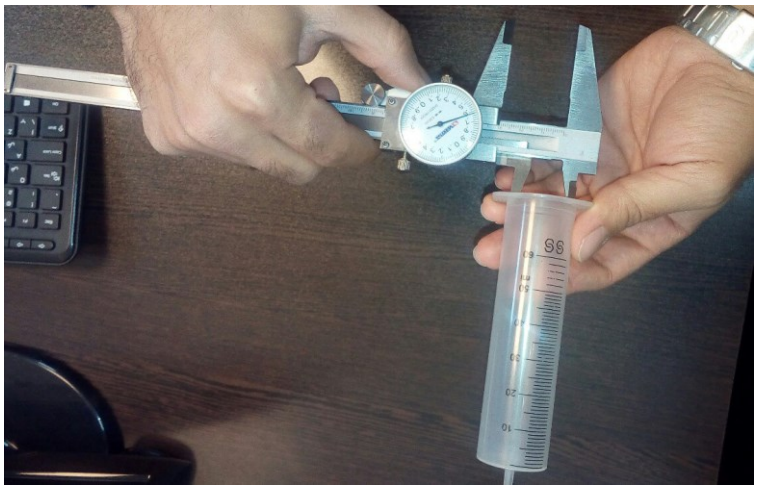
Note: High voltage power supply must be turned off during the calibration process.



Injection menu

All electrospinning units are designed and manufactured to meet their performance specifications at all voltages. It is sometimes necessary to check the calibration. The calibration process should be performed according to the following steps (it is not needed to mount syringe for doing calibration):

Step 1) Adjust the inner diameter of the syringe you want to use (the syringe diameter should be measured by a caliper),



Measuring the inner diameter of syringe using a caliper

Step 2) Adjust the flow rate of electrospinning solution,
Step 3) Adjust the target volume (the amount of solution that should be injected),
Step 4) Specify the start point of the pusher block of syringe pump (pusher block is the part that pushes the syringe to inject polymer solution),
Step 5) Press "Run" button on HMI "Home Page" to start the injection from the start point,
Step 6) After reaching the target volume, the machine will be stopped and now the end point should be specified and then the movement length of the pusher block (the distance between start and end point) should be measured,

Note: It is noteworthy that the injected volume of solution follows a simple mathematical formula:

$$V = \pi \times d^2/4$$

In which V is the injected volume of solution in ml, π is about 3.14, and d is the syringe diameter in mm.

For better understanding of the calibration procedure, the below example is presented:
Step 1) HMI panel → Home Page → Injection→ Diameter (mm): 10
Step 2) HMI panel → Home Page → Injection→ Rate (ml/h): 60
Step 3) HMI panel → Home Page → Injection→ Target (ml): 1
Step 4) Start point: ?
Step 5) HMI panel → Home Page → Run
Step 6) End point: ?, Calculate the distance between the start and end point. The obtained distance should be 12.73 ± 0.10 mm. If the calculated distance is higher or lower than 12.73 mm, the "Inject. calib. coefficient" in "Setting" menu should be changed.

Note: Entering the "Setting" menu needs password (Pass: 666666). In this case you can contact with us (info@fnm.ir).

Note: Please repeat the above procedure for injection rates of 6 ml/h and 1 ml/h (Step 2).

1.1.3 Warranty

Fnm Electroris® is warranted for a period of one year from date of purchasing. At its option, Fnm Co. will repair or replace the unit if it is found to be defective as to workmanship or material.

The warranty does not extend to:

- Damage resulting from transportation, wrong connections with other systems, connection with defective equipments, voltage fluctuations, fire or intensive heat, water or corrosive chemicals, dust, lightning, natural disasters, collision, misusing the machine or neglecting the manual description.
- The machines that have been repaired by other companies.
- The machines that have been manipulated.
- Damaging the machine labels or holograms
- Damage resulting from installation or updating the files, software, program and firmware by irresponsible people.
- Damage resulting from not connecting the machine to the earth.
- Damage resulting from connecting the high voltage wire to the body of machine, drum, syring pump and etc.

According to the warranty, our company will repair or replace the defective machine free of charge. You can send us the defective part(s) of machine (such as HV power supply or/and syringe pump) by post. We will accept any charge made for posting.

1.1.4 Repair Facilities and Parts

Fnm Co. stocks replacement and repair parts. While ordering, please describe parts as completely as possible. Preferably by using the part numbers, a sample or drawing.

1.1.5 CAUTION

➢ Improper use of the high voltage power supply can cause risk of electrocution and death. High voltages can bridge long distances and break through the isolation. On the surrounding objects, it can form a dangerous charge. If it is not connected properly to a suitable discharge resistor, capacitors can remain charged even after shutdown.

So, if the HVPS is on, do not open the machine door, and never connect the high voltage cable to another place (exception the nozzle).

➢ Solution inside the syringes is under pressure (especially while using nozzles with small diameters), which can lead to cut the nozzle(s) and spray the polymer solution around.

While working, to avoid spraying the solution, be sure the doors are closed or otherwise, use goggles and face shields.

1.1.6 Sparks in air

The dielectric breakdown strength of dry air, at Standard Temperature and Pressure (STP), between spherical electrodes is approximately 33 kV/cm. This is only as a rough guide, since the actual breakdown voltage is highly dependent upon the electrode shape and size. Strong electric fields (from high voltages applied to small or pointed conductors) often produce violet-colored corona discharges in air, as well as visible sparks.

1.1.7 Connecting the Machine to the Earth

Due to high voltages required to form polymeric nanofibers, it is necessary to connect the machine through an earth conductor of the power cord. Lack of a proper earth connection can cause electrical shock risks to the operator.
Given the importance of a proper earth connection, the laboratory wiring system should be equipped with an earth wire. Also, some power cables and sockets (three wires) must be used.
There is a screw at the back of the machine that should be connected to the water metal pipe in the laboratory by a piece of wire.

1.2 Maintenance and general safety summary

1.2.1 GENERAL SAFETY SUMMARY

Please read the following safety precautions to ensure a proper use of the machine. To avoid potential hazards and machine damage, use it only as instructed in this manual.
If the machine is used in a manner not specified by the manufacturer, the protection provided by the machine may be impaired.

1.2.2 To Prevent Hazard or Injury

Use a Proper Line Cord

Use only the specified line cord for this product and make sure the line cord is certified for country of use.

Use a suitable Power Supply

The unit is supplied with an approved power supply and line cord. To maintain the safety integrity of the machine, use only one of the following power supplies:

- 200 – 240 V AC, 50-60 Hz

Connecting Electroris® to earth

This product is connected to earth through the conductor of the power cord. To avoid electric shock, the earth connection conductor must be connected to earth. Before making any connections to the input or output terminals of the product, ensure that the product is properly connected to the earth.

Make Proper Connections

Make sure all connections are made properly and securely.

Use Proper Fuse

Use only specified fuses with product.

Avoid Exposed Circuitry

Do not touch any electronic circuitry inside of the product.

Do Not Operate with Suspected Failures

If damage is suspected on or to the machine, do not operate it. Contact with qualified service personnel.

Place the machine in Proper Environment

Review the operating manual for guidelines for proper operating environments. Keep the machine in a dry, clean and flat place. Avoid connecting the ventilation fan near the walls.

High viscosity solutions

Don't use high viscosity solutions and syringes with very low diameter nozzle (High gauges size).

Finishing the solution

Switch off the system after finishing the solution (Note: the target must always set at a suitable value).

Clean the machine

Clean the panel and body of the machine with a medium detergent.

Lubricating

Oil the syringe pump screws and their connections in certain time.

Observe all Warning Labels on Product

Read all labels on product to ensure proper usage. Please inform FNM Co. staff if there is any problem.

1.3 The machine limits

Accuracy of the electrospinning process largely depends on the syringe and its diameter. A measurement error will directly cause the injection error.

1.4 Warning

The sound alarm inside the machine can be set up to warn the user when each order is completed.

Chapter 2 Introduction

2.1 Theory of operation

2.1.1 Electrospinning process

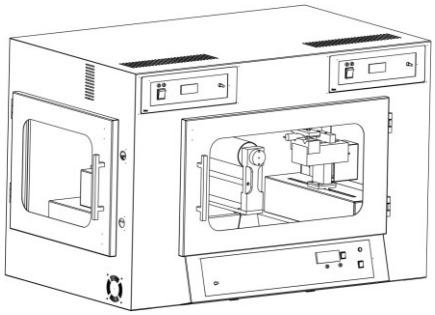
When a sufficiently high voltage is applied to a liquid droplet, the body of the liquid becomes charged, and electrostatic repulsion counteracts the surface tension and the droplet is stretched; at a critical point a stream of liquid erupts from the surface. This point of eruption is known as the Taylor cone. If the molecular cohesion of the liquid is sufficiently high, stream breakup does not occur (if it does, droplets are electro sprayed) and a charged liquid jet is formed.

As the jet dries in flight, the mode of current flow changes from ohmic to convective as the charge migrates to the surface of the fiber. The jet is then elongated by a whipping process caused by electrostatic repulsion initiated at small bends in the fiber, until it is finally deposited on the collector that is connected to the earth. The elongation and thinning of the fiber resulting from this bending instability leads to the formation of uniform fibers with nanometer-scale diameters.

2.1.2 Lab-scale dual pump Electrospinning unit (Electroris®)

Electroris® is a setup to prepare polymeric/ceramic nanofibers with diameter range of 50 nm to a few microns. Dual pump Electroris® electrospinning setup mainly consists of main body including two syringe pumps, two scan systems, collector system and two high voltage power supplies. Two different types of Electroris® are available: Standard model and dual pump Electrospinning system (Side by Side Electroris®).

This machine employs an HMI control panel for controlling electrospinning parameters including injection rate of polymer solution, working distance, rotating speed of collector drum, scan speed of injection systems, working temperature (room temperature to 45°C) and working time. Electroris® supplies sufficient safety scheme for users with respect to the handling of a high voltage power supply and chemical solvents.



Lab-scale dual pump Electroris®: 1) two high voltage power supplies (HVPSs), 2) drum collector, 3) controller & panel system, 4) two syringe pumps, 5) two scan systems

2.1.3 Characteristics and Capabilities

General
Chassis: Metallic body with 3 doors for easy access
Input power: 100-240 V AC/50-60 Hz
Ventilation: A programmable fan adjustable by HMI panel
Heating system: Adjustable from room temperature up to 45°C via HMI panel
Heater: 1000W, 4A
Safety: Voltage cut-off in case of door opening, earth connection problem, or process disruption
Dimensions (L×W×H): 131 × 80 × 96 cm
Weight: 140 kg

Main Features

- Advanced safety features
- Reliable performance
- Modular design
- 4.3" HMI touch screen control panel for controlling process parameters
- Emergency button to stop machine in any unexpected situation
- Easy use and maintenance
- Dual syringe pump model is available
- Operation Software (Optional)

Flexibility

- Various polymers and composites have the potential to be electrospun.
- Different product specifications such as porosity, morphology, diameter, and ability to load beads can be obtained.
- Different polymers can be electrospun simultaneously, due to the existence of two syringe pumps
- The process is easy and economical.
- Many different polymer types such as synthetic, biodegradable and natural polymers and/or polymer/composite may be processed.
- Aligned nanofibers can be produced by high speed rotating collector or using wire type collector

Spinneret
Number of syringes: Up to 4 syringes
Configuration: Horizontal
Scanning rate: 0-30 mm/s
Scanning range: 0-30 cm
Syringe pump injection rate: 1 μl/h to 500 ml/h

Usable syringe size: 1-25 mm (Inner Diameter)
Operation mode: Constant flow rate and maximum volume of injection
Accessories (Optional): Co-axial nozzle with tubing
2 syringe pumps (Up to 4 syringes can be used)
2 scan systems
2 distance systems

Collector
Type: Rotating drum (wire, cylinder, mandrel and disk collectors are optional)
Material: Stainless steel
Rotation speed: 350-3000 rpm
Spinning distance: 5-20 cm
Size:

- Drum:8(ø) cm × 30(L) cm
- Plate: 25(L) cm × 20(W) cm
- Wire: 8(ø) cm × 25(L) cm
- Disk: Diameter: 19.8 cm
- Mandrel:
  Length: 25 cm
  Diameter: 2, 4, 6, 8 and 10 mm

Attachable to negative high voltage power supply up to -20 kV (Optional)

High voltage power supply
Model: HV35P OV
Max. output voltage: 35 kV
Power: 35 Watt
Voltage monitoring: Digital, Accuracy: 0.1 kV
Body: Durable metal casing
Two high voltage power supplies are installed for dual pump series

Control
Type: PLC
HMI: 4.3” touch screen

- Start and end position of the nozzles
- Injection rate of syringe pumps
- Electrospinning distance
- Electrospinning time
- ON/OFF timer for exhaust fan
- ON/OFF timer for heater

- High voltage ON/OFF switch and ON/OFF button in HMI, Adjusting high voltage by a 10-turn potentiometer mounted on high voltage power supply
- Drum ON/OFF switch (RPM controller) in standard series, and control from HMI screen in dual pump series
- Temperature control (Dual pump series)
- Alarm after desirable volume of injection and after finishing the solution in syringe (after the operation of syringe pump switch)

2.1.4 An overview of Dual Pump Electrospinning Machine

The main components of a lab-scale dual pump electrospinning unit include the following:
2 HVPSs, drum collector, system controller & panel, 2 syringe pumps, 2 scan systems, 2 distance system.

2.2. Features

2.2.1 General

The syringe pumps of this machine have been designed in order to use a variety of syringes. The system is able to inject the certain volume of solution with different rates. All models employ a PLC which controls a small step angle stepping motor that drives a lead screw and Pusher Block. Micro-stepping techniques are employed to further reduce the steep angle, eliminating flow pulsation. A 4.3 inch HMI screen is used for entering the data to the pump. The diameter of the syringe is entered via the keypad on the screen; and the internal microprocessor drives a precision stepper motor to produce accurate fluid flow. The pump can hold syringes of nonconductive materials (plastic or glass). Nonvolatile memory stores the last syringe diameter and flow rate along with other configuration data.
This machine has two independent syringe pumps; and injection of the solution is done with 1 µl/h accuracy. In this model, on both sides of the drum, there are two injection systems including two syringe pumps, two scan systems, two distance adjustment systems and two controllable high voltage power supplies (from 0 to 35 kV).

In this machine, fibers from two sides of the drums are stacked, thus it is possible to produce nanofibers from different materials. Also you can add nanofibers in one side and nanoparticles or additives on the opposite side to them. So the dual pump model will be very convenient for medical, pharmaceutical and biological applications.

Due to the length and diameter of the drum, it is possible to collect smooth nanofibrous seals with dimensions 30×25 m^2. Due to the high-speed drum rotation, the production of arranged and parallel nanofibers, especially by using a wired drum is possible.

2.2.2 Easy-To-Use Interface

The essential information is shown on a touch screen HMI LCD, and the LCD background light facilitates the reading of information in the darkness. Different parameters such as flow rate, syringe diameter, maximum of injection, start & end scan position, scan speed and distance are adjustable.
There is a box in front of all adjustable variables in each menu. A virtual keyboard is shown by pressing the mentioned boxes and the variables can be changed. It should be noticed that the allowed range of each variable is indicated on the appeared numerical keyboard. If an out of range value is entered, "Error!" message will be shown.

2.2.3 Syringe Table and Custom Syringes

If a non-standard syringe is to be used, enter the inside diameter of the syringe in millimeters. Syringes are arranged according to manufacturer and material, and then according to size (Appendix A).

2.2.4 Target Volume

Specify the volume that is to be injected. The pump will run at the rate specified until this volume has been delivered in the Volume mode.

2.2.5 Nonvolatile Memory

All operational data entered into the pump from the HMI screen will be stored, including the program.

2.2.6 Smooth injection

Using a high accuracy motor and driver profiles deliver smooth and consistent flow, that is almost pulse free.

2.2.7 Adjusting the Pusher Block

Using two keys for each electrospinning unit in "Injection" menu that move the pusher block forward or backward can adjust their positions rapidly.

2.2.8 High Voltage Cable

Before turning on the machine, make sure the cable is connected to nozzle(s). Connecting the high voltage cable to every part of the machine (except the nozzle) causes transmission of high voltage to the machine and can fail it. Also it can damage the high voltage power supply.

Note: Before starting the electrospinning process, be sure the high voltage power supply is off.

2.2.9 Visual/Audible Alarm

In addition to visual alarm, the machine has an audio alarm that will sound in required times.

2.2.10 Package contents

Electroris® package contents are a power cable, earth cable, user manual, two syringes in two sizes, and two needles in two different gauges, alligator clips, Allen wrench in two different sizes, the polymer solution and two 5A fuses.

Chapter 3 Installation

3.1 Physical installation

The following conditions must be noticed at the place where you work:

- A dry, clean and hard surface to keep the machine
- Minimum of about 15 cm clearance around the machine.
- suitable environmental conditions
- a proper ventilation

3.2 Checking before turning on the machine

Due to the use of high voltage to form nanofibers, be sure the machine is properly connected to the earth system. Lack of proper earth connection can cause damage to electrical systems in a few seconds, as well as it can also have associated risks.

Given the importance of proper earth connection, wiring system of the laboratory should be equipped with the earth system. Also, power outlet and electrical wires with earth should be used.

Before turning on the machine, be sure that the connection of HV cables to suitable places is accurate. Connecting HV cable to anywhere of the machine, except suitable places, can cause transmission the high voltage to the electronic systems and fail them. It can also cause damage the HV.

When you turn on the machine, the electricity will enter to the HV. When you turn on any of the HVs, the power of HV will be transferred to the system. It can increase the risk of electric shock and damage to the machine because of the lack of user preparation.

Note: Be sure that the high voltage power supply is off before turning on the machine.

3.3 Turning on the machine

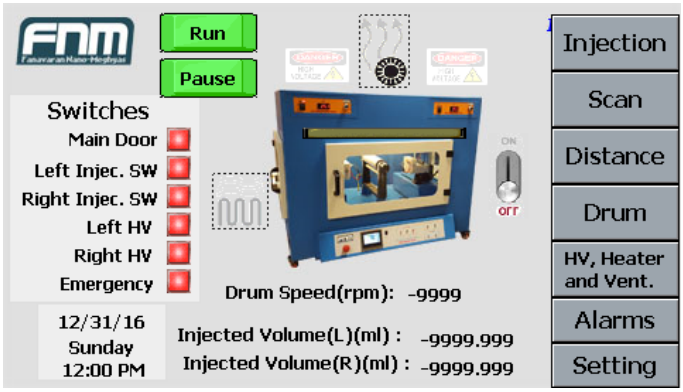
- Plug in the power and then connect it to the input voltage.
- Connect the Earth cable.
- Turn on the Miniature Circuit Breaker (MCB) key located at the back of the machine.
- Use the black key on the right side of the machine to turn on the Electronic control panel.
- Press the black On/Off key in front of the machine to turn on the HMI screen.
- At this time, the display will be turned on and “Home Page”, in which there are a schematic illustration of Dual-pump Electroris® and the menus, will be shown.
- Put the syringe(s) containing polymer solution(s) in the syringe pump (in “V” shape holder)
- Use  keys in 

menu to move the pusher blocks of the syringe pumps in each electrospinning unit and put them just behind the syringe(s).
- Connect the high voltage cable(s) to the syringe(s).

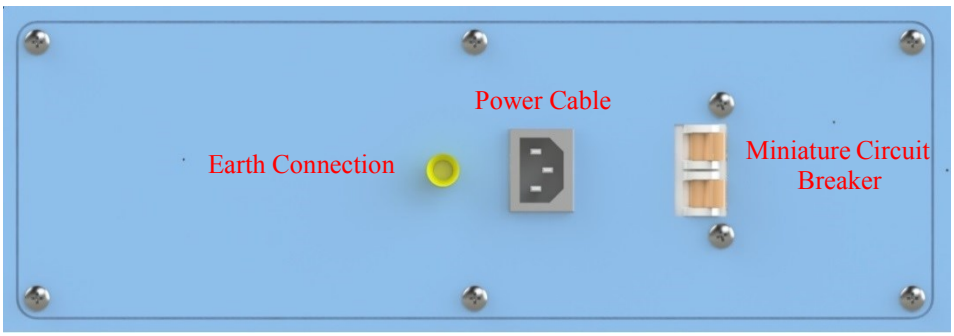
- Adjust the electrospinning distance for each electrospinning side in Distance menu.
- Adjust the scan speed, start and end position (scan range) for each spinneret in Scan menu.
- Adjust the rotating speed of drum collector in Drum menu.
- Adjust the temperature of the chamber, ON/OFF time of heater and ventilation system in HV, Heater and Vent. menu.
- By turning on the machine, the HVPSs are in standby mode that are shown by a blue LED. Use the On/Off key on the HMI in HV, Heater and Vent. menu and then the On/Off key on the high voltage power supplies to turn on them, at this time the red LED will be turned on.

Note: Before turning on the HVPSs, please be careful that the high voltage cables are not connected to the body of the machine. Additionally, set the voltage of HVPSs at the minimum value by rotating the 10-turn potentiometer counterclockwise, before turning on.

- Touch Run button on "Home Page" to start the electrospinning process.



HMI home page



Rear of the machine

Note: Before starting the electrospinning process, be sure that the Earth connection attached to the drum is connected correctly.

Warning:

1) If the temperature system is in trouble, the heating system switches (fuse) at the back of the machine should be checked.

2) The power input fuse of the control panel system is embedded inside the main key.

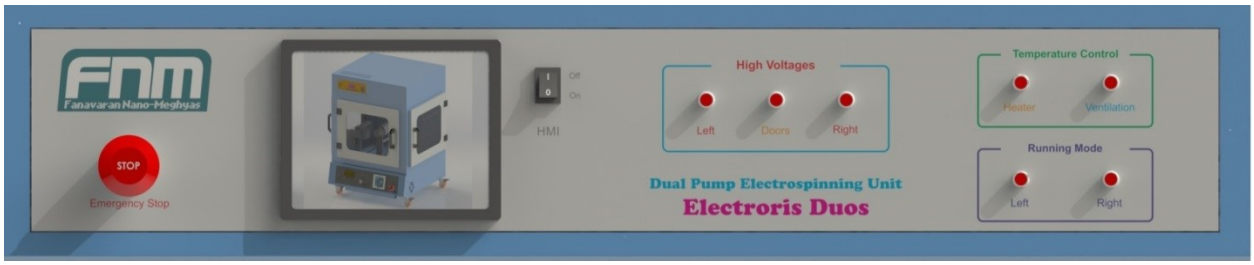
If the power input fuse is in trouble, you should check the fuse.

Chapter 4 Performance

4.1 Components

4.1.1 Human Machine Interface (HMI)

The screen of the dual-pump electrospinning machine is a 4.3 inch HMI touch screen which is assembled on the panel in front of the machine.



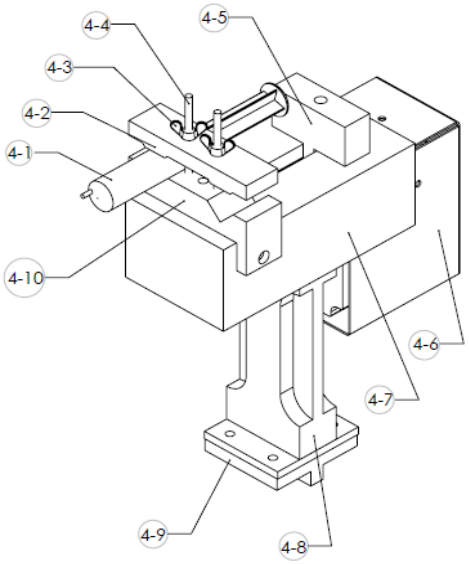
The panel of Fnm dual pump electrospinning machine

HMI screen is used to enter data and electrospinning parameters and changing the machine's settings. Data entry will be discussed in detail later in this chapter. Informational messages appear at various times to indicate such items as a data setting out of range, or a detected problem such as the pump out of range flow rate.

HMI home page

HMI home page screen contains six menus on the right side that are oriented vertically, some process information in the center, below the schematic image of electrospinning unit, and the machine's switches on the left side. The mentioned switches have two modes, when the machine is working the squares in front of them turn to green, however, if the doors are open, the injection is stopped, the high voltage is not applied or the emergency button is pushed, the machine will not operate and their related switches will turn to red, as well.

4.1.2 Syringe pump



4.1. Syringe
4.2. Syringe clamp
4.3. Thumbscrew
4.4. Clamp screw
4.5. Pusher block
4.6. Stepper motor case
4.7. Plastic case
4.8. Syringe pump system base
4.9. Interface part between syringe pump and distance system rail
4.10. Syringe holder base

4.1.2.1 Loading the Syringe

1. Adjust the syringe pusher block (4.5) by entering “Injection” menu on “Home Page” and pressing ◄►.
2. Raise the spring loaded syringe retainer (4.3) and swing it out of the way.
3. Lay the loaded syringe in the ‘V’ shaped syringe block.
4. Swing the syringe retainer so it holds the syringe in place.
5. Move the pusher block (4.5) by entering Injection menu on “Home Page” and pressing◄► so it makes contact with the syringe plunger.
6. Tighten down thumbscrews on syringe block bracket so that it captures flanges on syringe barrel.
7. Tighten thumbscrew into place when switch is set.

4.1.2.2 Proper syringe selection

Min Rate (Microliter/hour) = 0.5 * Syringe diameter (mm) ^ 2
Max Rate (Milliliter/hour) = 0.80 * Syringe diameter (mm) ^ 2

Example:
A: diameter syringe: 1 mm Min rate: 0.5 µl/h; Max rate: 0.8 ml/h
B: diameter syringe: 10 mm Min rate: 50 µl/h; Max rate: 80 ml/h
C: diameter syringe: 17 mm Min rate: 144 µl/h; Max rate: 231 ml/h

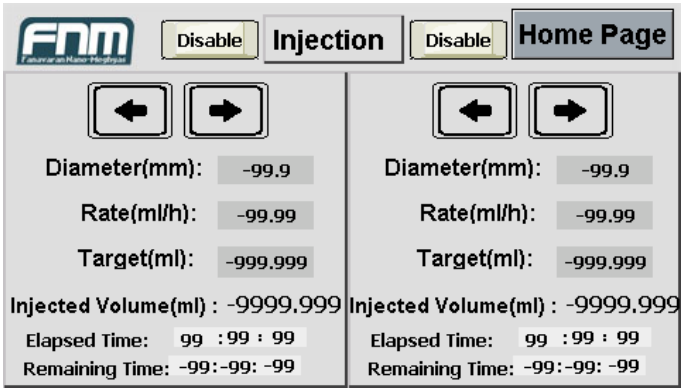
4.1.2.3 Syringe pump (injection) system

The syringe pump system can take one or two syringes in each electrospinning unit made by nonconductive materials (plastic or glass syringes) and sizes below 50 ml. The inner diameter of the syringe(s) should be entered at Diameter(mm): -99.9 on Injection menu and the internal microprocessor calculates the cross-sectional area to calibrate the pump for that syringe.

Note: The electricity can be transferred to the syringe, so the syringe shouldn't be contaminated by the solution. If the syringe is contaminated, you will hear the discharge noise. In this time, the "high voltage" should be turned off and cleaned off the contaminated area immediately.

In each syringe pump, one or two syringes can be used. Using two syringes in each electrospinning unit increases the amount of produced nanofibers. However, because of the interaction between the formed polymer jets on the nozzles' tip, using more than one syringe can alter the nanofiber size and its morphology. So, it is better to use one syringe to optimize the process.

By pressing "Injection" button (Injection) the following page will be shown. The left section belongs to the left electrospinning unit and in the right one the settings of right electrospinning unit can be adjusted.



Injection menu

Note: Since various syringes have different dimensions, and it is very difficult to determine the end point of injection automatically by the machine, it is recommended that the maximum injection volume is set at the volume of solution (in the syringe). For example, if the syringe contains 2 mililiters of the solution, the maximum volume should be set at 2, in order to be turned the machine off automatically after finishing the solution.

In this page 3 injection parameters are adjustable:

Diameter (Diameter(mm): -99.9): It is the most important parameter in calculating the flow rate, so it is necessary to measure and enter it correctly. When the syringe is changed, the new diameter value must be set. Units are in millimeters (mm). Enter the inside diameter (ID) of the syringe you wish to use. If you do not know your syringe diameter, refer to appendix A

for nominal inside diameters of most popular syringes. For the greatest accuracy or if your syringe is not listed in appendix B, measure the inside diameter with a vernier caliper or other precision measuring tool. For setting it, press the rectangular box in front of Diameter(mm): and enter the diameter of syringes in each side.

Rate (Rate(ml/h): -99.99)**:** The appropriate value for injection rate of each electrospinning unit should be set here which depends on polymer solution properties like molecular weight of polymer, viscosity and the concentration of solution.

Target (Target(ml): -999.999**):** The desirable amount of polymer solution to be injected in each electrospinning unit can be set here.

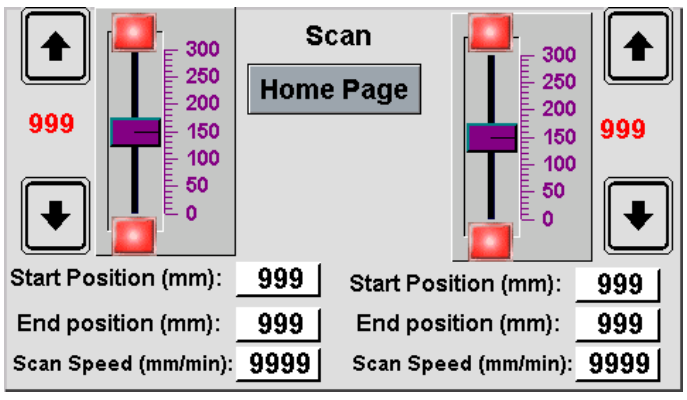
Minimum and maximum injection rate: According to the selected syringe, the maximum and minimum injection rate can be varying. Using a 5-ml syringe (for rates less than 10 ml/h) or a 2-ml syringe (for rates less than 1 ml/h) is suggested to increase the injection accuracy. For higher rates, you have to use a syringe larger than 5 ml.

Description: The minimum and maximum rates largely depend on the syringe diameter. If the entered injection rate is more than the defined rate for the system, the "Error!!!" message will be shown. So you have to use another syringe for your application.
Finishing the solution: When the pedal (Pusher Block) reaches to the end position, the system will automatically stop (the safety switch operates) in order to avoid damaging the screws and the motor, so the pedal must be moved backwards manually by pressing the positional buttons ( ) in each side and the syringe must be changed.

Note: Because of different sizes of syringes, automatically determining the end of injection is difficult. So, it is recommended that the maximum volume is set at the amount of solution. For example, if the syringe contains 2 milliliters of the solution, the maximum volume should be set at 2, to turn the machine off automatically after finishing the solution.

4.1.3 Nozzle Scan System

By pressing "Scan" button (Scan) on the "Home Page" the following page will be shown:



Scan menu

In this page, 3 parameters are adjustable:

"Start Position (mm)" Start Position (mm): 999 : Adjust the starting point of scan for each electrospinning unit by entering the value in the front box. It cannot be more than end position.

"End Position (mm)" End position (mm): 999 : Adjust the ending point of scan for left or right scan system by entering the value in the front box. It cannot be less than start position.

To move the scan system manually, ⬆ or ⬇ should be pushed in each electrospinning unit.

"Scan Speed (mm/min)" Scan Speed (mm/min): 9999 : Adjust the scan speed for left or right scan system by entering the value in the front box. It cannot be more than.

Example 1: Start Position = 100; End Position = 250; Scan Speed = 500

According to the example, the scanning is done from the starting point (100 mm) to the end point (250 mm) with the rate of 500 mm/min.

Example 2: Start Position = 150; End Position = 150; Scan Speed = 0

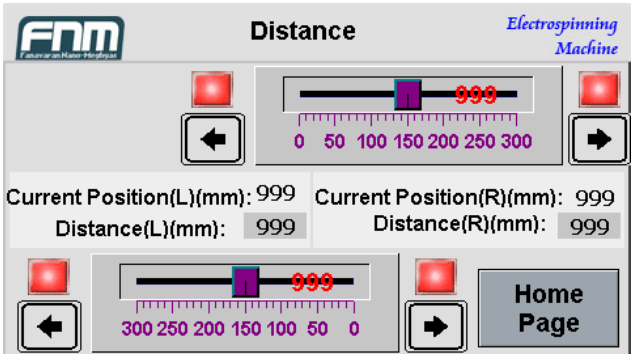
According to the example, only adjusting the nozzle is done at the point of 150 mm and remains constant.

4.1.4 Distance adjustment system

Distance between the nozzle tip and the collector is called "electrospinning distance" based on the conditions, it is usually from 10 to 20 cm, more or less. In most systems, the collector is connected to the earth; however, connecting the negative voltage to the collector has interesting results.

Note: According to different sizes of nozzles, the electrospinning distance can be more/less than the calculated value, so it must be corrected by the user.

By pressing Distance, the following page will be shown:



Distance menu

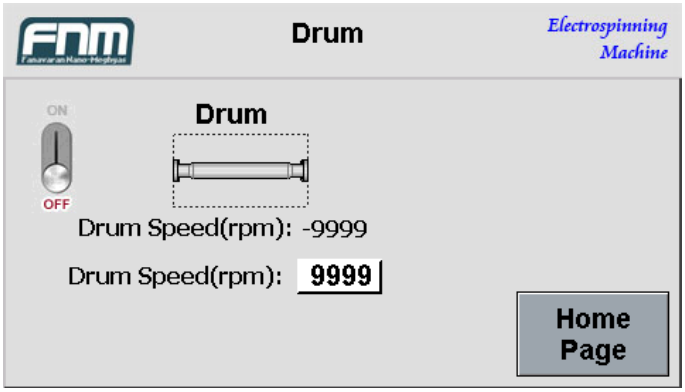
Current Position(L)(mm): shows the current position (distance) of the left syringe pump toward the drum collector.

Current Position(R)(mm): shows the current position (distance) of the right syringe pump toward the drum collector.

Adjusting the electrospinning distance for the left and right electrospinning units should be done by pressing the box in front of Distance(L)(mm): and Distance(R)(mm): , respectively. The distance of each electrospinning unit is changed manually by pressing ◄ or ► buttons in Distance menu.

4.1.5 The drum (collector) rotation speed

By pressing Drum on "Home Page" the following page will be shown:



Drum menu

The collector speed can be adjusted in Drum Speed(rpm): section in the box in front of it. The upper Drum Speed(rpm): shows the momentum speed of drum collector. Due to the type of electrospinning system, the minimum and maximum drum rotation speed can be variable. In high speed systems (up to 2500 rpm), the minimum rotation speed is about 350 rpm.

Moving the scroll in 

turns ON/OFF the drum collector.

4.1.6 High voltage, heater and ventilation system

To turn ON/OFF the heater, in "Heater" section the scroll in 

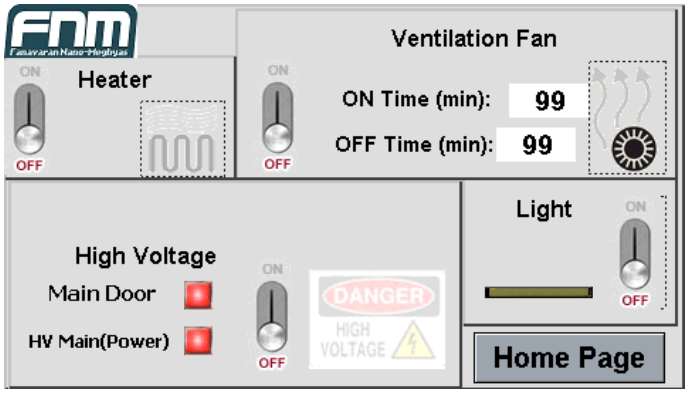
should be moved. The maximum temperature of chamber can be set at 45 °C. The red LED indicates that the heating system is "ON" and the blue LED shows that the ventilation system is "ON". The right key is used to turn this system ON/OFF. The ventialtion fan is turned ON/OFF by moving 

scroll in "Ventilation Fan" section. The time in which the ventilation fan works, is shown in front of

ON Time (min): and it is changeable by pressing the front rectangular box. The machine's off time is shown in the rectangular front box (OFF Time (min):) and it can be changed by pressing the box and entering value via the exhibited keypad.

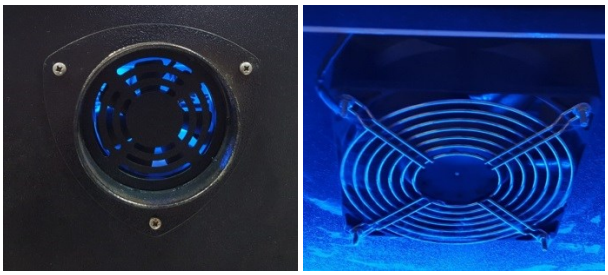
To turn ON/OFF the chamber's light 

should be put on "ON" mode in "Light" section.



HV (High Voltage), Heater, and Vent Menu

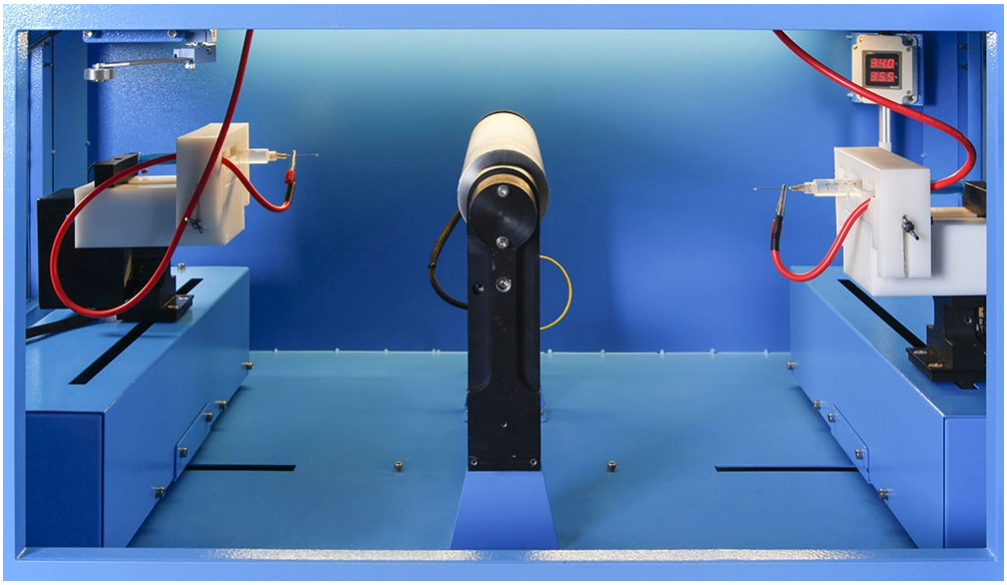
Ventilators: Since the formation of nanofibers is done by evaporating the polymer solvent, any factor that reduces the evaporation can impair the formation of nanofibers. Because the chamber is closed, after a short time, the solvent vapor saturates the chamber and the evaporation process will be slow. So, it is necessary to bring the solvent out of the chamber without affecting the temperature. Hence, a small ventilation fan is placed behind the machine. It is controlled by a thermostat timer and is automatically turned on/off.



Ventilator at top of the machine

Description: If it is necessary to work at room temperature, it is better that the desired temperature is set below the room temperature rather than turning off the heating system (that makes the ventilation fan turn off).

Because the temperature can directly affect the viscosity and surface tension of polymeric solutions, it is one of the most important parameters in electrospinning process, especially in research works.



Inside view of a dual pump Electroris®

Note:

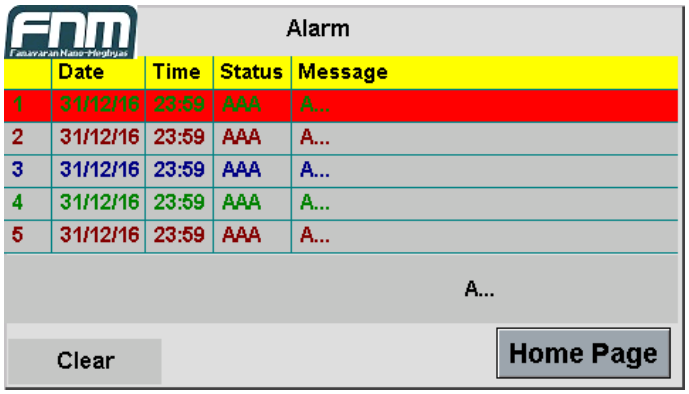
After finishing the electrospinning process, it is necessary to clean inside the nozzles and the junction point of nozzles and syringe thoroughly, and to place a thin wire inside the syringe to prevent drying polymer and plumbing.

Note:

It is better to wrap the syringe by a dry plastic bag, because plastic syringes do not have enough strength to prevent passage of high voltage power, especially when using very high voltage (above 25 KV).

4.1.7 Alarms

In case of occurring any unwanted event, the reason will be recorded in "Alarms" page. These events are like opening the doors, suppressing high voltage, emergency stop, reaching the syringe to end limit, finishing the process.

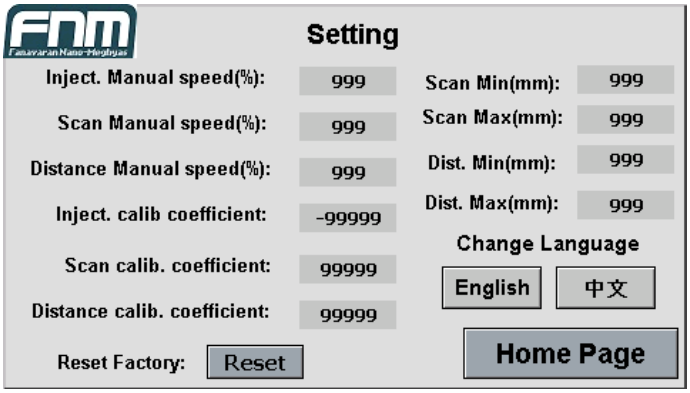


Alarm menu

4.1.8 Setting menu

All of Electroris® settings such as injection, scan, distance and all calibrations related to the machine and language settings are located in setting menu as following.

Note: This menu needs password to enter and is not accessible for users. The settings in this menu are adjusted by FNM Co. and they can be changed by the company if the machine needs repair.



Setting menu

4.2 Safety in working with the machine

4.2.1 Earth connection

The machine should be connected to the earth appropriately to prevent damaging electronic parts of Electroris® especially high voltage power supplies.

4.2.2 Emergency stop

When an unexpected event occurs during the machine operation (such as arc in high voltage power supplies) or the operation is interrupted, the "Emergency" button should be pressed to prevent damaging the machine. At this time, the activity of all parts of the machine stops. To restart the machine, "Emergency" button should be rotated in clockwise rotation.

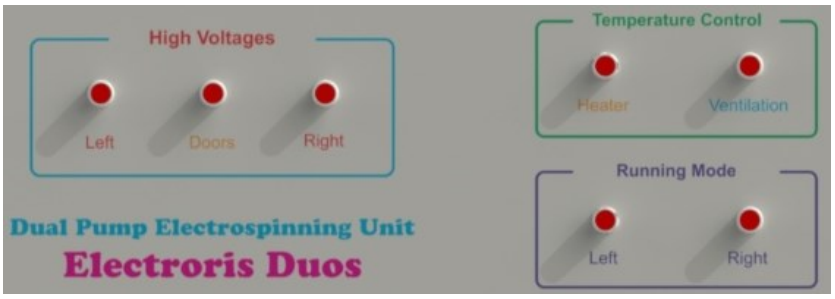
Emergency Stop button

Note: According to the independent power and discrete wiring, be sure the emergency disconnect switch to be tested often.

4.2.3 LED lights on the panel

There are 3 sets of LED lights on the panel which can be on or off based on some conditions. Left and right LEDs (red lights) (in "High Voltages" section) are related to the left and right HVPSs, respectively and each of them will be on when its related HVPS is working during electrospinning process. If one of the doors is open, "Doors" LED (yellow light) in "High Voltages" section will be turned on and the HVPSs do not apply due to the safety reasons. "Heater" (red light) and "Ventilation" (blue light) LEDs are located in "Temperature Control" section and will be turned on during heater and ventilation operation, respectively. There are two LEDs in "Running Mode" section which are related to the left and right

syringe pumps and during the operation of each syringe pump, its related LED will be turned on.



LED lights on dual pump Electroris® panel

Note 1: The maximum adjustable temperature is 45°C. Although it's possible to be more than 45°C, but it is recommended to set the temperature below 45 °C to avoid damaging the electronic parts and power supply system.

Note 2: In this machine, you cannot set the chamber temperature less than ambient temperature.

4.3 High Voltage Power Supply (HVPS)

OV Series with an output high voltage indicator (Accuracy=0.1 kV).

OC series with an output high voltage indicator (Accuracy=0.1 kV) and an output current display (Accuracy=1 micro-amp).

Two power supplies (each electrospinning unit has one high voltage power supply) with a positive 35 kV output have been embedded in this machine that have a current indicator based on microampere (custom).

4.3.1 Turning on the HVPSs

Putting 

in “ON” mode in “High Voltage” section turns on the high voltage power supply (from 

menu on HMI screen). At this time, the blue LED is on. By putting “ON/OFF” key (on the HVPS) in “ON” mode the HVPS turns on.

Note: Before turning on the machine, make sure that the ON/OFF key on the HVPS is "OFF".

There is a 10-turn voltage regulator on the right side of the high voltage power supply to increase or decrease the voltage.

Note: For more safety, before turning on the HV, set the potentiometer at a low voltage and then adjust it at the desired value. In this case, any unwanted connection will be identified and fixed at lower voltages. After turning on the HVPS, the red LED will be "on".

Kilo-Voltmeter: The display indicates output voltage of the power supply (KV) with accuracy 0.1 kV (100 V).
For more safety, three switches have been placed on the machine doors. When the door(s) is (are) open, these switches operates and do not transmit high voltage from the source to the cable.

Note: If you turn on the HV but Kilo-Voltmeter shows zero, you should check the doors be closed.
Micro ampere meter (custom-made): There is a micro-ampere meter to show the current at the high voltage output that provides interesting information about electrospinning process. Accuracy of the ampere meter is one Micro-ampere (one-thousandths MA).
Note: Due to low electricity consumption in the electrospinning process (the amount of current flowing from the nozzle tip to the drum), any increasing in the current shows the discharge. In this case, the machine should be turned off and the discharge situation, especially connection sites in the syringe pump, should be checked.

Chapter 5 Safety

5.1 Risk of electric shock

Improper use of the high voltage power supply can provide a risk of electric shock. Before starting to work with HV, all safety measures should be considered. All connections, especially the earth, should be investigated. Make sure they are correct.
The high voltage power supply in electrospinning machine can vacate the high voltage from a few centimeters to any conductive point such as human body. So, you should not open the door of the machine while the HV is working. Also, you should not connect the cable of HV to any place exception the collector and tubs.
Note: Compliance with safety tips for you and your colleagues is your responsibility.

5.2 Safety equipment and emergency procedures

5.2.1 General Information

Chemistry laboratories are equipped with one or more eye to wash fountains and safety showers. Each person who uses such laboratories must be familiar with the locations of this equipment and know how to use it. Properly equipped laboratories will also have fire extinguishers; do not attempt to use a fire extinguisher unless you have been trained in its use by a qualified firefighter. Your laboratory has a plan for everyone to follow if an evacuation is necessary. Be sure that you know the main and the alternate evacuation routes as well as the procedures for assembling outside the building and accounting for each person who was in the laboratory.
In case of an emergency, as much as possible, follow procedures that have been established and that you have practiced. The first and most important step in any emergency procedure is this:
Before helping another person, evaluate the potential danger to yourself. If you try to help and are injured, you cannot be of much further help to someone else.

When an emergency occurs, the following actions are recommended:

- Report the nature and location of the emergency to your instructor and, if necessary, to the appropriate fire or medical facility. State your name, location, and phone number you are using. Tell where you will meet the emergency vehicle. If individuals are involved, report how many; whether they are unconscious, burned, or trapped; whether an explosion has occurred; and whether there is/has been a chemical or electrical fire.
- Tell others in the area about the nature of the emergency.
- Do not move any injured individual unless they are in immediate danger from chemical exposure or fire. Keep them warm. Unnecessary movement can severely complicate neck injuries and fractures.
- Meet the ambulance or fire crews at the place you indicated. Send someone else if you cannot go.
- Do not make any other telephone call unless they relate directly to the control of the emergency.

5.2.2 Fire Prevention

The best way to fight a fire is to prevent it. You can prevent fire and reduce its severity considerably through proper housekeeping and thoughtful reflection about what you are doing.

This includes:

Maintaining unobstructed aisles and exits, storing only limited quantities of flammable material, promptly disposing of waste, and separating flammable liquids from combustible materials, such as cardboard boxes and paper towels.

Stand back, take a look, and ask:

- Are there any frayed wires?
- Is a stirrer with a sparking motor being used to stir a flammable liquid?
- Are those bottles too close to the edge of the bench?
- Is the workspace cluttered?
- Do I understand each of the potential hazards in what I am about to do?
- Am I prepared in advance to take preventive steps?

5.2.3 Dealing with a fire

When a fire occurs, the following actions are recommended:

● A fire contained in a small vessel can be often suffocated. For example, use a watch glass to suffocate a fire in a beaker by covering the mouth of the beaker. Do not pick up a vessel that is on fire. Do not cover it with dry towels or cloths; use a wetted material. Remove nearby flammable materials to avoid spreading the fire.

● Activate the fire alarm. Notify co-workers and your instructor. Call the fire department.

● If the fire is burning over an area too large for the fire to be suffocated quickly and simply, everyone should evacuate the area except those trained and equipped to fight fires. Use the stairs to leave the building, do not use the elevators. Follow evacuation procedures that have been established and that you have practiced during prior fire drills.

● It is easy to underestimate a fire. Never attempt to use a fire extinguisher unless you have been trained in its usage, and know that it is likely to extinguish the fire. If you have been trained in the use of a fire extinguisher, locate yourself between the fire and an escape route (e.g. a door) and fight the fire from this position, but be sure you can escape. Small fires just starting can be often extinguished, but not always. If not extinguished, a fire can quickly threaten your life and your co-workers.

5.2.4 Personal injuries involving fires

When a person's clothing is on fire, you may need to lead him/her to the safety shower. Some people instinctively run randomly if their clothes are on fire, which fans the flames and increases their injuries. If possible, stop an individual from running.

If the shower is not readily available, douse the individual. Get him/her to stop, drop, and roll; that is, to lie down and roll to put out the fire. Then, try to extinguish any small, still-burning flames by patting them out. Beat out the flames around the head and shoulders. Then, work downward toward the feet. Next, cover the victim with a coat, blanket, or whatever is available but leave the head uncovered.

Do not use fire blankets until the fire is extinguished.
While wearing gloves if necessary, remove any clothing contaminated with chemicals. To prevent contamination of the eyes, use scissors when removing pullover shirts or sweaters. Place clean, wet and cold cloths on burned areas. Wrap the victim to avoid shock and exposure. Get medical attention promptly.
If the victim is standing, wrapping the body with a fire blanket or other material can force flames toward the face and neck and, if wrapped tightly, can press melted globs of what once was polymeric clothing fabric into the flesh. Thereby, it accentuates the severity of injury to the victim.

5.3 Chemicals on Skin, Clothing, and Eyes

For small liquid spills that only affect a small area of skin, immediately flush with flowing water for at least 15 minutes. Remove any jewelry to facilitate removal of possible residual liquid. If there is no visible injury, wash the entire area with warm water and soap. Check the MSDS to see whether any delayed effects should be expected. It is advisable to seek medical attention for even minor chemical burns. Hydrofluoric acid spills require special treatment; Solid chemicals that are spilled on the skin can usually be brushed off with no adverse consequences. The brushed-off solid should, of course, be put into the appropriate hazardous waste container. If the solid adheres to your skin, call your instructor.
Larger spills of a liquid on the skin and any spills of liquid on clothing can have serious consequences. Do not waste time by attempting to wipe or flush off the spill; get to the safety shower immediately. Quickly step under the showerhead and in the falling water spray; remove all contaminated clothing, shoes, and jewelry while the safety shower is on. Don't waste time with modesty. Try to avoid spreading the chemical further over your skin, especially into your eyes. Don't contaminate your eyes by removing pullover shirts or sweaters—someone else should cut the garment off with scissors while you are still in the shower. Flood the affected body area with temperate water for at least 15 minutes. Resume if pain returns. Do not use creams, lotions, or salves. Get medical attention without delay.
Launder contaminated clothes separately from other clothing or discard, as recommended in the MSDS.
Note: Never work with chemicals in a laboratory unless it is equipped with a safety shower that has been tested within the past six weeks.
A record, usually a tag affixed to the safety shower, should state the most recent test date and the tester's initials. For splashes into the eye, immediately flush the eye with temperate potable water from a gently flowing source for at least 15 minutes. Use your thumb and forefinger to hold your eyelids away from the eyeball, move your eyes continuously up and down and sideways, to flush out thoroughly behind the eyelids and behind the eyeball itself. An eyewash fountain should be used, but if one is not available, injured persons should be placed on their backs and water gently poured into the corners of their eyes for at least 15 minutes. After any first aid treatment to the eyes, promptly visit a member of a medical staff or an ophthalmologist who is acquainted with the management of chemical injuries to the eyes.

Note: Do not touch a person in contact with a live electrical circuit. Disconnect the power first! Otherwise, you may be too seriously injured.

5.4 Spills cleanup

Clean up all spills promptly, efficiently, and properly. Call your instructor for help. Warn all individuals who may be at risk to be exposed to the hazard, and minimize its spread. The toxicity of the substance is often more important than the volume of the spill.

If a flammable material is spilled, warn everyone to extinguish all flames immediately to turn off spark-producing equipment such as brush-type motors, and leave the area. You should do any work with a flammable toxic material in a laboratory hood; if a spill occurs, close the hood and call your instructor.

The smaller area is involved, the less the damage is and the easier the cleanup. Follow your instructor's directions.

Many small liquid spills on the floor or laboratory bench (e.g., less than 200 ml) can be absorbed with paper towels, sand, or special absorbent. Of course, whatever is used becomes contaminated and must be handled as a hazardous waste. Be particularly careful that flammable liquids absorbed during cleanup are not present in the fire hazard.

Most spills of solids can be brushed up and disposed of in appropriate solid waste containers, but exercise care to avoid reactive combinations with a chemical that was put in the container earlier. Do not leave materials used to clean up a spill in open trash-cans. Follow your instructor's directions.

Dike larger liquid spills on the floor by surrounding the involved area with an absorbent retaining material. Commercially available or homemade spill control kits can be useful. If possible, use an absorbent material that will neutralize the liquids (limestone or sodium carbonate for acids, sodium thiosulfate solution for bromine, etc.). Commercial absorbents (e.g., Oil-Dri and Zorb-All), vermiculite, or small particles (about 30 meshes) of kitty litter or other satisfactory clay absorbents can be used. Dry sand is less effective.

Use a dustpan and brush, and wear protective gloves to clean up dry spills and liquid spills that have been absorbed by an absorbent. Wear leather or other protective gloves while cleaning up broken glass. Then, clean the contaminated area with soap and water, and dry it. Place a warning sign that says "Wet and slippery floor," or sprinkles some absorbent on the spot.

However, note that vermiculite, kitty litter, and some other absorbents can create a slipping hazard if they are scattered on a wet surface.

5.5 Apparel in the Laboratory

- Wear appropriate eye protection (i.e. chemical splash goggles) in the laboratory.
- Wear disposable gloves, as provided in the laboratory, when handling hazardous materials.
- Remove the gloves before exiting the laboratory.
- Wear shoes that adequately cover the whole foot; low-heeled shoes with non-slip soles are preferable. Do not wear sandals, open-toed shoes, open-backed shoes, or high-heeled shoes in the laboratory.

- Avoid wearing shirts exposing the torso, shorts, or short skirts; long pants that completely cover the legs are preferable.
- Secure long hair and loose clothing (especially loose long sleeves, neck ties, or scarves).
- Remove jewelry (especially dangling jewelry).
- Synthetic finger nails are not recommended in the laboratory; they are made of extremely flammable polymers which can burn to completion and are not easily extinguished.

5.6 Hygiene Practices

- Keep your hands away from your face, eyes, mouth, and body while using chemicals.
- Food and drink, open or closed, should never be brought into the laboratory or chemical storage area.
- Never use laboratory glassware for eating or drinking purposes.
- Do not apply cosmetics while you are in the laboratory or storage area.
- Wash hands after removing gloves, and before leaving the laboratory.
- Remove any protective equipment (i.e. gloves, lab coat or apron, chemical splash goggles) before leaving the laboratory.

5.7 Emergency Procedure

- Know the location of all the exits in the laboratory and building.
- Know the location of the emergency phone.
- Know the location of the following things and know how to use them:
- Fire extinguishers
- Alarm systems with pull stations
- Fire blankets
- Eye washes
- First-aid kits
- Deluge safety showers

In case of an emergency or accident, follow the established emergency plan as explained by the teacher and evacuate the building via the nearest exit.

Chapter 6 Maintenance

6.1 Safety measures and maintenance

- Before using the machine, read the instructions carefully.
- Do not open the machine without coordination with Fnm Co.
- Use a proper input power cord with the earth for the machine.
- Before using the machine, make sure the proper earth connection.
- Put the machine in a suitable place and climatic conditions (dry, clean, and flat).
- For proper ventilation, avoid putting the fan attached to the wall or other objects.
- To clean the machine, do not use solvents that cause damage to the framework and keyboard of the machine. It is recommended to use a mild detergent for cleaning the machine.

6.2 Necessary studies before turning on the machine

6.2.1 Earth Connection System

Due to high voltages required to produce polymer nanofibers, it is necessary to connect the machine to the earth through the conductor of the power cord. Lack of a proper earth connection can cause damage to the electronic systems of the machine in a few seconds, and also can carry electrical shock risks to the operator.

Given the importance of a proper earth connection, the laboratory wiring system should be equipped with an earth wire. Also, some power cables and sockets (three wires) must be used.

6.2.2 Investigating connection to the HVPS cable

Before turning on the machine, make sure that the HV cables are connected properly to the desired places. Connecting the cable to anywhere of the machine, exception the needle, causes transmission high voltage to the electronic systems and their failure. It can also cause damage to the HVPS.

6.3 Checking Parts

No.	Part Name
1	Checking systems calibrations
2	Checking the switches for all doors
3	Checking the ventilation fan
4	Checking heating system

Chapter 7 Troubleshooting

- If the HMI panel does not command, you should check that the emergency switches are not active.
- If electrospinning process is not done despite applying a voltage, you should:
  - Check the connection of HV cable to the tip of nozzle(s).
  - Check that the viscosity of the solution is not very low or high.
  - Check the amount of temperature and humidity of the chamber.
- If the high voltage power supply do not activate, make sure the green LED (Doors) on the panel is off. On the contrary, if this LED is on, you should check the doors and its switches. If "Doors" LED is off and the doors are closed, the high voltage power supply should be checked by FNM experts.

In order to fix potential problems, before contacting the company, use the guide below:

Problem	Reason	Solution/suggestion
The machine does not have electricity.	Power cord is not plugged in.	Plug in the power cord with caution.
The machine power cord is plugged in but it is not "on".	The machine is "off".	Check the miniature switch at the rear of machine. It should be on "ON" mode. Then the HMI screen should be turned on by "ON/OFF" key next to the HMI screen.
The machine does not located at "Set Zero" state by pressing "Run" button on HMI home page before the electrospinning process starts.	• The first reason: lack of moving of the scanning or distance system • The tray sticks to the lower part of machine or any other external machine prevents moving of scan / distance system. • Failure of distance / scan motors. • failure or withdrawal of belt connected to the motor • The second reason: software problem in sending or receiving commands.	The first solution: • The external machine should be out or the tray should be moved. • In case of failure of the scan / distance motor, you should contact the company. • In case of disconnecting or withdrawing of the belt, you should contact the company. • The second solution: Contact the company.
The pusher block of syringe pump goes forward, but the solution does not go out from the nozzle.	Clogging of the nozzle by the dried polymer solution.	By a piece of thin wire, open the clogging nozzle(s) or replace it.
The amount of injected polymer solution is wrong.	Value of the syringe diameter is not correct.	Measure the syringe diameter with a caliper accurately and then enter it. (All calculations related to the injection rate are based on the

		diameter.) (See page 1, section "1.1.2 Calibration")
The pusher block of syringe pump does not go backward.	The pusher block reaches to the end and stucked.	Using hands, press back the pusher block and simultaneously press  in "Injection" menu until the key is released into the syringe pump.
The drum does not rotate.	• The drum is off. • The drum rotation speed is low (less than 350 rpm). • The socket of drum is not connected. • The drum is stucked.	• Turn on the drum collector from  menu and then turn the potentiometer volume on the panel. • Connect the socket and tighten its screws. • Rotate the drum by hand to make sure it is not stucked. **Note:** According to the above solutions, in the absence of rotation, to prevent damage to the motor, turn the machine off and contact us.
Lack of solution injection and the following message: "Injected volume reaches to max limit"	The injection of solution has reached the target volume which is specified in "Injection" menu.	Press the "Stop" button on HMI home page to reset the injected value to zero.
The HV is on, but by turning the volume, the voltage is still zero.	The door of machine is open. **Note:** At the beginning, by pressing "Run" button on HMI home page the machine will be in "Set Zero" mode and then the syringe pump is located in adjusted distance from the collector, at this time the HVPS will be turned on and the electrospinning will be started.	Check all the doors. **Note:** Be careful that by closing all doors, the electrical field will be established between the nozzle(s) and the collector; so before closing the doors, make sure the high voltage volume is low and high voltage (e.g. 35 KV) is not applied to the system suddenly.
By opening the doors, the HV will not be "off".	The door switches maybe stuck or corrupted. The jack behind the HV is out.	Check all the door switches. Connect the jack (To do this, screws behind the HVPS in the should be opened).
The heater does not reach high temperature.	• Very high temperature has been selected. • To prevent damage to the heater, the machine has been turned off.	• Select a low temperature. Extreme temperatures (above 45 °C) are not recommended for the machine. • Wait until the heater thermostat re-connects.

Appendix A: Syringe inside Diameter

Terumo

Size	Diameter
3 cc	8.95 mm
5	13.00
10	15.80
20	20.15
30	23.10
60	29.10

Sherwood Monoject Plastic

Size	Diameter
1 cc	4.65 mm
3	8.94
6	12.70
12	15.90
20	20.40
35	23.80
60	26.60
140	38.40

Popper & Sons, Inc. "Perfektum" Glass

Size	Diameter
0.25 cc	3.45 mm
0.5	3.45
1	4.50
2	8.92
3	8.99
5	11.70
10	14.70
20	19.58
30	22.70
50	29.00
100	35.70

Stainless Steel

Size	Diameter
8 cc	9.525 mm
20 cc	19.130
50 cc	28.600
100 cc	34.900

Becton Dickinson Plastic "Plasticpak"

Size	Diameter
1 cc	4.78 mm
3	8.66
5	12.06
10	14.50
20	19.13
30	21.70
50/60	26.70

Air Tite "All Plastic"

Size	Diameter
2.5 cc	9.60 mm
5.0	12.45
10	15.90
20	20.05
30	22.50
50	29.00

Unimetrics Series 4000 & 5000

Size	Diameter
10 µl	0.460 mm
25	0.729
50	1.031
100	1.460
250	2.300
500	3.260
1000	4.610

SGE Scientific Glass Engineering

Size	Diameter
25 µl	0.73 mm
50	1.03
100	1.46
250	2.30
500	3.26
1.0 ml	4.61 mm
2.5	7.28
5	10.30
10	14.57

Hamilton Microliter Series Gastight

Size	Diameter
.5 µl	0.103 mm
1	0.1457
2	0.206
5	0.3257
10	0.460
25	0.729
50	1.031
100	1.46
250	2.3
500	3.26
1.0 ml	4.61 mm
2.5	7.28
5	10.3
10	14.57
25	23.0
50	32.6

Appendix B: Syringe Needle Chart

Needle	Nominal Outer Diameter			Nominal Inner Diameter			Nominal Wall Thickness		
Gauge	inches	mm	*tol. inches (mm)*	*inches*	*mm*	*tol. inches (mm)*	*inches*	*mm*	*tol. inches (mm)*
7	0.180	4.572	±0.001 (±0.025)	0.150	3.810	±0.003 (±0.076)	0.015	0.381	±0.001 (±0.025)
8	0.165	4.191	"	0.135	3.429	"	"	"	"
9	0.148	3.759	"	0.118	2.997	"	"	"	"
10	0.134	3.404	"	0.106	2.692	"	0.014	0.356	"
11	0.120	3.048	"	0.094	2.388	"	0.013	0.330	"
12	0.109	2.769	"	0.085	2.159	"	0.012	0.305	"
13	0.095	2.413	"	0.071	1.803	"	"	"	"
14	0.083	2.108	"	0.063	1.600	"	0.01	0.254	"
15	0.072	1.829	±0.0005 (±0.013)	0.054	1.372	±0.0015 (±0.038)	0.009	0.229	±0.0005 (±0.013)
16	0.065	1.651	"	0.047	1.194	"	"	"	"
17	0.058	1.473	"	0.042	1.067	"	0.008	0.203	"
18	0.050	1.270	"	0.033	0.838	"	0.0085	0.216	"
19	0.042	1.067	"	0.027	0.686	"	0.0075	0.191	"
20	0.03575	0.9081	±0.00025 (±0.0064)	0.02375	0.603	±0.00075 (±0.019)	0.006	0.1524	±0.00025 (±0.0064)
21	0.03225	0.8192	"	0.02025	0.514	"	"	"	"
22	0.02825	0.7176	"	0.01625	0.413	"	"	"	"
22s	"	"	"	0.006	0.152	"	0.0111	0.2826	"
23	0.02525	0.6414	"	0.01325	0.337	"	0.006	0.1524	"
24	0.02225	0.5652	"	0.01225	0.311	"	0.005	0.1270	"
25	0.02025	0.5144	"	0.01025	0.260	"	"	"	"
26	0.01825	0.4636	"	"	"	"	0.004	0.1016	"
26s	0.01865	0.4737	"	0.005	0.127	"	0.0068	0.1734	
27	0.01625	0.4128	"	0.00825	0.210	"	0.004	0.1016	"
28	0.01425	0.3620	"	0.00725	0.184	"	0.0035	0.0889	"
29	0.01325	0.3366	"	"	"	"	0.003	0.0762	"
30	0.01225	0.3112	"	0.00625	0.159	"	"	"	"
31	0.01025	0.2604	"	0.00525	0.133	"	0.0025	0.0635	"
32	0.00925	0.2350	"	0.00425	0.108	"	"	"	"
33	0.00825	0.2096	"	"	"	"	0.002	0.0508	"
34	0.00725	0.1842	"	0.00325	0.0826	"	"	"	"