FTS Systems SP SCIENTIFIC
Making Time for Science

AIR FLOW DEVICE OPERATOR'S MANUAL

FTS SYSTEMS AIRJET XE
SAMPLE COOLER

Part Number 200-32650

Rev 013, 05/23

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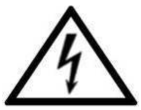
Important Symbols

WARNING! INJURY OR EVEN DEATH MAY RESULT IF A RECOMMENDATION MARKED WITH THIS SYMBOL IS NOT HEEDED.

CRUSH HAZARD. KEEP HANDS CLEAR WHEN OPERATING DOOR.



ELECTRIC SHOCK DANGER! USE APPROPRIATE CAUTION TO AVOID INJURY OR DEATH.

CORROSIVE CHEMICAL. WEAR SUITABLE GLOVES, SAFETY GLASSES, AND PROTECTIVE CLOTHING.

BURN DANGER! POTENTIALLY HOT SURFACE. USE APPROPRIATE CAUTION.

PROPERTY CAUTION! TO PREVENT DAMAGE TO CHAMBER EQUIPMENT AND/OR LOAD, ADHERE TO PROCEDURES MARKED BY THIS SYMBOL.

DO NOT STORE FLAMMABLE MATERIALS IN CHAMBER.

PRACTICAL OPERATING TIP. THESE RECOMMENDATIONS STREAMLINE UNIT OPERATION AND PREVENT COMMON OPERATOR ERRORS.

WEAR SAFETY GLASSES.

EXPLOSIVE MATERIALS HAZARD! KEEP OBJECTS AWAY FROM HEAT.

Safety Warnings

- ✓ ***Never*** *use with toxic, corrosive, flammable or organic materials unless special precautions are in place to prevent injury to personnel or damage to equipment.*
- ✓ ***Never*** *operate unit without all covers in place.*
- ✓ ***Never*** *clean with solvents. Use mild detergent and water only.*
- ✓ ***Never*** *allow hands or body to be exposed to open vacuum ports.*
- ✓ ***Always*** *verify that the electric service and other utilities match the unit's requirements before connecting to power.*
- ✓ ***Always*** *wear safety glasses when using glass flasks.*
- ✓ ***Always*** *practice team lifting when moving heavy equipment.*
- ✓ ***Always*** *ensure that refrigeration air intake is clear and clean.*
- ✓ ***Always*** *ensure that only an authorized technician services the refrigeration, heat transfer, vacuum and electrical systems.*
- ✓ ***Always*** *assume that internal parts may be very cold or very hot. Utilize personal protective equipment to avoid burns.*

Warranty Information

FTS Systems AirJet XE air flow devices are warranted by SP Scientific to be free of defects in material and workmanship when operated under normal conditions as specified in the instructions provided in this manual. Please take this opportunity to locate the serial tag on your new FTS Systems AirJet XE and record the information below for future reference. SP Scientific also recommends that you complete and return your unit's warranty registration card.

Model Number ____

Serial Number ____

Part Number ____

Limited Warranty

SP Scientific (the "Company") shall warrant each of its products against defects in material or workmanship for a period of 12 months from the date of shipment provided that the product is used in a reasonable manner under appropriate conditions and consistent with the applicable operating instructions.

The obligation of the Company shall be, at its option, to repair or replace, without charge any parts that prove to be defective within the warranty period, if the purchaser notifies the Company promptly in writing of such defect. No product shall be returned to the Company without prior approval of the Company.

This limited warranty shall cover the costs of parts and labor to repair or replace all defective product(s) at the Seller's factory. For all products installed by the Company and located within the Company service travel areas, this warranty shall cover transportation charges to ship the product to and from the Company's factory and/or the costs of travel, room and board if the Company's employees conduct repair at the Buyer's location. In lieu of repair or replacement at the Company's factory, the Company may, in its discretion, authorize a third party to perform the repair or replacement at the Buyer's location, and at the Company's sole expense.

The Company shall not be responsible for labor charges payable with respect to persons other than Company employees. Replacement or repair of parts pursuant to this warranty shall not in any way extend the original warranty period. The Company shall not be responsible for any unauthorized repairs, replacements or product modifications, nor will it be responsible for any product failures resulting from such unauthorized repairs, replacements or product modifications negligently or otherwise made by persons other than Company employees or authorized representatives of the Company. The buyer shall assume transportation charges to ship the product to and from the Company's factory and the costs of travel, room and board if the Company's employees conduct repair at the Buyer's location within the warranty period if the product was not installed by the Company's and/or is not located within the Company's service travel areas.

THE COMPANY DOES NOT MAKE AND EXPRESSLY DISCLAIMS ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE OR ANY OTHER WARRANTY, EXPRESSED OR IMPLIED, WITH RESPECT TO THE SALE, INSTALLATION, DESIGN OR USE OF ITS PRODUCTS. ADDITIONALLY, THE COMPANY SHALL NOT BE LIABLE FOR ANY CONSEQUENTIAL DAMAGES RESULTING FROM THE USE OF OR ANY DEFECTS IN ITS PRODUCTS.

The Company's employees are available to provide general advice to customers concerning the use of the Company's products; however, oral representations are not warranties with respect to particular products or their uses and may not be relied upon if they are inconsistent with the relevant product specifications for the items set forth herein.

Notwithstanding the above, the terms and conditions set forth in the Company's formal sales contracts shall be controlling and supersede any inconsistent terms contained herein, and any changes to such contracts must be made in writing and signed by an authorized executive of the Company.

WARNING! THE DISPOSAL AND/OR EMISSION OF SUBSTANCES USED IN CONNECTION WITH THIS EQUIPMENT MAY BE GOVERNED BY VARIOUS FEDERAL, STATE OR LOCAL REGULATIONS. ALL USERS OF THIS EQUIPMENT ARE URGED TO BECOME FAMILIAR WITH ANY REGULATIONS THAT APPLY IN THE USERS AREA CONCERNING THE DUMPING OF WASTE MATERIALS IN OR UPON WATER, LAND OR AIR AND TO COMPLY WITH SUCH REGULATIONS.

Contents

Introduction

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1

Overview

Congratulations on your decision to purchase an FTS Systems AirJet XE Sample Cooler. This controlled temperature, air delivery device is based on a cascade refrigeration system, and offers rapid transitions and precise control ranging from -75°C to +225°C, within ±0.1°C, for flows between 1 and 6 SCFM. The flexible delivery line permits easy and precise nozzle positioning. Accessory shrouds and positioning stands provide additional control of the testing environment.

The system can be configured to either control the air stream temperature directly, or the device under test (DUT) temperature by means of a cascade control loop. The custom Watlow® F4 Series Ramping Controller functionality includes auto-tuning, ramp/soak programming and remote operation. Available communications are serial, GPIB, or the WatView®.

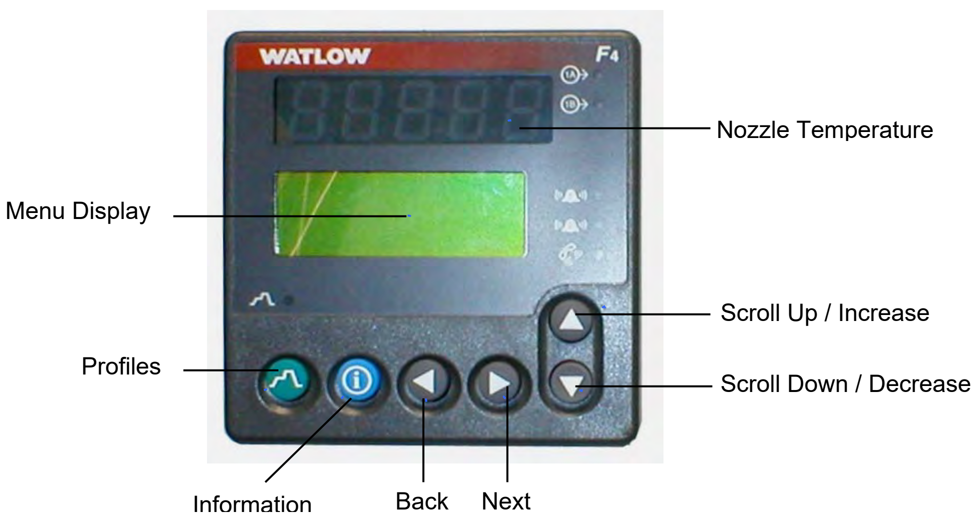
The XE sample cooler has an integral pressure regulator, flow control valve, and rotameter. It can be operated on either a dry (less than -80°C dew point) air/nitrogen supply, or on house (compressed) air with the use of the AD100 accessory air dryer. The system is protected from excessive nozzle temperature excursions by a combination of independent over-temperature and low-flow cutout circuits. The system also comes equipped with a lock-out-ready main breaker.

XE Performance Specifications and Requirements

		XE751_00	XE752_00	XE753_00
Temperature Range	2 SCFM	-75°C to +225°C	-75°C to +225°C	-75°C to +225°C
	3 SCFM	-55°C to +185°C	-55°C to +225°C	-55°C to +225°C
	4 SCFM	-35°C to +145°C	-35°C to +225°C	-35°C to +225°C
	5 SCFM	-25°C to +125°C	-25°C to +225°C	-25°C to +225°C
	6 SCFM	-15°C to +100°C	-15°C to +200°C	-15°C to +225°C
Transition Data	2 SCFM	-55°C to +125°C, <10 sec.	-55°C to +125°C, <10 sec.	-55°C to +125°C, <10 sec.
	2 SCFM	+125°C to -55°C, <20 sec.	+125°C to -55°C, <20 sec.	+125°C to -55°C, <20 sec.
	4 SCFM	-15°C to +100°C, <10 sec.	-15°C to +120°C, <10 sec.	-15°C to +120°C, <10 sec.
	4 SCFM	+100°C to -25°C, <20 sec.	+125°C to -25°C, <20 sec.	+125°C to -25°C, <20 sec.
System Requirements	Electrical	120VAC, 60Hz, 1phase, 15A	120VAC, 60Hz, 1phase, 20A	220VAC, 50Hz, 1phase, 13A
	Air / Gas	Clean Dry Air (CDA) @ 75 PSI, -80°C Dewpoint		
	Environment	23°C to 30 °C (72°F to 86°F), <75% Humidity		

Watlow® F4 Series Ramping Controller

The Watlow® F4 ramping controller has two LED displays. The upper, single line LED displays the nozzle temperature. The lower, multi-line LED displays additional operating parameters and is used to scroll through menu items and to enter/modify control variables.



Button Functions

- The Up Arrow key, ▲, is used to scroll up the menu or to increase a parameter value. When leaving the Setup Mode, it is also used as the save button.
- The Down Arrow key, ▼, is used to scroll down the menu, or to decrease a parameter value. When leaving the Setup Mode, it is also used as the restore button.

  Note: *The Up and Down Arrow keys, ▲ and ▼, act in two different modes when entering process values. When pressed and released, these buttons will increment/decrement the value by a single unit. When pressed and held down, the values will continue to increment/decrement at an accelerating rate.*

- The Next Arrow key, ►, is used to enter into a menu choice and to proceed to the next parameter in a menu. When on a parameter entering screen, it acts an "enter" or "accept" button.
- The Back Arrow key, ◄, is used to go back to a previous menu choice and ultimately back to the main menu page.

  Note: *The Next and Back Arrow keys, ► and ◄, loop through each menu. E.g., if in the middle of a menu, the user may Next, ►, to the end to save, or Back, ◄, to the beginning where a "Save" prompt will appear.*

- The Information button ( ) will bring up an explanation of the function or parameter that the cursor is directly beside. The information mode is exited by pressing the button for a second time.
- The Profile button ( ) will bring up the start profile menu.

Key Features

- The air (or dry gas) supply inlet is located at the rear of the refrigeration cabinet. The air flows through the eight foot (244 cm) flexible delivery line to the hermetically sealed evaporator.
- The refrigeration housing can be placed up to eight feet (244 cm) away from the nozzle. The temperature controller is housed in a separate cabinet and must be placed within six feet (183 cm) of the refrigeration housing.
- A heater located immediately after the evaporator supplies heat to control the exiting air stream temperature.
- A thermocouple provides feedback to the digital controller/indicator, which in turn regulates the heater output.
- The exit air temperature setpoint and display resolutions are both 0.1°C.
- The system can be set up to either control the nozzle temperature directly or to control a device under test (DUT) via a cascade control loop. DUT Mode provides a second (outer) control loop that compares the DUT temperature (measured with a second thermocouple) to the DUT setpoint and automatically adjusts the nozzle (inner) control loop setpoint to achieve the desired DUT temperature. The controls are discussed further in the Operations chapter.

  Note: *While the XE sample cooler will accept temperature setpoints between -100°C and +225°C, the nozzle exit temperature ranges from -75°C to +225 °C.*

Installation and Startup

Chapter **2**

Initial Inspection

Your FTS Systems AirJet XE sample cooler was carefully packed and thoroughly inspected before leaving the SP Scientific factory. However, in the unlikely event that shipping damage has occurred, retain all packing material and contact your freight carrier immediately.

DO NOT ACCEPT DAMAGED SHIPMENTS FROM A CARRIER WITHOUT A SIGNED NOTIFICATION OF DAMAGES.

Upon receiving your shipment, inspect all contents of your equipment for damage. Uncrate and/or unwrap the unit. Carefully remove all packing material from the unit and inspect for visible damage. Check packing material for small accessory items.

If concealed damage or loss is discovered, contact the freight carrier immediately.[1] Keep all contents, packing material and related paperwork intact until a written report is obtained.

Note: *SP Scientific will cooperate in the matter of collecting your claim, but is not responsible for the collection or free replacement of the material. When possible, replacement parts will be shipped and invoiced to you, making them a part of your claim.*

[1] "Concealed damage or loss" refers to damage or loss that does not become apparent until the merchandise has been unpacked and inspected. Should damage or loss be discovered, you may make a written request for inspection by the carrier's agent within 15 days of the delivery date. You may then file a claim with the freight carrier or SP Scientific, depending on the terms of your shipment. If your shipment was "FOB Destination" file your claim with SP Scientific and include the inspection report and any other supporting documents. If your shipment was "FOB Shipping Point" file your claim with the freight carrier and include the inspection report and any other supporting documents.

Setup

NEVER PLACE THE UNIT IN AND AREA WHERE EXCESSIVE HEAT, MOISTURE OR CORROSIVE MATERIALS ARE PRESENT.

Air Flow Considerations

The FTS Systems AirJet XE is equipped with an air-cooled refrigeration system. Air is pulled from the left side of the unit to cool the refrigeration system components and then exits the rear panel. When positioning your system, ensure that it is located on a firm, level surface in an area that provides adequate air circulation.

Place the refrigeration module in an area with a minimum of four (4) inches clearance at the front and rear. Cooling air is drawn through the front grill and expelled at the rear. Blocking either grill will reduce the refrigeration performance, and may, in certain cases, cause system failure.

Ambient Conditions

For best low-temperature operation, consider that the ideal ambient temperature for your FTS Systems AirJet XE is approximately 22 °C (72 °F). Higher ambient temperatures may interfere in the system's ability to achieve its ultimate low temperature.

Services and Utilities

CAUTION! IF YOU ARE UNSURE ABOUT THE AVAILABLE ELECTRICAL VOLTAGE SUPPLY IN YOUR FACILITY, CONSULT A QUALIFIED ELECTRICIAN.

The unit operates using typical laboratory electrical service (15 or 20 Amp for 115V models, and 13 Amp for 220V models).

Installation

The following installation procedure outlines the first assembly, start up and system test.

1. Unpack the XE sample cooler components and confirm that all items are present. When unpacking the unit there are four items to check for:

    a. The XE sample cooler base unit with 8 ft. flexible delivery line and heated nozzle.

    b. The control module.

    c. The communication umbilical cord.

    d. The power cord.

    If you purchased the optional air dryer (AD100), you should also check for:

    e. The air dryer housing (beige with smoked acrylic door).

    f. The air hose with two 3/8” female quick disconnects.

    If you purchased the optional shroud, you should also check for:

    g. The shroud (transparent, phenolic, or acrylic).

    h. The nozzle-to-shroud adapter ring.

    If you purchased the optional nozzle stand, you should also check for:

    i. The stand base, upright, and horizontal arm.

    If you purchased the optional mobile cart stand, should also check for:

    j. The blue work cart with two shelves.

    In addition, you should have a user’s manual for the Watlow® Series F4S/D controller (Watlow® document 0600-032-0000 Rev G, April 2004, copies available in PDF format from the Watlow® website). The SP Scientific owner’s manual includes instructions for the basic set up and use of the custom F4 series controller; however, it is strongly recommended the user review the Watlow® manual and make themselves familiar with the basic as well as advanced features. Specifically the operator should review Chapter 2 of the Watlow® manual (“Keys, Displays and Navigation”) before operation.

2. Place the unit in the area where you intend to operate it.
3. Route the flexible delivery line and nozzle to the spot where you want the air stream directed. If applicable, mount the nozzle in the optional stand. Once the refrigeration system is turned on, refrain from moving or bending of the flex line excessively.

CAUTION: IF THE NOZZLE IS POSITIONED HORIZONTALLY, MAKE SURE THAT IT IS DIRECTED AWAY FROM ANY OPERATORS OR OBSERVERS. EYE PROTECTION SHOULD BE WORN BY ALL PERSONNEL IN THE IMMEDIATE VICINITY.

4. Connect the control module to the base unit with the umbilical cord. The cord has a CPC and a male mini thermocouple connector on either end.
    a. Connect the male CPC connector to the base unit, and the female CPC connector to the control module receptacle (press the connector in place and tighten the retaining ring).
    b. Plug the thermocouple connector at either end into the slot marked "Nozzle 1".
5. Set all three toggle switches (air flow, refrigeration and heater) on the control module "OFF."
    a. Push down the emergency off button (EMO).
    b. Set the breaker at the back of the refrigeration unit "OFF".
    c. Plug the power line cord (female end) into the back of the refrigeration unit and then into an appropriately rated electrical outlet, as specified below:

Model	Electrical Outlet
XE751_00	15A/115VAC
XE752_00	20A/115VAC
XE753_00	13A/220VAC

Note: *The electrical service requirements may be found on the rating label on the rear of the unit.*

6. Connect the dry gas supply to the inlet at the rear of the unit, with the supply shut off. If the optional AD100 air dryer is used, first ensure that the power switch is off, then connect the air dryer to the refrigeration base, and finally to the compressed air supply. Once the air connections are firmly in place, connect the AD100 to the appropriate power receptacle (see the AD100 instructions at the end of this manual for more details on drier operation and maintenance).

Notes: *The air/inert gas supply must be capable of delivering up to 6 SCFM at >75 PSIG to the base refrigeration unit to fully utilize the system capacities.*

If the air line is new, or if the line has not been used recently, blow out any debris or standing water (condensate). Flowing liquid into the drier may saturate the drier beds, and result in off specification air entering the refrigeration unit. Extended runs with elevated dewpoint air will eventually lead to ice build up in the unit and performance degradation, or plugging.

7. Open the air supply line. The refrigeration unit is now pressurized up to the air isolation valve in the base unit.

Note: *If the AD100 is used, you must turn on the power to the unit (the toggle switch will light up to indicate power) before starting the refrigeration unit and it must remain on throughout operation. The failure to provide dry gas (dew point < -80°C) will lead to ice build up in the unit, and eventually, plugging. The air dryer operates by alternating the gas flow between a pair of desiccant beds. As the system cycles you may hear a brief hiss from the purge gas venting.*

8. Turn the unit "ON" by switching on the breaker at the back of the refrigeration unit and pull up the EMO button on the control module. You should now hear the fan turn on in the base unit, and the controller will power up.

9. Set and test the air flow:
    a. Position the nozzle in a safe orientation (facing away from personnel).
    b. Activate the air switch on control module (leftmost switch),and note that the switch illuminates. The sensor light above the switch will illuminate once the air flow exceeds ~0.5 SCFM.
    c. Adjust pressure to 75 PSIG on the base unit (pull out the regulator cap to adjust; push into lock).
    d. Open air valve completely on the base unit (rotameter should read ≥6 SCFM). Shut air valve completely (sensor light should go out ≤0.5 SCFM).
    e. Adjust air flow to 2 SCFM at the middle of the rotameter ball float (re-adjust pressure regulator if needed).

    Note: *If the facility can deliver -80°C dewpoint air, skip the following and go to step #10.*

    f. Allow the air to flow (through the air dryer) for 15 to 30 minutes before starting the refrigeration system; this will help remove any residual moisture in the system.
10. Turn on and test the refrigeration system.
    a. Activate the refrigeration switch (middle) on the control module and note that the switch illuminates. The first stage compressor is now on. After approximately 10 minutes, when the inter-stage heat exchanger reaches a (factory) preset temperature, the second stage compressor will start. Then the refrigeration indicator light (located above the refrigeration switch) will illuminate, and the nozzle temperatures will begin to drop.
    b. Monitor the nozzle temperature; the system should reach greater than -75°C in 15 to 20 minutes. While the refrigeration is cooling down proceed with steps 12 through 16 to confirm that the controller has the proper initial set up parameters.

    Note: *During a normal start up the operator should allow the unit to reach its steady-state bottom out temperature (BOT) before proceeding with operation. Not only will this ensure that the machine is ready to operate across its entire temperature range, it will also help identify potential refrigeration problems.*
11. Confirm the initial controller setpoint. Scroll controller cursor to Setpoint (use ▲/ ▼ buttons). If the value equals 25°C, then go to step 13; if not enter 25°C (use ► to enter mode, ▲/ ▼ to adjust the value and ◄ to return to main page).
12. Confirm that the controller has the correct general settings.
    a. From Main Page, scroll cursor down to “Go to Setup” (▼ to scroll and ► to enter).
    b. Scroll to “System” (▲/▼ and then ► to enter).
    c. Choose “Air” (only choice, ► to enter).
    d. Enter 2.0 (▲/▼ and then ► to enter).
    e. Enter current time, hours ▲/▼, ►, minutes ▲/▼, ► secs ▲/▼, ►.
    f. Enter current date, month ▲/▼, ►, day ▲/▼, ►, years ▲/▼, ►.
    g. Choose “US, Reset/Rate” (▲/▼, and then ► to enter).

h. Choose “Yes, Upper Display” (▲/▼ and then ►).
i. Enter 90% for Ch 1 Autotune SP (▲/▼ and then ► to enter).
j. Enter 0% for Air In Fail (▲/▼and then ► to enter).
k. Choose Open Loop Ch1 “OFF” (▲/▼ and then ►).
l. Enter 10 sec Power Out Time (▲/▼ and then ► to enter).
m. Choose “Idle” Power Out Action (▲/▼ and then ► to enter).
n. Enter 25 °C Ch 1 Idle Sp (▲/▼ and ► to enter).
o. Remain in Setup Menu and proceed to step 14.

13. Confirm that the controller high power scale is set to the model-appropriate value to achieve 225°C for 2 SCFM.
    a. Scroll to “Control Output 1” (▲/▼ and ► to enter).
    b. Choose “Heat” Function (▼ and ► to enter).
    c. Choose “0 – 10V” (▼ and ► to enter).
    d. High power scale should be set to 100% (▲/▼ and ► to enter).
    e. Set high power scale to the appropriate value listed below (Table 4) by model number (▲/▼and ► to enter).
    f. Flow power scale should be set for 0% (▲/▼ and ► to enter).
    g. Remain in Setup Menu and proceed to step 15.

Model	High Power Scale Value[2]
XE751_00	90
XE752_00	45
XE753_00	38

Note: *Limiting the output scale is not necessary for safe operation; a preset over-temperature board will limit the nozzle temperature to greater than 240°C, regardless of the flow or controller setting. This function is intended to improve the control action at low flows, and ensure that auto-tuning can occur without tripping the over-temperature safety.*

14. Confirm that nozzle thermocouple and setpoints are set correctly.
    a. In the Setup Menu, scroll up to “Air Temp” and enter (▲ to scroll and ► to enter).
    b. Choose “Thermocouple” (► to enter).
    c. Choose Type “K” (▼ and ► to enter).
    d. Choose “0.0” (▼ and ► to enter).
    e. Input low limit should be set for -100 °C (▲/▼ and ► to enter).
    f. Input high limit should be set for 225 °C (▲/▼ and ► to enter).
    g. Offset type to “Single linear” (▲/▼and ► to enter).

[2] For full temperature range, operate at 2 SCFM.

h. Calibration Offset should be “0.0”.

i. Filter time should be set to 1.0 sec (▲/▼and ► to enter).

j. For Error Latch, choose “Self-Clear” (► to enter and return to Setup Menu).

k. Remain in Setup Menu and proceed to step 16.

15. Confirm that the controller is in nozzle control and the cascade mode is off.

    a. In the Setup Menu, scroll down to “DUT Temp” (▼ to scroll and ► to enter).

    b. Choose “Off” (▼ and ► to enter and return to Setup Menu).

    c. Exit Setup and return to Main Page (◄ to return).

    d. Save settings (▲ to save).

16. Confirm initial nozzle control PID settings.

    a. From the Main Page, scroll up to “Go to Operations” (▲ to scroll and ► to enter).

    b. Choose “Edit PID” (▼ and ► to enter).

    c. Choose “Air PID Set” (► to enter). d. Choose “PID Set 1” (► to enter).

    d. Enter “Proportional Band” (► to enter).

    e. Set PB value to 55.0ºC (▲/▼ and ► to enter).

    f. Scroll down to “Reset” (▼ and ► to enter).

    g. Set Reset value to 15.0/min (▲/▼ and ►to enter).

    h. Scroll down to “Rate A” (▼ and ► to enter).

    i. Set Rate value to 0.01 min (▲/▼ and ► to enter).

    j. Exit Operations and return to Main Page (press ◄◄◄◄ to return).

    The controller is now set to finish initial checkout. As soon as the nozzle temperature steadies out at its BOT (bottom out temperature), proceed with step 17.

    Note: *The nozzle PID settings entered above are values found to provide good overall response to large (step) setpoint changes, and should provide a stable starting point for familiarization, and general set up testing. Details on manual PID setting and auto-tuning are presented below.*

17. Activate the heater. Press the heater switch on the control module (the toggle switch will illuminate) and allow the controller to raise nozzle temperature to 25°C and steady out.

    Note: *In the event that the nozzle temperature exceeds 240°C, the over- temperature board will interrupt the heater power and activate the RED over-temperature indicator light. The over-temperature board must be manually reset by pushing the indicator light (button).*

18. Check the heater upper limit.

    a. Raise the set temperature (Setpoint) to 150°C and allow temperature and % output to steady. (▲/▼ to Setpoint, ► to enter, ▲/▼ to change set temperature, and ► to enter).

b. Raise the set temperature (Setpoint) to 200°C and allow temperature and % output to steady.

c. Raise the set temperature (Setpoint) to 225°C and allow temperature and % output to steady. Nozzle temp should be less than 215°C (line voltage dependent), % output should read ~100%.

d. Reduce the setpoint to 25°C.

If the performance conditions listed above are met, the system is ready for operation and the operator may proceed to the operations and controller sections for more detailed descriptions of how to change the setup for their particular application.

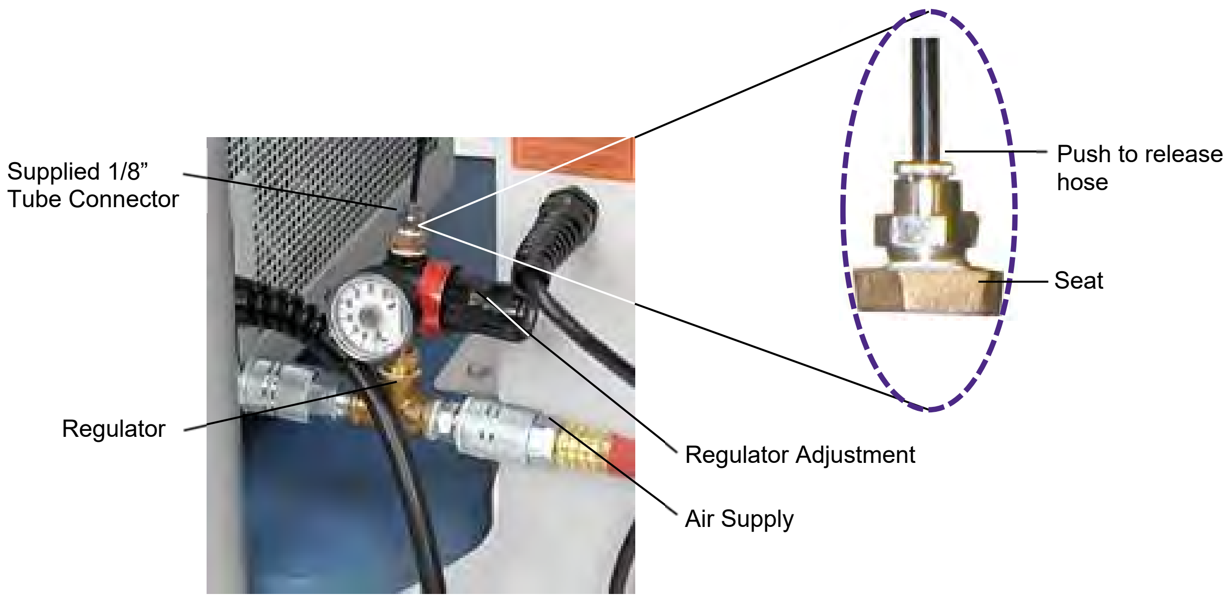
If the performance conditions have not been met, contact SP Scientific Service.

Nozzle Stand Option

With the arm securely mounted to work area:

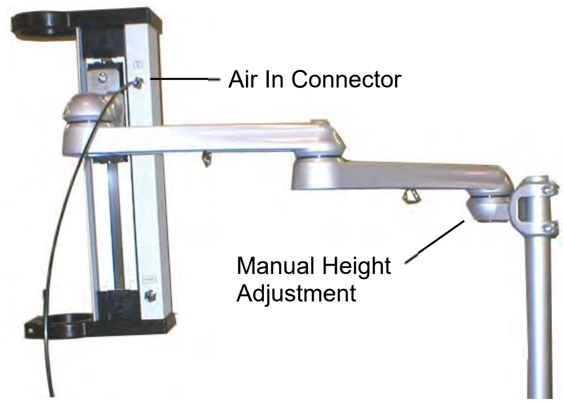
1. Affix regulator to XE sample cooler.
2. Connect the air supply, turned off, to regulator. Do not turn on yet.

Note: *The XE uses 1/8" push-in tube connectors for the air hoses. Install the hose by pushing it into the connector until it is seated. Test the connection by tugging on the hose. To release a hose, push down on the external ring.*



3. Connect supplied hose to "Air In" on rear of pneumatic lift. Allow for arm travel up and down, side to side and trim hose to fit.
4. Connect the other end of the hose to the regulator.
5. Turn on air supply.
6. Adjust the regulator to 40#.

7. Test the lift. Toggle up and toggle down.



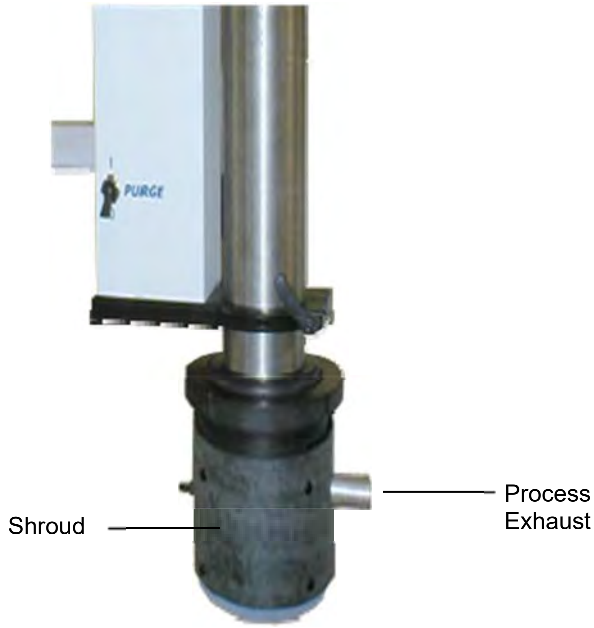
8. Install nozzle, secure with tee handle.

If a shroud assembly has been purchased:

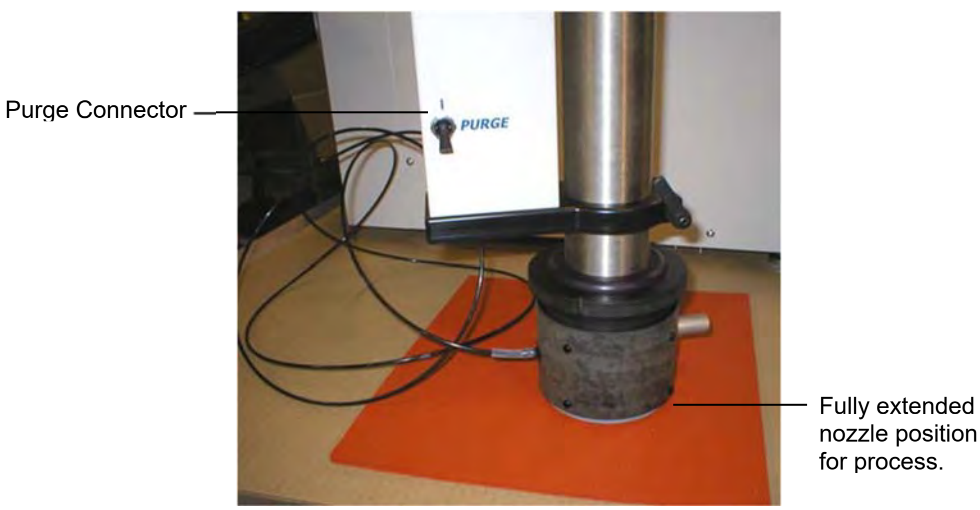
1. Install nozzle, secure with “tee” handle.
2. Install adaptor with a 3/32” Allen wrench (four screws).

3. Install the static eliminator to the nozzle tip with a 5/64” Allen wrench.

4. Snap shroud in place and position process air exhaust away from operator position.



5. Turn down locking ring to secure.
6. Use excess trimmed 1/8” hose to connect to the Purge connector on the back of the lift.



7. Connect the supplied ¼” x 1” piece of silicone tube to the nipple on the shroud.

8. Connect purge line into ¼” tube.
9. Use the Down toggle to lower the nozzle. Use the manual adjust to set nozzle/shroud assembly flat on the sponge.

Unit Precautions

- ✓ Do not lift or move the unit by pulling the flexible refrigeration line, or the control module umbilical cord.
- ✓ Do not push the refrigeration unit back against a wall, or other objects.
- ✓ Do not block the front ventilation grill.
- ✓ When storing or transporting the refrigeration system, do not coil the flexible line tighter than a 12" inner diameter. Allow the coiling flex line to twist naturally; resisting the rotation may damage the inner core.
- ✓ Do not locate the refrigeration module near heat sources such as hot plates, vacuum pumps, or motors, even in air-conditioned rooms. These heat sources can locally overwhelm room air-conditioning systems.
- ✓ Do not turn on the refrigeration system without dry air (less than -80°C dew point) connected to the inlet port or room moisture will freeze and block the heat exchanger (the last 30" before the nozzle). If the flow does get blocked off due to freezing, turn off the refrigeration system and heater, position the nozzle so that the last 48" is inclined downwards, and allow the system to thaw and drain. Before restarting the refrigeration system or the heater, start a 3-6 SCFM dry air flow and maintain it for at least 15 to 30 minutes after all signs of moisture in nozzle flow are absent.
- ✓ The flexible line connecting the refrigerant evaporator to the refrigeration unit consists of a corrugated stainless-steel tube covered with foam insulation. Although this stainless tube is extremely strong in tension and abrasion, it can be damaged to the point of rupture if it is repeatedly bent too sharply or forcibly twisted axially. The number of bending and straightening cycles that the line will withstand is a direct function of the bend radius. The smaller the radius, the higher the stress, and, consequently, the shorter the stainless-steel fatigue life. The flexible line must remain gas-tight to contain the refrigeration charge.
- ✓ Do not bend the flexible line while the refrigeration unit is working. Limit the movement of the line to that needed to raise and lower the nozzle/shroud, on and off test devices. The flexible line insulation becomes brittle at low temperature and bending it will result in insulation cracking. If planning to move or store the device, allow the unit to run for ~30 minutes with the refrigeration system off, and full air flows to allow the insulation temperature to approach room temperature.

Chapter 3

Operation

Overview

The system can be set up to directly control the nozzle temperature (Nozzle Mode), or to control a device under test (DUT Mode) via a cascade control loop. When operating in Nozzle Mode, the temperature of the air exiting the nozzle is directly controlled by a single (inner) control loop.

DUT Mode provides a second (outer) control loop that compares the DUT temperature (measured with a second thermocouple) to the desired setpoint for the device and automatically controls the nozzle temperature to achieve the desired DUT temperature.

For both modes of operation, custom profiles can be created and saved with minimal programming. The system also has built in PID auto-tuning capabilities for both the nozzle (inner loop) and DUT (outer loop). Because of the rapid nozzle response time, SP Scientific recommends that the user not use the auto-tune function to set the nozzle PID for cascade control.

A quick-start guide on creating profiles and auto-tuning is found later in this section. For more complete details on your Watlow® F4 controller, please refer to the Watlow® User's Manual.

System Power Up

Note: *If powering up for the first time, please refer to the Installation Procedure earlier in this manual.*

To power up the system:

1. Turn the unit "ON" by switching on the breaker at the back of the refrigeration unit, and pull up the EMO button on the control module. You should now hear the fan turn on in the base unit and the controller will power up.
2. Set and test the air flow.
    a. Position the nozzle in a safe orientation (facing away from personnel). The air flow is adjusted by means of a metering valve, pressure gauge, pressure regulator and rotameter, all located on the front of the XE refrigeration unit.
    b. Activate the air switch on control module (leftmost switch) and note that the switch illuminates.
    c. Adjust pressure to 75 PSIG, if required, on the base unit (pull regulator cap to adjust; push into lock).
    d. Adjust air flow to the desired value using the middle of the rotameter ball float (re-adjust pressure regulator if needed). After adjustment, push the pressure control knob back in.

For either operating mode (Nozzle or DUT), the desired air flow must be determined and adjusted prior to operation. The air flow will determine the maximum and minimum achievable nozzle temperature (as listed in the Model Specifications).

The operator should always choose flow conditions whose temperature range extends beyond both the intended high and low test range. The amount by which the air temperature range must exceed the target range will depend on:

- the degree of isolation (insulation), and
- heat generation within the device (if any).

The maximum temperature range and cooling capability for the XE family nominally occurs between 2 and 2.5 SCFM. Above this air flow the minimum achievable nozzle temperature rises with increased flow rate.

Note: *Finding the appropriate flow range for a given DUT and test profile will require some experimentation. Once set, the air flow can now be turned on and off by means of the air flow switch located on the controller.*

Under most conditions the AirJet XE can be used immediately by following the next steps three through six. However, if the optional air dryer has been powered off and/or disconnected from an air source for more than 48 hours, or if the air quality of the air supply is suspect, it is recommended to run the air dryer at the intended flow for 15 to 30 minutes before starting the refrigeration system. This will help ensure that the system starts “dry”. Once set, the air flow can now be turned on and off by means of the air flow switch located on the controller.

Ideally, run the optional air dryer at the intended flow for 15 to 30 minutes before starting the refrigeration system. This will help ensure that the system starts “dry.” Once set, the air flow can now be turned on and off by means of the air flow switch located on the controller. Shutting off the air flow will automatically lock out the heater.

3. Turn on and test the refrigeration system.
    a. Activate the refrigeration switch (middle) on the control module and note that the switch illuminates. The first stage compressor is now on.
    b. After approximately 10 minutes, when the inter-stage heat exchanger reaches a preset temperature, the second stage compressor will start, the refrigeration indicator light (located above the refrigeration switch) will illuminate, and the nozzle temperatures will begin to drop.

       Monitor the nozzle temperature; the system should reach greater than -75°C in 15 to 20 minutes.
       Note: *During a normal start up the operator should allow the unit to reach its steady-state bottom out temperature (BOT) before proceeding with normal operations. Not only will this ensure that the machine is ready to operate across its entire temperature range, it will also help identify potential refrigeration problems.*
4. Confirm the initial controller setpoint.

   On the Main Page, scroll to Setpoint 1, shown as SP1 (use ▲/▼ buttons). If the value equals 25°C, then go to step 5; if not, enter 25°C (use ► to enter mode, ▲/▼ to adjust the value and ◄ to return to main page).
5. After changing the air flow, the operator needs to adjust the controller output high power scale to match the flow rate. The appropriate output high power scale limits are listed in the table below. Failure to do so may result in the inability to reach the maximum temperature at higher air flow, or tripping the over-temperature protection when auto-tuning a cascade loop at lower air flow.
    a. From Main Page, scroll cursor down to “Go to Setup” (▲/▼ to scroll and ► to enter).
    b. Scroll to “Control Output 1A” (▲/▼ and ► to enter).
    c. Choose “Heat” Function (▼ and ► to enter).
    d. Choose “0 – 10V” (▼ and ► to enter).

e. Set high power scale to the appropriate value listed below by flow rate and model number (▲/▼ and ► to enter).

Air Flow (SCFM)	XE751_00 High Power Scale Setting (%)[3]	XE752_00 High Power Scale Setting (%)[3]	XE753_00 High Power Scale Setting (%)[3]
1	73	38	31
1.5	90	45	38
2	100[4]	50	42
3	100[4]	59	47
4	100[4]	68	54
5	100[4]	79	57
6	100[4]	100[4]	60

Notes: *Limiting the output scale is not necessary for safety; a preset over-temperature board will limit the nozzle temperature to greater than 240°C, regardless of the flow or controller setting. This function is intended to (1) improve the control action at low flows, and (2) ensure that auto-tuning can occur without tripping the over-temperature safety.*

The values given above may vary with voltage. If, after setting the high power scale value, the system does not reach 225°C, adjust the value upwards in 1 to 2 % increments until 225°C is attained.

If the user wishes to impose a "hard" limit on the nozzle temperature below 225°C, the user can reduce the High Output Scale value. Doing so, however, will degrade response time, and may require tuning parameter adjustment. In order to achieve this lower temperature "ceiling", (1) note the output % value displayed on the LED at the desired temperature setting, (2) compute the product of the output % value and the existing High Output Scale setting, and (3) enter that value as the new High Output Scale setting as described above.

f. Low power scaling should be 0% (▲/▼ and ► to enter and return to Setup Menu).

g. Exit Setup and return to Main Page (◄).

h. Save settings (▲ to save).

6. Activate the heater. Press the heater switch on the control module (the toggle switch will illuminate) and allow the controller to raise nozzle temperature to 225°C and steady out. The unit is now ready for operation.

[3] Estimated Values.

[4] Maximum Temperature < 225 °C, actual temperature value will depend on line voltage.

Nozzle Control Mode

Nozzle Control Mode (Nozzle Mode) allows the operator to directly control the outlet air temperature from the system via a single (inner) control loop. The Installation Procedure in this manual sets up the system in Nozzle Mode, and therefore no changes are required to operate in this mode. If the system was last operated in DUT Mode, and Nozzle Control mode is desired, the system must be switched back to Nozzle Mode.

Switching from DUT Mode to Nozzle Mode (if required)

1. With the system powered up and on the Main Page, scroll to “Go to Setup” and enter (▲/▼ to scroll and ► to enter).
2. Scroll to “DUT Temp” (▲/▼ and ► to enter).
3. Choose “Off” (▼ and ► to enter and return to Setup Menu).
4. Exit Setup and return to Main Page (◄ to return).
5. Save settings (▲ to save).

The following section is a quick start guide to operating in nozzle mode.

Operation

1. If off, power up the system, per the instructions at the beginning of this chapter.
2. Direct the nozzle at the specimen to be temperature controlled.

   Note: *The nozzle should be located as close as possible to the specimen to achieve maximum efficiency. The maximum and minimum achievable temperatures for device under test (DUT) will depend how well isolated (insulated) the DUT and the air stream are from the ambient conditions. Using insulation beneath the DUT and a shroud to isolate the gas space above will minimize the steady state temperature difference between the air stream (nozzle temperature) and the DUT. The thermal mass of the DUT will affect how quickly it responds to changes in the air stream temperature. In addition, any heat dissipated within the DUT will limit the ultimate low temperature.*

3. Begin operation by setting the controller setpoint to any allowable temperature (-100 °C to 225 °C).
   a. To set temperature, on the Main Page scroll to Setpoint and enter (▲/▼ to scroll and ► to enter)
   b. Choose set temperature (▲/▼ and ► to enter).
   c. The system will now adjust to the new set temperature.

   Note: *If the control temperature is set below the minimum achievable temperature (heater off), the nozzle temperature will fluctuate a few degrees as the evaporator temperature changes with ambient temperature, line voltage, and air flow fluctuations. If constant temperature is required, the setpoint value should be a few degrees above the minimum low to eliminate these fluctuations.*

4. To run a profile, hit the green “profile” button ( )located on the front of the controller.
5. For a quick start on setting up and running profiles, follow the instructions located in the Controller Programs chapter of this manual. More complete details are found in the Watlow® User’s Manual.

DUT Control Mode

The following section will aid the user in DUT operation. For more complete details on the Watlow® F4 controller, please refer to the Watlow® User's manual.

The system can directly control the device under test (DUT) temperature by operating under DUT Mode. DUT Mode provides a second (outer) control loop that compares the DUT temperature (measured with a second thermocouple) to the desired setpoint for the device, and automatically adjusts the nozzle (air) temperature to achieve the desired DUT temperature.

It should be noted, however, that since the overriding objective is to control the measured DUT temperature, this control mode may result in large air temperature overshoots (relative to the air steady state temperature), and more oscillatory air temperature control, while achieving the desired DUT temperature control.

If fast DUT response is required, the temperature overshoot will be more severe. Because of this, SP Scientific recommends using "Deviation Control" while in DUT Control Mode.

Deviation Control

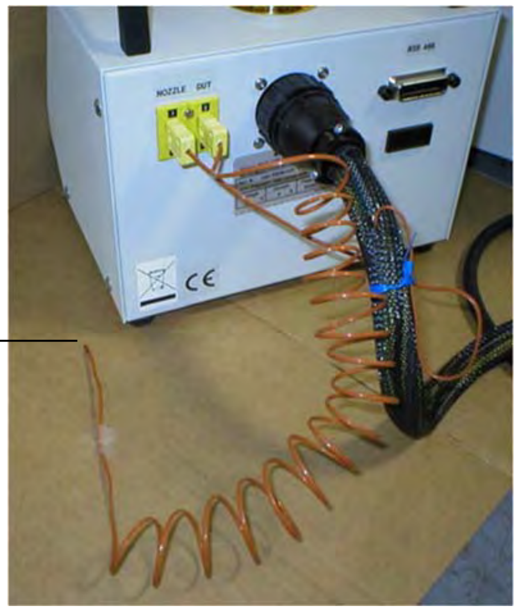
Deviation control constrains the nozzle to an upper and lower limit. For example, if the constraints were set to +20 and -10, and the DUT temperature setpoint was set to 100°C, the nozzle would be limited to 120° and 90°. A cold set point example of -40 would result in limits of -50 to -20.

In addition to DUT Control Mode, there is a DUT Monitoring Mode (No Cascade). This allows the operator to monitor the DUT temperature on the Watlow® controller, yet still remain in Nozzle Control Mode.

Operation in DUT Mode (Monitoring Only)

1. If off, power up the system, per the instructions at the beginning of this chapter.
2. If not connected, plug the DUT thermocouple connector into the slot marked "DUT" located on the back of the controller and attach the sensing end of the thermocouple to the device under test (DUT).

Thermocouple End



3. Direct the nozzle at the DUT. DUT control can be improved by optimizing the following variables:
    a. Locate the nozzle as close as possible to the specimen.
    b. Isolate the DUT and the air stream are from the ambient conditions. This can be accomplished by insulating beneath the DUT and using a shroud to isolate the gas space around the DUT.
    c. Minimize the thermal mass of the DUT.
    d. Minimize heat dissipated from the DUT to achieve the ultimate low temperatures.
4. DUT Monitor Mode:
    a. With the system powered up and from the Main Page, scroll to "Go to Setup" and enter (▲/▼ to scroll and ► to enter).
    b. Scroll to "DUT Temp" (▲/▼ and ► to enter).

c. Choose “Thermocouple” (▲/▼ and ► to enter).
d. Choose Type “K” (▼ and ► to enter).
e. Choose “0.0” (▼ and ► to enter).
f. Set low limit (▲/▼ and ► to enter).
g. Set high limit (▲/▼ and ► to enter).
h. Set Offset type to “Single linear” (▲/▼ and ► to enter).
i. Calibration Offset should be set to 0.0 (▲/▼ and ► to enter).
j. Filter time should be set to 1.0 sec (▲/▼ and ► to enter).
k. For Error Latch, choose “Self-Clear” (► to enter).
l. Choose “DUT Monitor” (► to enter and return to Setup Menu).
m. Scroll down to “Custom Main Page” (▲/▼ and ► to enter).
n. Scroll to “P2” (▲/▼ and ► to enter).
o. Choose “DUT Temp” (▲/▼ and ► to enter).
p. Return to “Set Up” (◄◄◄ to return).
q. Exit Setup and return to Main Page (◄ to return).
r. Save settings (▲ to save).

The system may now be operated as in Nozzle Mode (see previous section). The DUT temperature will be displayed on the main page, labeled “DUT”.

Operation in DUT Mode (with Control Activated)

1. If off, power up the system, per the instructions at the beginning of this chapter.
2. If not yet connected, plug the DUT thermocouple connector into the slot marked “DUT” located on the back of the controller and attach the sensing end of the thermocouple to the device under test (DUT).
3. Direct the nozzle at the DUT. DUT control can be improved by optimizing the following variables.
    a. Locate the nozzle as close as possible to the specimen.
    b. Isolate the DUT and the air stream are from the ambient conditions. This can be accomplished by insulating beneath the DUT and using a shroud to isolate the gas space around the DUT.
    c. Minimize the thermal mass of the DUT.
    d. Minimize heat dissipated from the DUT to achieve the ultimate low temperatures.

Set up Upper and Lower Temperature Parameters:

4. To determine the Upper Deviation Parameters, manually adjust the air nozzle set point while observing the DUT temperature. The following example resulted in a deviation of +15° for a DUT set point of 100°.
    a. Set SP1 approximately 10% above the upper desired temperature (*e.g.*, 110°).
    b. Soak until DUT has stabilized (*e.g.*, DUT stabilized at 97°).

c. If DUT doesn't reach desired temperature, increase the nozzle temperature until the DUT reaches desired temperature (*e.g.*, 115°).

Note: *A higher or wider deviation will decrease the transition time and will increase overshoot. Many other factors, including material properties that are sensitive to extreme temperature excursions, should also be considered when establishing deviation parameters.*

d. Soak at 115° until DUT has stabilized (*e.g.*, DUT has now reached 100°).

e. The upper deviation would be 15° for this example.

5. To determine the Lower Deviation Parameters, manually adjust the air nozzle set point while observing the DUT temperature (Input 3). The following example resulted in a deviation of -10° for a DUT set point of - 40°.

    a. Set SP1 below the lowered desired temperature (*e.g.*, SP1 set to -45°).

    b. Soak until DUT has stabilized (*e.g.*, DUT has stabilized at -38°).

    c. If DUT doesn't reach desired temperature, decrease nozzle temperature until DUT reaches desired temperature (*e.g.*, decrease SP1 to-50°).

    d. The lower deviation would be -10° for this example.

6. Switch the controller to DUT Mode.

    a. With the system powered up and from the Main Page, scroll to "Go to Setup" and enter (▲/▼ to scroll and ► to enter).

    b. Scroll to "DUT Temp" (▲/▼ to scroll and ► to enter).

    c. Choose "Thermocouple" (▲/▼ to scroll and ► to enter).

    d. Choose Type "K" (▼ and ► to enter).

    e. Choose "0.0" (▼ and ► to enter).

    f. Set low limit (▲/▼ and ► to enter).

    g. Set high limit (▲/▼ and ► to enter).

    h. Set Offset type "Single linear" (▲/▼ and ► to enter).

    i. Calibration Offset should be set to 0.0 (▲/▼ and ► to enter).

    j. Filter time should be set to 1.0 sec (▲/▼ and ► to enter).

    k. For Error Latch, choose "Self-Clear" (► to enter).

    l. Choose "Deviation Cascade" (▼ and ► to enter).

    m. Set low deviation as determined in step 5 above. (In the example it is -10°).

    n. Set high deviation as determined in step 4 above. (In the example it is +15°).

    o. Scroll to "Custom Main Page" (▲/▼ and ► to enter).

    p. Scroll to "P2" (▲/▼ and ► to enter).

    q. Choose "DUT Temp" (▲/▼ and ► to enter).

    r. Scroll to "P3" (▲/▼ and ► to enter).

   s. Choose “AIR Setpoint” (▲/▼ and ► to enter).

   t. Return to “Set Up” (◄ to return).

   u. Exit Setup and return to Main Page (◄ to return).

   v. Save settings (▲ to save).

7. Begin operation by setting the controller (Setpoint) to any set temperature within the operating range.

   a. To set temperature, on the main page scroll to DUT SP and enter (▲/▼ to scroll and ► to enter).

   b. Choose set temperature (▲/▼ and ► to enter).

   c. The display is now configured to read:

   Main page = nozzle air temperature

   DUT Temp = DUT thermocouple
   AIR SP = setpoint
   DUT SP = DUT setpoint

   To customize these displays to the operator’s needs, please refer to the Watlow® F4 User’s manual.

   Notes: *If the control temperature is set below the minimum achievable temperature (heater off), the nozzle temperature will fluctuate a few degrees as the evaporator temperature changes with ambient temperature, line voltage, and air flow fluctuations. If constant temperature is required, the setpoint value should be a few degrees above the minimum low to eliminate these fluctuations.*

   After setting deviation cascade temperature ranges, SP Scientific recommends running on Auto-Tuning.

8. To run a profile, hit the green “profile” button ()located on the front of the controller. For information on setting up and running profiles, follow the quick start guide located in the Create Profile section of this manual. For more complete Profile instructions, please refer to the Watlow® F4 User’s manual.

Powering the System Down

1. Change the controller set temperature to 25°C.

2. Turn “OFF” the heater and the refrigeration switches located on the front of the controller.

3. Allow the air flow to continue until the nozzle temperature reaches room temperature (~+20°C) and wait an additional three to five minutes. This will permit the refrigerated heat exchanger to rise to room temperature while it is being purged with dry gas.

   Note: *If the system is turned off before the heat exchanger returns to room temperature, moist air may enter the heat exchanger through the nozzle and condense on the heat exchanger. If this is the case, when the air flow is started for its next operation, a small amount of moisture may be discharged from the nozzle or freeze onto the heat exchange surface when the refrigeration is turned on.*

Chapter

4

Controller Programs

Creating Profiles

A profile is a user defined sequence of operations (ramps, soaks, holds, step changes, *etc.*) that are programmed into the controller for immediate or future execution. The Watlow® F4 Series Ramping Controller can handle as many as 40 different profiles and a total of 256 steps, all stored in memory under default or user defined profile names. Chapter 4 of the Watlow® manual contains a detailed description of the profile functions and programming features, profile examples and profile record templates.

Note: *Set up the controller in the desired operating mode (e.g., nozzle, DUT, DUT monitoring control) and with the desired air flows (High Output Scale) before programming/saving profiles. The save/update function, executed upon exiting the Set Up Mode, will erase the saved profiles. Document profiles as you program them.*

The controller has six possible profile step types. They are:

AutoStart
Sets a time and/or date to initiate the profile.

Ramp Time
Changes the temperature setpoint to a new value in a chosen period of time.

Ramp Rate
Changes the temperature setpoint to a new value at a chosen rate.

Soak
Maintains the setpoint from the previous step for a chosen time.

Jump
Jumps to another step or profile.

End
Termination step with multiple options.

To create a profile:

1. From the Main Page, scroll to “Go to Profiles” and enter (▲/▼ to scroll and ► to enter).
2. Choose “Create Profile” (► to enter).
3. Choose to name file.
    - Choose “No” to accept a default name (► to enter), or
    - Choose “Yes” to name profile (▼ and ► to enter, use ▲/▼/► to adjust name and ►to save).

4. For each step, choose one of the step types listed above and input the proper parameters for each step. For more detailed help on programming profile steps, refer to Chapter 4 of the Watlow® Manual. A different PID Set (up to a maximum of 5 different sets) may be used for each step. For a quick start guide on programming multiple PID sets, see the subsequent Controller Tuning section of this manual.
5. To run a profile, hit the green profile button ( ) on the front of the Watlow® controller.
6. Choose “Yes” to start a profile (▲ to choose yes).
7. Choose the profile name you wish to run (▼ and ► to enter).
8. Scroll to the step you wish to start with and enter (▼ and ► to enter).
9. The profile will now execute as programmed.
10. To terminate or hold profile, press the green profile button ( ) on the front of the controller and choose either “Don’t Hold, “Hold”, or “Terminate” (▼ and ► to enter).

Controller Tuning

Both the nozzle (inner) control loop and the DUT (outer) control loop Proportional Integral Derivative (PID) parameters can be calibrated for optimal performance. This calibration can be performed manually, or by using the built-in auto-tuning capability in the Watlow® controller. For more details on controller features, please refer to the Watlow® F4 User’s manual.

Tuning PID Parameters in Nozzle Mode

During operation (excluding running programmed profiles), the controller uses PID parameters from PID Set 1. However, multiple PID Sets (up to 5 total) may be programmed and used for different steps within a profile (see Creating Profiles section).

Although the nozzle can be auto-tuned, SP Scientific strongly suggests that the nozzle be run with the factory set values for fast response, with the low overshoot values listed below or with values determined manually.

Standard auto-tuning algorithms works best if the characteristic response times are greater than 30 seconds. The rapid response time of the nozzle (and certain small DUTs) may produce poor control.

Autotuning the nozzle PID parameters may result in very good performance for the set point change used for the tuning, but may produce large overshoots, or oscillatory control, at other control points.

To Manually Edit PID Parameters in Nozzle Mode:

1. From the Main Page, scroll to “Go to Operations” and enter (▲/▼ to scroll and ► to enter).
2. Choose “Edit PID” (▼ and ► to enter).
3. Choose “Air PID Set” (► to enter).

4. Choose desired PID set to manually tune (1, 2, 3, 4, or 5) and press enter (▼ and ► to enter). PID Set 1 is the default set used during non-profile operations. Multiple PID sets may be used for different steps within a programmed profile.
5. Manually edit the PID parameters:
   a. Scroll down to “Proportional Band” (▼ and ► to enter).
   b. Enter Manual Setting for PB value (▲/▼ and ►to enter).
   c. Scroll down to “Reset” (▼ and ► to enter).
   d. Enter Manual Setting for Reset value (▲/▼ and ► to enter).
   e. Scroll down to “Rate” (▼ and ► to enter).
   f. Enter Manual Setting for Rate value (▲/▼ and ► to enter).
   g. Exit Operations and return to Main Page (press ◄◄◄◄ to return).

Response Type	Proportional Band	Reset	Rate
Aggressive (fast response with moderate overshoot)	55	15	0.01
Conservative (moderate response with small overshoot)	15	5	0.01

6. Change the system temperature (Setpoint) and observe control. If desired control is achieved, proceed with testing. If desired control is not achieved, try auto-tuning (above) or refer to the “Help with PID Parameter Tuning” section of this manual.

Tuning PID Parameters in DUT Mode

Verify the controller is in DUT mode. One must then be in either Process Cascade or Deviation Cascade.

The PID parameters for controlling DUT temperature can be optimized either manually or through the auto-tuning capability with the Watlow® Controller.

E.g., during operation (excluding running programmed profiles), the controller uses PID parameters from PID Set 1. However, multiple PID Sets (up to 5 total) may be programmed and used for different steps within a profile (see the Controller Programs Chapter).

When tuning the cascade loop always tune the outer (DUT) loop. The Inner (Nozzle) Loop may also be tuned, however SP Scientific recommends that the inner loop be set up with the factory values and only manually tuned when absolutely necessary.

“Optimal” DUT (outer) control loop PID parameters will vary significantly with DUT characteristics (size, mass, heat capacity, conductivity, *etc.*), thermocouple placement/contact and isolation/insulation. PID values listed below should only be considered a crude starting point.

To Auto-tune PID parameters in DUT Mode:

1. Choose a DUT set temperature within the operating range and allow the system to stabilize.
2. From the Main Page, scroll to “Go to Operations” and enter (▲/▼ to scroll and ► to enter).
3. Choose “Autotune PID” (▲/▼ and ► to enter).
4. Choose “DUT Autotune” to auto-tune the DUT control loop (▼ and ► to enter).
5. Choose desired DUT PID set to auto-tune (1, 2, 3, 4, or 5) and enter (▼ and ► to enter). DUT PID 1 is the default set used during non-profile operations. Multiple PID sets may be used for different steps within a programmed profile.
6. The system will now oscillate around the current setpoint, and try to determine an optimal set of PID parameters for that setpoint. Wait until the nozzle temperature stops oscillating, thereby signaling the end of the procedure.
7. Exit Operations and return to Main Page (◄◄ to return).
8. Change the system temperature (Setpoint) and observe control. If desired control is achieved, proceed with testing. If desired control is not achieved, try auto-tuning at an alternate temperature within the desired cycle or proceed with manual editing of PID parameters. (Repeat steps 3-8.)

To Manually Edit PID Parameters in DUT Mode:

Manually editing the PID values is useful when the auto-tuning procedure does not provide optimal control. Each of the PID parameters can be adjusted manually. Below is a brief description of each parameter and its effect on temperature transition, control, and stability. For more information you may refer to page 6.5 of the Watlow® F4 Controller manual provided.

- Proportional Band:
  Define a band for PID control. Lower values increase gain, which reduces droop but can cause oscillation. Increase the proportional band to eliminate oscillation.
- Integral (Reset):
  Define reset in repeats per minute.
- Derivative (Rate):
  Define the derivative (rate) time in minutes. Large values prevent overshoot but can cause sluggishness and reduced transition rates.

1. From the Main Page, scroll to “Go to Operations” and enter (▲/▼ to scroll and ► to enter).
2. Choose “Edit PID” (▼ and ► to enter).
3. Choose “DUT Loop” (to tune the DUT control loop) (▼ and ► to enter).
4. Choose desired DUT PID set to manually tune (1, 2, 3, 4, or 5) and press enter (▼ and ► to enter). PID DUT 1 is the default set used during non-profile operations. Multiple PID sets may be used for different steps within a programmed profile.

5. Manually edit the PID parameters:
    a. Scroll down to “Proportional Band” (▼ and ► to enter).
    b. Enter Manual Setting for PB value (▲/▼ and ►to enter).
    c. Scroll down to “Reset A” (▼ and ► to enter).
    d. Enter Manual Setting for Reset value (▲/▼ and ► to enter).
    e. Scroll down to “Rate A” (▼ and ► to enter).
    f. Enter Manual Setting for Rate value (▲/▼ and ► to enter).
    g. Exit Operations and return to Main Page (press ◄◄◄◄ to return).

Response Type	Proportional Band	Reset	Rate
Aggressive (moderate response with overshoot)	55	5	0.01
Conservative (slower response with smaller overshoot)	100	1	0.01

6. Change the system temperature (Setpoint) and observe control. If the desired control is achieved, proceed with testing. If desired control is not achieved, try auto-tuning (above) or refer to the subsequent “Help with PID Parameter Tuning” section of this manual.

Help With PID Parameter Tuning

Control loop tuning can be a frustrating and time consuming task. Before tuning a loop manually or modifying existing PID parameters it is recommended that the operator review general loop tuning procedures in a standard control textbook or in the Watlow® manual (pg 3.5 and pg 6.4 through 6.6). Before starting loop tuning it is important to clearly determine the control goals (overshoot, rise/fall time, settling time, *etc.*), the target operating conditions (air flows, temperature, set point, *etc.*) and the sequence of steps. It is also important to have realistic expectations.

1. The temperature rate change is limited by the air flow, thermal mass, heat losses and available power.
2. There is a tradeoff between fast response and overshoot.
3. The heating rate will typically be faster than the cooling rate.
4. Controller response will be different for heating and cooling step changes.
5. Controller response may be different for large and small setpoint changes.
6. Controller response may be different at high and low temperature settings.
7. DUT (cascade) control optimizes the DUT temperature response; the nozzle temperature (inner loop) will vary as specified by the DUT (outer) loop.
8. Restricting the inner loop response (decreasing the inner setpoint range or limiting the nozzle temperature below 225°C) will degrade transient response.
9. For a passive DUT, the nozzle air temperature will always be higher than the DUT when heating and colder when cooling.

Manual Tuning

When tuning a control loop from scratch the normal procedure is to:

1. Choose a starting and a target setpoint.
2. Set the proportional band (PB) for slow response (*e.g.*, approximately 100), and set both the integral and derivative terms to 0.
3. Observe the step change response from the start and target set points.
4. Adjust the PB. Decrease PB to speed response and reduce offset or increase PB to reduce oscillations.
5. Repeat 3 and 4 until the onset of oscillations, and then back off (increase) PB until oscillations stop.
6. Begin to add integral action in small increments.
7. Observe the step change response from the start and target set points.
8. Increase integral reset to reduce response/setting time or decrease integral reset to reduce oscillations.
9. Repeat steps 7 and 8 until an acceptable balance between response time and overshoot/settling time is reached.
10. (Optional) Gradually add small amounts of derivative action in the same systematic manner as for integral action. Derivative action can reduce initial overshoot, but can increase oscillation/decrease overall stability with noisy signals. Derivative action may help the outer (DUT) loop, but should generally be avoided, or kept to very small values for the inner (nozzle) loop.

    Note: *It is very important while tuning that only one control variable be changed at a time and the full transient between start and target setpoint are observed. Loop tuning results will improve and the overall effort will decrease by following a deliberate, systematic process.*

Adjusting Existing (Auto-Tuned) PID Values

When adjusting existing control parameters it is important to consider the following:

- Were these parameters developed for the current test conditions, controller set up (output limits, *etc.*) and DUT? If the test device or conditions were intentionally changed, the system should be retuned as described above. If the test device, controller set up or DUT were inadvertently changed, return the unit to its initial state and re-evaluate the control.
- Were these parameters developed by the auto-tune algorithm? For nozzle control, reconsider the factory recommended values, or manual loop tuning. For DUT control, consider auto-tuning at a more appropriate setpoint for a given range or at multiple points for profiles.

The same guidelines that applied for manual tuning still apply to adjustments. PB will affect initial response, integral reset will eliminate offset, but cause oscillations if too high. Derivative can reduce initial overshoot, but cause instability/erratic behavior if too high. You should change only one value at a time and observe the complete transient response. Tune the inner loop first.

- If the response is noisy, erratic, or borderline stable, try decreasing/ eliminating the derivative value.
- If the response has too much overshoot, or is oscillatory,
    a. eliminate/reduce the derivate,
    b. reduce the integral/decrease the PB (one at a time) and
    c. (optional) re-establish derivative.
- If the response is too slow to settle out,
    a. eliminate/reduce the derivate,
    b. increase the integral/increase the PB (one at a time) and
    c. (optional) re-establish derivative.

Calibration Offset

For the calibration procedure, refer to the Watlow® Controller Manual Series F42/D, Chapter 9. The following is a Quick Start guide to a visual aid in calibrating the controller.

Note: *Input 1 = Air, Input 3 = DUT.*

The Watlow® control allows the user to apply a single or multiple point (constant) offset to make the nozzle, or DUT temperature, match an external measuring device at a given flow conditions and temperature set point. These offsets are applied uniformly across the entire temperature range. Offsets are applied through the Set Up screen, as described below.

Note: *Changing/updating the offset values will erase existing profile programming.*

Enter a Nozzle Calibration Offset:

1. From the Main Page, scroll to “Go to Setup” and enter (▲/ ▼ to scroll and ► to enter).

2. Scroll to “Air Temp” (▲/ ▼ to scroll and ► to enter).
3. Choose “Thermocouple” (► to enter).
4. Choose Type “K” (▼ and ► to enter).
5. Choose “0.0” (▼ and ► to enter).
6. Set low limit (▲/▼ and ► to enter).
7. Set high limit (▲/▼ and ► to enter).
8. Set Offset type to “Single linear” or “Multiple point” (▲/▼ and ► to enter).
9. Choose desired calibration type. If single, go to step 7. If multiple, go to step 10.
10. Enter Calibration Offset value (▲/ ▼ and ► to enter).
11. Filter time should be set to 1.0 sec (▲/ ▼and ► to enter).
12. For Error Latch, choose “Self-Clear” (► to enter and return to Setup Menu).

    If “Multiple point” was chosen in step 8, continue to step 13.
13. Clear Air Offsets. “No” will leave previous values. “Yes” will default offset values.

	Offset Point	Offset Value
1	Operator specific lower calibration (ex. -55).	Operator specified offset.
2	Operator specified middle calibration point.	Specified offset.
3	Typically higher (125).	

14. Exit Setup and return to Main Page (◄ to return).
15. Save settings (▲ to save).

Enter a DUT Calibration Offset:

1. From the Main Page, scroll to “Go to Setup” and enter (▲/ ▼ to scroll and ► to enter).
2. Scroll to “Analog Input 3” (▲/ ▼ to scroll and ► to enter).
3. Choose “Thermocouple” (▲/ ▼ to scroll and ► to enter).
4. Choose Type “K” (▼ and ► to enter).
5. Choose “0.0” (▼ and ► to enter).
6. Input low limit should be set for -100 °C (▲/ ▼ and ► to enter).
7. Input high limit should be set for 225 °C (▲/ ▼ and ► to enter).
8. Enter Calibration Offset value (▲/ ▼ and ► to enter).
9. Filter time should be set to 0.5 sec (▲/ ▼ and ► to enter).
10. For Error Latch, choose “Self-Clear” (► to enter).
11. Choose “Process Cascade” (▼ and ► to enter).
12. Set cascade low range to -100ºC (▲/ ▼ and ► to enter).

13. Set cascade high range to 225ºC (▲/ ▼ and ► to enter and return to Setup Menu).
14. Exit Setup and return to Main Page (◄ to return).
15. Save settings (▲ to save).

External Communication Links

Serial Communications

To be used with WatView®. If the user chooses to create a program, see Watlow® Controller Manual Series F42/D, Chapter 7, “Communications.” Recommended additional parts:

- Black Box IC1620A-F RS232 to RS485 Converter
- Black Box PS1003 120VAC to 12VDC 500mA

IEEE-488 Communications (Using Modbus Protocol)

The purpose of these instructions is to provide the basic information necessary for the operation of the IEEE-488 port.

Configuration
This operation allows the user to set the IEEE address, determine the command set being used, and the termination characters.

Custom Message Four string setup procedure:

To get the Custom Message Four with the Watlow® controller:

1. Scroll down to “Go to Setup” and click right arrow to enter.
2. In Setup, scroll down to “Static Message” and click right arrow to enter.
3. In Static Message, scroll down to Message 4 and enter the user’s parameters.

Example
A04C0T1S0 will give IEEE address 4. C0 is an SP Scientific command set, T1 is single character determination, and S0 is an SRQ event generated during initial start up.

- “AaaCcTtSs”

  aa = IEEE address (0-30 valid)

  c = Command Set

  0 – SP Scientific

  1 – T2500 488.1

  2 – T2500 488.2

  3 – ThermoStream 488.2

  t = Number of termination characters.

  1 – Single char (LF or CR) response terminated same as command.

  2 – Two char (CR,LF or LF,CR) response terminated same as command.

  s = Service request enable/disable.

  0 – System generates a power ON SRQ event.

  1 – System does NOT generate a power ON SRQ event.

Available commands:
Commands common to all modes.

Notes: *All of the commands listed may not be available, depending on the model of the controller.*

Do not change Watlow® communications settings. The settings must remain at: Baud Rate = 19,200 and Address = 1.

Command		Description
General Commands	?SP	Request the systems current temperature setpoint (°C).
	?PV	Request system temperature. If in DUT returns DUT temp; if system is in Nozzle mode returns nozzle temp (°C).
	?TA	Request Nozzle temperature (°C).
	?TD	Request DUT temperature (Exact when the DUT temperature turns off/disable manually, it reads the last valid DUT temperature).
	?AL1	Request Nozzle temperature, 0 = ‘No’ alarm is present, 1 = ‘TC’ Open Nozzle Thermocouple
	?AL2	Request DUT temperature, 0 = ‘No’ alarm is present, 1 = ‘TC’ Open Nozzle thermocouple
	?TC	Request control status (0 = Nozzle, 1 = DUT).
	SPxxx	Change Setpoint value and x = -75.0 to 225.0.
	TCn	Nozzle or DUT n = 0,1.
	ID	Return to Idle mode.
	HL	Halt program run.
	CN	Continue program run.
GPIB Commands Set	*IDN?	Product ID.
	*STB?	Read Status Byte.
	*SRE(?)	Read/Write Service Request Enable.
	*TST?	Read Self Test Result.
	*ESR?	Read Event Status Register.
	*ESE(?)	Read/Write Even Status Enable.

Chapter

Maintenance 5

ALWAYS REMOVE POWER FROM THE UNIT BEFORE PERFORMING MAINTENANCE PROCEDURES.

Overview

There are no user serviceable components in the main refrigeration unit; all maintenance to this unit should be performed by SP Scientific service personnel or their qualified designees. Before removing the unit cover, the service personnel should depress the emergency off “EMO” button, lock open the main breaker and disconnect the power.

The refrigeration unit is a hermetically sealed system. With the possible exception of cleaning dust out of the air cooled condenser, this system does not require regular maintenance. In the event of a refrigeration leak, however, the refrigerant type and pressure are listed on the serial tag on the rear of the unit. Each compressor stage has a pair of access valves, for testing and recharging, located at the back of the unit. Refrigeration system testing, repair and recharging may only be performed by SP Scientific service personnel or their qualified designees.

If the refrigeration unit has difficulty starting it may be for one of the following reasons:

Low voltage can cause starting problems.

- Check the wall voltage at the receptacle both with the unit disconnected, and with the unit connected and “ON”. The voltage for proper operation should be ±10% of the rating on the nameplate.
- If the voltage does not meet this criteria, try another receptacle. Low voltage can also be a result of other heavy electrical equipment on the same line or a long, insufficient gauge extension cord. Preferably, the refrigeration unit will be plugged into a dedicated line with the proper breakers and wire gauge for the nameplate requirements. Your electrical department can assist with this problem.
- If the unit has been running, shut off, and immediately restarted, the compressor will have to come up to speed while working against the high discharge pressures. In addition, the temperature of the inter-stage heat exchanger may still be sufficiently cold that both compressor start simultaneously. This may cause the unit to vibrate. If for any reason the unit continues to vibrate, turn the unit “OFF” and allow the refrigeration system to warm up for 15 to 20 minutes before attempting to restart. In general, cycling the compressors on and off should be avoided.

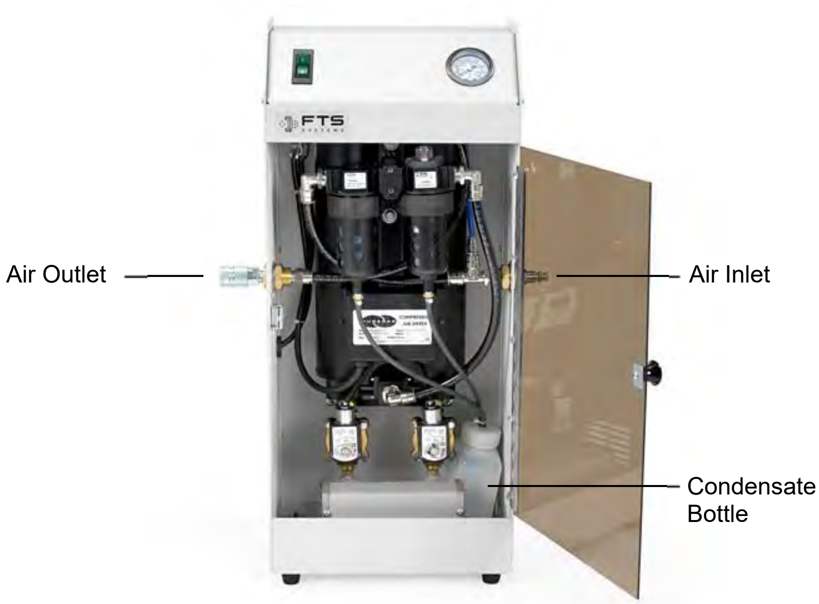
Appendix A: Optional Equipment

Optional Air Dryer (AD100)

The AD100 is designed to dry incoming compressed air to < -80°C dew point, as required for the XE series sample coolers. To fully exploit the XE sample cooler's capabilities, the AD100 should be connected to an air supply capable of providing ≥6 SCFM at pressures ≥75 PSIG. When provided with relatively oil free, dry air this unit will provide years of trouble-free service.

Operation

1. Verify the facilities voltage matches the requirement for the machine. The electrical information is printed on the serial tag on the rear of the machine.
2. Ensure the rocker power switch on the front of the unit is in the OFF position (O).
3. Plug in the line cord.
4. Attach one of the quick disconnect hoses to the OUTPUT of the AD100 and to the INPUT of the refrigeration unit.



5. Attach the shop air line to the INPUT of the AD100.
6. Turn on the AD100; toggle the rocker switch to the ON position (I).

7. The system is now operational. The operator will hear the solenoid valves clicking and air being purged from the off-line desiccant bed on a ~60 second regeneration cycle.

   Note: *The AD100 must be activated before starting and must be kept powered up while running the XE sample cooler. Although the system will allow air to pass through one of the two desiccant beds without power, the bed will not regenerate and no moisture removal will take place. This will ultimately lead to ice blocking off the air flow in the XE sample cooler heat exchanger.*

Drop Filters

Depending on the quality of the INPUT air, it may be necessary to put a container under the drain lines (inside the AD100) to capture excess water or oil trapped by the pre-filters on the input air line.

The air dryer manufacturer recommends that the water and oil separator elements be changed every 6 months. Contact SP Scientific Service for replacement part numbers and procedures.

Appendix B: Refrigerant Information

THE REFRIGERANTS AND INSULATING FOAM USED IN THE MANUFACTURE OF THIS EQUIPMENT CONTAIN FLUORINATED GREENHOUSE GASES.

EU F-Gas Regulation (517/2014)

SP Scientific freeze dryers, low temperature chillers, glycol coolers and low temperature vapor condensers utilize several hydrofluorocarbons (HFC) refrigerants and foam blowing agents. The import and use of these HFC refrigerants within the European Union (EU) are regulated by the EU F-Gas Regulation (517/2014). As a result, all SP Scientific products containing HFCs shall be labelled, and instruction manuals shall include the information placed on the label.

F-Gas labels shall include:

- The type of HFC refrigerants used.
- The quantity of HFC refrigerants expressed in weight (Kg),
- The GWP (global warming potential) of HFC refrigerants.
- The total CO_2 equivalent (CO_2e) of HFC refrigerants contained in the equipment.
- A reference that the refrigerants and insulating foam contain fluorinated greenhouse gases.

The following F-Gas information is provided for (MODEL) equipment. This information shall also be included on the F-Gas label attached to equipment after 1 January 2017.

Equipment Model	Gas #1			Gas #2			Gas #3			Total CO_2e (tonnes)
	F-Gas	Charge (Kg)	GWP	F-Gas	Charge (Kg)	GWP	F-Gas	Charge (Kg)	GWP	
AirJet XE75	R1150	0.043	3.7	R1270	0.015	1.8	N/Ap	N/Ap	N/Ap	0.000
AirJet XE75 Vistakon	R404A	0.035	3922	R508b	0.097	13396	N/Ap	N/Ap	N/Ap	1.437

General EU Compliance Guidelines

Leak Prevention & Checking

Any equipment with less than 5 tonnes CO_2e (non-hermetic) or 10 tonnes CO_2e (in hermetically sealed systems[5]) is exempt from leak checking under the EU F-Gas regulation as of 01 January 2017. Owners and end-users of SP Scientific products with CO_2 weight limits above the aforementioned may be subject to the automatic leak detection requirement.

Record Keeping / F-Gas Registry

Many SP Scientific products are below the CO_2 weight limit threshold for meeting the record keeping requirement, however, some SP Scientific products are above the size threshold specified. In such cases, owners and end users must understand and comply with the record keeping requirements of the EU F-Gas regulation.

Note: *All importers of equipment pre-charged with HFCs must have a registry account.*

Recovery

Equipment owners and users must understand and meet mandatory obligations regarding the recovery of HFC refrigerants and foam blowing agents at end-of-life from equipment of all sizes. SP Scientific shall not assume responsibility for the disposal and/or recovery of HFC refrigerants and foam blowing agents.

Service, Training and Certification

All servicing that involves breaking into the refrigeration circuit must be performed by technicians holding relevant training certificates. This applies to equipment of all sizes.

Control of Use / Service Ban

The 2014 EU F-Gas Regulation includes a “service ban” that bans the use of HFCs with a GWP above 2500 for the maintenance of existing refrigeration equipment with virgin refrigerant after January 2020.
The ban includes:

- A size threshold of 40 tonnes CO_2e.
- An exemption for equipment that cools products to below -50 ^oC.
- An exemption for the use of reclaimed refrigerant until 2030.

Note: *Many SP Scientific products are below size threshold specified or operate with products below -50 ^oC. For these products, the service ban has no impact. However, for medium- and large-sized systems that use a refrigerant with a GWP above 2500, and do not operate below -50 ^oC, the service ban requires compliance which shall be the responsibility of the equipment owner and/or end user.*

[5] “Hermetically sealed equipment” means equipment in which all fluorinated greenhouse gas containing parts are made tight by welding, brazing or a similar permanent connection, which may include capped valves or capped service ports that allow proper repair or disposal, and which have a tested leakage rate of less than 3 grams per year under a pressure of at least a quarter of the maximum allowable pressure.

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