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George C. Marshall Space Flight Center
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FACILITY OPERATING PROCEDURE FOR SUNSPOT THERMAL VACUUM CHAMBER

ENVIRONMENTAL TEST FACILITY BRANCH
STRUCTURAL AND ENVIRONMENTAL TEST DIVISION
TEST LABORATORY
ENGINEERING DIRECTORATE

FACILITY OPERATING PROCEDURE
FOR SUNSPOT THERMAL VACUUM CHAMBER

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1.0 GENERAL INFORMATION

1.1 PURPOSE

This document describes the procedures for the operation of the Sunspot Thermal Vacuum Chamber located in MSFC Building 4619.

1.2 SCOPE

The procedures and practices outlined in this document are to be followed in the operation of the Sunspot Thermal Vacuum Chamber. This document provides a record copy of Sunspot chamber operations.

1.3 APPLICABLE DOCUMENTS

MPR 8715.1	Marshall Safety, Health, and Environmental (SHE) Program
MWI 8715.1	Electrical Safety Program
ET24-ETF-OWI-001	Environmental Test Facility Test Operations
ET24-LOTO-SOP-001	Control of Hazardous Energy (Lockout/Tagout) Procedure for the Environmental Test Facility
ET24-UnattnOps-SOP-001	Unattended Operation of the Environmental Test Facility
ET24-LN2-FOP-001	Facility Operating Procedure for the Liquid Nitrogen System
ET24-Crane-SOP-001	Overhead Crane Operations Safety Requirements Document Utilizing Overhead Crane/Hoist RR335
ET24-RGA-SOP-001	Detailed Operating Procedure for Residual Gas Analyzer System
ET24-TQCM-SOP-00	Detailed Operating Procedure for Temperature-Controlled Quartz Crystal Microbalance (TQCM) System
ED26 (02-01)	Memorandum, Safety Assessment for the ETF (soon to be issue as an ET24 memo, number unknown)

1.4 SAFETY

All test personnel working in this facility shall be familiar with the safety documents listed above and shall report any safety hazards, unsafe practices, safety incident or near misses to the ETF Branch Chief or the 4619 Building Manager Assistant. In addition to the above safety precautions, all personnel involved in facilities using cryogenics shall be aware of the possibility of freeze burns by contact with cold surfaces or liquids. All personnel involved in handling of cryogenics or when making repairs/modifications to cryogenic facilities shall wear protective clothing including eye protection and gloves. Only certified cryogenic handlers shall perform repairs/modifications to cryogenic systems. In the event of a cryogenics spill, line ruptures, or similar emergencies, personnel shall first ensure that there is no possibility of asphyxiation due to oxygen displacement. Use a portable oxygen monitor to verify oxygen is adequate before entering the spill area.

During chamber operations, the pit entrance shall be chained off and a warning light shall be displayed to limit access to the enclosed pit area.

The chamber can reach extreme temperatures both hot and cold. The test chamber and test article shall be given sufficient time to return to ambient temperature $\pm$10 degrees C ($\pm$ 18 degrees F) before entering the test chamber.

The personal protective equipment (PPE) requirements and job hazard analysis (JHAs) for operation of the chamber are listed in the ET24 Safety Assessment, Memorandum of Record ED26 (02-01) (soon to be issued as an ET24 memo, number unknown). Chamber operators shall be familiar with these documents to understand associated hazards and methods to mitigate the risk from these hazards.

1.5 RESPONSIBILITY

ETF personnel shall be responsible for the operation of the Sunspot Thermal Vacuum Facility. The designated operator of the chamber shall be responsible for the safe operation and conduct of the facility. This responsibility includes safety for personnel, the test article, and the facility. The operator shall record his name in the chamber logbook.

Other task assignments and responsibilities at the ETF shall be in accordance with ET24-ETF-OWI-001.

1.6 EMERGENCY TELEPHONE NUMBERS

Dial **911** for all emergencies, including:

Medical	**911**
Fire	**911**
Ambulance	**911**
Security	**911**
Chemical Spills	**911**

Other number that can be used to obtain information about emergency, security, safety, and utilities are:

Medical Center	544-2390
Security	544-4357
Safety	544-0046
Utilities	544-3919
Other Assistance	544-4357 (4-HELP)

1.7 CHECKOUT TEST

Prior to testing an item in the facility, particularly for critical qualification tests, it is recommended that a "dummy" test article be used for determining program set-points for the thermal controllers and safety devices. The "dummy" test article shall provide an accurate thermal simulation of the actual test article.

********** **WARNING**********

Maintenance or operating procedures, techniques, restrictions, etc., may result in severe personnel injury, loss of life or major equipment damage if not followed exactly.

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1.8 HAZARDS LIST

- 120, 208, and 480 volts AC electrical power.
- Extreme temperatures in the chamber (hot and cold)
- Liquid nitrogen (LN_2)
- High kinetic energy in turbo pump
- Vacuum pump oil
- Removal of top hatch

**********WARNING**********

Prior to performing maintenance on any equipment, lockout and tag the equipment in accordance with Lockout/Tagout Procedure ET24-LOTO-SOP-001. Maintenance shall be performed by qualified technicians only.

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1.8.1 Minimizing Electrical Shock Hazards

1.8.1.1 All electrical repairs and modifications shall be performed by electrical technicians to minimize the electrical shock hazard.

1.8.1.2 All bare electrical parts inside the chamber with a potential to ground of 50 volts or greater shall remain de-energized when the chamber is open. If this is infeasible, then safety related work practices shall be employed to prevent electrical shock. The safety related work practices shall be documented in accordance with MWI 8715.1 and approved by a senior

ETF electrical engineer. All work near energized bare electrical parts shall be performed by qualified persons.

1.8.1.3 Personnel shall not enter into or reach into a chamber with energized bare electrical parts where there is a lack of illumination or an obstruction of view. Personnel shall never blindly reach into an area that may contain energized bare electrical parts.

1.8.1.4 Personnel shall remove all conductive apparel before working near energized bare electrical parts, including jewelry, watches, key chains, metalized aprons, and metal head gear.

1.8.1.5 Personnel may not perform housekeeping duties at close distances to energized bare electrical parts unless adequate safeguards are provided. Only non-conductive cleaning materials shall be used.

1.8.1.6 Any ladder used to enter chambers containing bare electrical parts energized at 50 volts or greater shall have nonconductive side-rails.

1.8.1.7 Personnel working near bare electrical parts energized at 50 volts or greater shall be provided protective equipment adequate to insulate the potential shock hazard. Personnel shall use insulating tools near energized bare electrical parts.

1.8.1.8 Safety signs or tags shall be used to warn personnel that electrical shock hazard is present when there are bare electrical parts energized at 50 volts or greater.

1.8.1.9 Barricades shall be used in conjunction with signs or tags to limit personnel access.

1.8.1.10 Any de-energized electrical parts that are not locked-out, tagged-out, or unplugged shall be considered energized. If tag-out is the method used, two or more safeguard measures shall be used. Any bare electrical part that is energized at less than 50 volts to ground need not be locked-out or tagged-out provided there is no risk of burns or arcing.

1.8.1.11 All live electrical parts located outside the chamber and energized at 50 volts or greater shall be guarded against accidental contact. Guarding methods include approved enclosures or permanent partitions or screens that restrict access by non-qualified personnel.

1.8.1.12 Personnel shall not handle, energize or de-energize, plug-in or unplug any electrical device when the device is wet, the employee is wet, or the floor is wet.

1.8.1.13 Locking type connectors shall be properly secured after connection.

1.8.1.14 After a circuit has been de-energized by the opening of a protective device, the circuit shall be inspected by an ETF electrical technician before the circuit is re-energized.

1.8.1.15 Over-current protective devices shall not be modified.

1.8.2 Minimizing Extreme Temperature Hazards

The test chamber and test article shall be given sufficient time to return to ambient temperature ±10 degrees C (±18 degrees F) before entering the chamber in order to minimize the extreme temperature hazard.

1.8.3 Minimizing LN_2 Hazards

Personnel shall be aware of the possibility of freeze burns by contact with cold surfaces or liquids. All personnel involved in handling of cryogenics or when making repairs/modifications to cryogenic facilities shall wear protective clothing, eye protection and gloves. Repairs/modifications to cryogenic systems shall be performed by certified cryogenic handlers. In the event of a cryogenics spill, line ruptures, or similar emergencies, personnel shall first ensure that there is no possibility of asphyxiation due to oxygen displacement. Use a portable oxygen monitor to verify the area is safe before entering.

1.8.4 Minimizing Turbo Pump Hazards

The turbo pumps have several rotors, each with numerous thin blades that rotate about 27,000 rpm. Mechanical shock and particles in the flow stream can cause rapid unpredictable failure of the pump. Allow adequate time for the rotors to come to a complete stop before any work is performed on the turbo pumps. Never allow the pumps to be mechanical shocked or moved when they are operating.

1.8.5 Minimizing Pump Oil Hazards

The vacuum pump oil can cause skin and eye irritation. Avoid skin and eye contact with the oil. Remove this oil from the skin using soap and water. Wear eye protection and gloves while adding or changing oil. Remove oil from the eyes by flushing with water for 15 minutes. Avoid breathing vacuum oil mist.

Any spilled oil is a slip hazard. Clean the area of any spilled oil immediately. Use barricades to limit access in the area until the spill is cleaned.

1.8.6 Minimizing Overhead Lifting Hazards

Adhere to the requirements of the Overhead Crane Safety Requirements Document to minimize the hazards during removal/replacement of the top hatch using the crane. Only personnel that are identified by their signature in Overhead Crane Safety Requirements Document MSOP-SC -ETF-408 (soon to be superseded by ET24-Crane-SOP-001) shall be involved in the top hatch removal.

2.0 FACILITY DESCRIPTION

2.1 CHAMBER DESCRIPTION AND DIMENSIONS

The Sunspot Chamber is a stainless steel vessel with black interior surfaces. The Sunspot Vacuum Chamber has an internal dimension of 10 feet diameter by 12 feet high. The top entrance is restricted to 9 feet 2 inches in diameter by the inward flare of the thermal shroud. A three-foot extension can be added to the chamber to increase the internal working height to 15 feet. The chamber is equipped with a thermal shroud for test articles heating and cooling and infrared lamps for heating. Installation of infrared lamps reduces the useable interior space.

2.2 VACUUM SYSTEM

The vacuum system consists of a Stokes 1722 pumping skid for roughing the chamber. The chamber is isolated from the roughing pumps by a 12-inch sliding gate valve. For primary chamber pumping a CVI Torr Master TM 1200 Cryo Pump is utilized. The chamber is isolated from the cryo pump by a GBN 48-inch sliding gate valve. A Varian V-1800 turbo pump backed by a Varian SD-700 roughing pump is used for additional high vacuum pumping capability.

2.3 CONTROL SYSTEM

The control system consists of a programmable logic controller (PLC) connected to a desktop computer running *Intellution iFIX* control software. Additional, control of the sunspot chamber requires the operation of manual hand valves and switches located at the chamber. *iFIX* software also controls the flow of LN_2 in the seven shroud zones during thermal conditioning. Three Dimension Controllers provide control of the infrared lamp.

2.4 THERMAL SYSTEM

Cold thermal conditioning is provided by thermal shrouds using liquid nitrogen for a coolant. Hot thermal conditioning is provided by either hot gas in the shrouds or infrared lamps mounted on a metal frame powered by a 3-phase power phaser. Thermal conditioning by infrared lamps is controlled by three Dimension controllers. The infrared lamp array is temporary and is usually removed to increase internal space when not required. The cryogenic shrouds are more difficult to remove and remain in the chamber.

2.5 PERFORMANCE

This chamber is designed to operate from 760 torr (ambient pressure) to $1x10^{-8}$ torr with cryogenic shroud capability below $1.0x10^{-3}$ torr (1 millitorr). Pumping speeds varies with test specimen, gas load, and internal chamber conditions. The cryo pumps requires three hours for cool down, which may be started prior to chamber pump down. A clean-dry system performs approximately as follows:

- Atmosphere to 50 E -3 torr (1.0 E 5 to 6.7 Pascal) in approximately 40 minutes
- 50 E -3 torr to 1 E -6 torr (6.7 to 1.3 E-4 Pascal) in approximately 45 minutes (with cryo pump in cold standby)

- Atmosphere to 1 E -6 torr (1.0 E 5 to 1.3 E-4 Pascal) in approximately 4 hours (when starting cryo pump)

NOTE

Maintenance or operating procedures, techniques, restrictions, etc., requires emphasis for safe operation.

3.0 FACILITY OPERATION

The operations of the Sunspot Chamber varies according to the temperature range, off-gassing rate of the test article, and whether steady state or varying environments is required. This procedure provides general instructions on how to operate the chamber, but does not cover every possible scenario. Operating personnel shall be thoroughly familiar with vacuum chamber operation, the thermal conditioning software and the data acquisition software.

Complete the As-run Buy-off Sheet when operating the chamber. These sheets are typically provided with the TPS. If none are provided, use a copy of Attachment A.

3.1 FACILITY PREPARATION

3.1.1 Review the Safety Assessment, Memorandum of Record ED26 (02-01) (soon to be issued as an ET24 memo, number unknown), to determine the JHAs and PPE that applies to operation of this chamber. Implement the risk mitigation methods listed in the JHAs and use the required PPE to minimize risk from potential hazards while operating this chamber.

3.1.2 Ensure that all connections to the chamber are compatible with proper operation of the chamber. Determine that the test is ready to start.

**********WARNING**********

Prior to performing maintenance on any equipment, lockout and tag the equipment in accordance with Lockout/Tagout Procedure ET24-LOTO-SOP-001. Maintenance shall be performed by qualified technicians only.

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3.1.3 Calibration

3.1.3.1 Verify that all instrumentation used to record data on this test have current calibration labels.

3.1.3.2 Verify that the calibration does not expire before the expected test conclusion date.

3.1.3.3 Select the channels needed for the test on the Sunspot data acquisition computer.

3.1.4 Roughing Pumps

3.1.4.1 Visually inspect the level and condition of the oil in the five roughing pumps. There are two sight glasses on each of the two Roots pumps, one on the Microvac pump, and one on each of the two Varian SD 700 pumps. Add or change oil as needed. Oil shall be changed whenever it is darkened, contaminated, milky, or if the pump performance has degraded. Wear eye protection and gloves when changing oil. Wash water from the skin with soap and water. Flush an eye with water for 15 minute if an eye is contaminated with vacuum pump oil.

3.1.4.2 Any spilled oil is a slip hazard. Clean the area of any spilled oil immediately. Use barricades to limit access in the area until the spill is cleaned.

3.1.4.3 Drain a small amount of oil from the cryo roughing pump and the Microvac pump (HOV305) to remove any water in the oil. Drain into a transparent container and inspect for water contamination. Add oil as needed after water is removed. Wear eye protection and gloves when adding oil. Dispose of changed oil in the waste oil drum, near the emergency generator.

3.1.4.4 Drain the water from the roughing line (HOV303).

3.1.4.5 Verify the two cooling water inlet hand valves are open, one above the Microvac pump and one above Blower 2.

3.1.4.6 **CLOSE** the gas ballast valve (small cock valve near center on north and south sides of the Microvac pump).

3.1.4.7 Verify the oil drain valve is closed (faucet valve on southeast corner of the Microvac pump).

3.1.4.8 **CLOSE** the leak detector attachment-port hand valve (small stainless valve above the small Roots pump).

3.1.4.9 Visually inspect the condition of the roughing pump drive belts (3 sets of belts). Replace damaged and worn belts.

3.1.5 Visually inspect all liquid and gas system components for leaks.

3.1.6 Verify the cryo compressors cooling water hand valves are opened.

3.1.7 Visually inspect the level of the oil in the turbo pump. There is a sight pan at the bottom of the pump. Add oil as needed. Wear eye protection and gloves when adding oil.

3.1.8 Verify the GN_2 hand valves are open. These are the GN_2 valves for cryo pump purge (GN1), the turbo pump cold trap purge (GN2), the roughing line cold trap purge (GN3), and the Cryo pump high-vac control (GN4).

3.1.9 Verify the chamber bottom flange is **CLOSED**.

3.1.10 Inside the chamber, verify the top of the roughing line gate valve is free of debris. Vacuum as needed.

3.1.11 Remove all unneeded equipment from the chamber.

3.1.12 Photograph the test article and test setup. Take as many photographs as necessary dependent on the complexity of the test setup. Copies of these photographs shall be given to the ETF Test Data Administrator before or immediately following the end of testing. Omit this step when the customer restricts photographing of the test article.

3.1.13 Verify test article instrumentation monitored by the ETF is properly connected and operational.

3.1.14 Verify there are no personnel in the chamber, and then **CLOSE** the man entry door using side clamps.

3.1.15 Verify that all vacuum connections and ports are sealed.

3.1.16 Verify that the cryogenic lines are connected to the chamber top and west dome. Visually inspect all liquid nitrogen supply lines for leaks, typically indicated by frost or condensate.

*******************************WARNING: LN_2*********************************

The Sunspot thermal vacuum test chamber has numerous overhead LN_2 lines. Any liquid leaking shall be assumed to be LN_2 until established otherwise. The area of an LN_2 leak shall be roped-off to prevent personnel from inadvertently entering this area. Personnel shall comply with safety precautions of Section 1.4 and 1.8 and wear adequate personnel protective gear when entering the leak area.

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3.1.17 Verify inside pneumatic panels located near the southwest corner of the chamber.

3.1.17.1	GN_2 Supply	950 $\pm$ 50 psig
3.1.17.2	LN_2 Tank Pressurization	400 $\pm$ 50 psig
3.1.17.3	Control Valve GN_2	95 $\pm$ 10 psig
3.1.17.4	Auxiliary GN_2	95 $\pm$ 10 psig
3.1.17.5	Automatic Controller	18 $\pm$3 psig
3.1.17.6	Air Supply	1100 $\pm$90 psig
3.1.17.7	1st Stage Air	250 $\pm$ 30 psig
3.1.17.8	2nd Stage Air	9 $\pm$ 2 psig

3.1.18 Verify hand valve positions located inside pneumatic panels.

3.1.18.1 **OPEN** LN_2 Tank Pressure Supply Valve HOV201.

3.1.18.2 **OPEN** Control Valve GN_2 Supply Valve HOV203.

3.1.18.3 **OPEN** 200 PSIG AUX. GN_2 Supply Valve HOV204.

3.1.18.4 **OPEN** Control Valve GN_2 Supply Valve HOV205.

3.1.18.5 **OPEN** Air Supply Valve HOV206.

3.1.18.6 **OPEN** Air Chamber Backfill Valve HOV207.

3.1.19 Verify pressures at the pneumatic panel located outside at the north end of LN_2 Vessel SV3.

3.1.19.1	Panel Supply Pressure	400 $\pm$ 30 psig
3.1.19.2	Tank Pressurization Pressure (GNR38)	100 $\pm$ 10 psig
3.1.19.3	Controller Pressure (GNR39)	25 $\pm$ 2 psig
3.1.19.4	SOV Supply Pressure (GNR41)	60 $\pm$ 10 psig

3.1.20 Operate the LN_2 system using Facility Operating Procedure for the Liquid Nitrogen System, ET24-LN2-FOP-001.

3.1.21 Visually inspect electrical equipment for external damage including flexible cords, connectors, and plugs. An ETF electrical technician shall repair damage before proceeding to the next step.

3.1.22. **Data Acquisition**

The following instruction is for the PACRATS Data Acquisition software. If the Sunspot Chamber is using *iFIX* software for data acquisition, skip to Section 3.2.

3.1.22.1 If using PACRATS, verify that the data acquisition system is programmed in accordance with customer's data requirements.

3.1.22.2 If using PACRATS, start recording data prior to chamber pump down.

3.1.22.3 If using *iFIX* for data acquisition, select channel used on the data acquisition computer.

3.1.22.4 If there is test article instrumentation that is recorded on the ETF data acquisition system, verify this instrumentation is operational.

3.2 SYSTEM STARTUP

The chamber is controlled from the Sunspot computer display. Components may be operated by using the mouse to move the cursor to the component and then clicking the left mouse button. Another method of operating components is by touching them on the touch sensitive screen. Operators shall ensure a non-operator does not touch the screen. If a component must be operated manually, a component location shall be given in the following instructions.

3.2.1 Switch **ON** the Sunspot control computer and start *iFIX* control software**.**

3.2.2 Roughing Preparations

3.2.2.1 **CLOSE** the roughing line vent valve (HOV303) located in the pit.

3.2.2.2 Switch **ON** the pit warning light and place the chain across the pit entrance.

3.2.3 Roughing and Starting Cryo

The following switches are on the *iFIX* control screen unless indicated otherwise. Devices icon on the control screen changes to a bright color to indicate it is switched ON or OPENED. When black or gray the device is OFF or CLOSED.

3.2.3.1 **OPEN** the Pump Cooling Water.

3.2.3.2 **OPEN** the Sunspot/V11 LN_2 input valve (ROV2) located on the LN2 system control computer.

3.2.3.3 **OPEN** the LN_2 Bypass Valve (ROV11).

3.2.3.4 Monitor the LN_2 vent line outside. When the LN_2 vent line starts to frost over, **CLOSE** the LN_2 Bypass Valve. Visually inspect all liquid nitrogen supply lines for leaks, typically indicated by additional frost or condensate at the area of the leak.

3.2.3.5 **RUN** the Cryo Roughing Pump.

3.2.3.6 Wait one minute, and then **RUN** the Cryo Pump Roughing LN_2 Controller.

3.2.3.7 Wait until the cryo pump roughing LN_2 controller cycles, and then **OPEN** the Cryo Pump Roughing Valve.

3.2.3.8 When the cryo pump pressure reaches $1.0x10^{-1}$ torr (100 millitorr), **CLOSE** the Cryo Pump Roughing Valve.

Note: Never let the cryo roughing pressure go below $7.5x10^{-2}$ torr.

3.2.3.9 If the pressure rises at a rate greater than 15 millitorr / minute, then rough the cryo pump again by returning to step 3.2.3.7.

3.2.3.10 **RUN** Cryo Compressors 1 or 2.

3.2.3.11 **RUN** the Cryo Pump LN_2 Shroud LN_2 Controller.

3.2.3.12 **STOP** the Cryo Pump Roughing LN_2 Controller.

3.2.3.13 **OPEN** the Cryo Roughing Cold Trap Purge Valve.

3.2.3.14 Allow the Cryo Roughing Cold Trap to purge for 30 minutes, and then **CLOSE** the Cryo Pump Cold Trap Purge Valve.

3.2.3.15 **STOP** the Cryo Roughing Pump.

3.2.3.16 **RUN** the Microvac Pump.

3.2.3.17 **OPEN** the Roughing Valve.

3.2.3.18 Wait until the chamber pressure reaches 500 torr or less, and then remove the man entry door side clamps.

3.2.3.19 Wait until the pressure reaches 100 torr or less, and then **START** the Chamber Roughing LN_2 Controller.

3.2.3.20 When chamber pressure reaches 25 torr, **RUN** Blower 1.

3.2.3.21 When chamber pressure reaches 10 torr, **RUN** Blower 2.

3.2.3.22 When the chamber pressure reaches 500 millitorr ($5x10^{-1}$ torr) **OPEN** the LN_2 supply valve (VV6 LN_2 Bypass) to the scavenger plate. This green handle valve is located on the north side of the chamber near the stair well railing.

3.2.3.23 Allow the chamber to rough pump to 100 to 60 millitorr ($1.0x10^{-1}$ to $6.0x10^{-2}$ torr).

3.2.4 High Vacuum Operation

3.2.4.1 Verify back line vent is **CLOSED**.

3.2.4.2 **RUN** the Turbo Backing Pump

3.2.4.3 **RUN** the Turbo Backing LN_2 Controller..

3.2.4.4 Allow the turbo backing cold trap to cycle, and then switch **ON** the Turbo Controller.

3.2.4.5 If the chamber is at 100 millitorr ($1.0x10^{-1}$ torr) or less, **CLOSE** the Roughing Valve.

3.2.4.6 **OPEN** the Turbo Hi-Vac Valve.

3.2.4.7 Allow the cryo pump to reach a temperature of 20K or less (15K is best), and then **OPEN** the Cryo Hi-Vac Valve.

3.2.4.8 When the Convectron gauge indicate pressure in 10^{-4} range, switch **ON** the ion gauge on the gauge controller.

3.2.4.9 Verify the chamber pressure begins to drop rapidly (Gauge 1).

3.2.4.10 To start cryo walls operation, go to Section 3.4.

3.2.4.11 **STOP** Blower 2.

3.2.4.12 Wait 30 seconds, then **STOP** Blower 1.

3.2.4.13 **STOP** the Chamber Roughing LN_2 Controller.

3.2.4.14 **OPEN** the Chamber Roughing Cold Trap GN_2 Purge valve.

3.2.4.15 Allow the chamber Roughing Cold Trap to purge from thirty minutes to one hour, and then **CLOSE** the Chamber Roughing Cold Trap Purge Valve.

3.2.4.16 **STOP** the Microvac Pump.

3.2.4.17 **OPEN** the chamber roughing line vent valve (HOV-303) located in the pit.

3.3 CONTAMINATION MONITORING

The contamination levels in the chamber shall be monitored at least twice during the test. The first monitoring period shall be soon after the chamber reaches high vacuum. The chamber contamination level shall be monitored again before venting the chamber at the end of the test. This last monitoring period establish the chamber's contamination baseline for the next test. If the chamber has significant contamination, the next-test baseline shall be established after the chamber is cleaned. Contamination data shall be maintained as a record separate from the test data. This data may be provided to the customer upon request. Use both a temperature-controlled quartz crystal microbalance

(TQCM) and a residual gas analyzer (RGA) to monitor the contamination. The RGA shall be operated in accordance with ET24-RGA-SOP-001 and the TQCM shall be operated in accordance with ET24-TQCM-SOP-001.

3.3.1 Complete initial monitoring of chamber contamination. Skip the next step and complete the rest of testing before returning to Contamination Monitoring Step 3.3.2.

3.3.2 Monitor the contamination once more before the end of the test. Return to Section 3.7.1 once monitoring is completed.

3.4 THERMAL CONDITIONING

Thermal conditioning can be accomplished in one of three ways: 1) using infrared lamps to heat, 2) using the shrouds to heat, 3) using the shrouds to cool.

3.4.1 Cryogenic Wall Operation

The following switches are on the *iFIX* control screen unless indicated otherwise.

3.4.1.1 **OPEN** the Cold Panel Input Valves as needed.
3.4.1.2 Allow the shrouds to cool for 50 minutes.
3.3.1.3 Verify zone in use are indicating cryogenic temperatures and are functioning correctly.

3.4.2 Hot Wall Operation

The following controls are located at or near the heater, near the southeast corner of the pit, unless indicated otherwise.

CAUTION***********************************

This section is not for cryogenic wall shutdown. Proceed to Section 3.7.3 for cryogenic system shutdown.

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3.4.2.1 **OPEN** the Warm-up System Supply Valve (HOV-202) located near the southwest corner of the chamber on the inside air panel.
3.4.2.2 **SET** heater thermostat to the desired temperature.
3.4.2.3 **OPEN** the Valve HOV-312 (hot gas supply valve).
3.4.2.4 Switch **ON** the heater.
3.4.2.5 Open the shroud control valves on the control computer to the zones needing heat.

3.4.3 Infrared Lamp Operation

3.4.3.1 Switch **ON** the R.I. limiter, located south of the clean room near the power phaser cabinets.

3.4.3.2 Press the R.I. limiter reset button.

3.4.3.3 Adjust the R.I. limiter dial to a number corresponds to the temperature at which cutoff is to occur (see Attachment B).

3.4.3.4 Switch on the phaser power.

3.4.3.5 Switch on the needed phaser at the phaser cabinets .

3.4.3.6 Switch **ON** the Dimension controllers. The toggle switch is located between the Dimension controllers.

3.4.3.7 **SET** the Dimension controller set point or temperature profile per test requirements.

3.4.3.8 Verify test article temperatures on data system, and adjust the Dimension set point accordingly.

3.5 UNATTENDED OPERATION

The thermal vacuum chamber is designed for continuous automatic operation. To preclude inadvertent automatic shutdown of the chamber or anomalies in the test environment and/or test data, complete the following steps before leaving the operating equipment unattended.

3.5.1 Verify that all facility expendable sources will be available for the unattended period.

3.5.2 Complete applicable sections of the procedure ET24-UnattnOps-SOP-001, Unattended Operation of the Environmental Test Laboratory.

3.6 REGENRATION OF CRYO PUMP

3.6.1 **CLOSE** the cryo pump's Hi-vac valve.

3.6.2 Switch **ON** the REGEN CRYO PUMP button.

3.6.3 When the REGEN button returns to the gray color, switch **ON** the cryo compressor 1 or 2.

3.6.4 When the cryo temperature has reached 20K or lower, **OPEN** the cryo pump's hi-vac valve.

3.7 SYSTEM SHUTDOWN

The following section directs the standard shutdown of the Sunspot vacuum chamber, including cooling and warming of the shrouds, shutdown of the high vacuum system, and venting of the chamber.

3.7.1 Go to Section 3.3 to perform the final contamination monitoring.

3.7.2 Verify all circuits in the chamber are switched off and de-energized, including IR lamp circuits and all of the customer's circuits. If it is infeasible to de-energize all circuits, comply with all requirements of Section 1.8.1 Minimizing Electrical Shock Hazards. If it is infeasible to de-energize all circuits on the test article, provide the customer with a copy of Section 1.8.1 Minimizing Electrical Shock Hazards.

3.7.3 Cryogenic System Shutdown

The following are controlled at or near the heater, near the southeast corner of the pit, unless indicated otherwise.

3.7.3.1 **OPEN** the Warm-up System GN_2 Supply Valve (HOV202).
3.7.3.2 **OPEN** the GN_2 bypass Valve (HOV-310). Allow gas to blow out the LN_2 in the shroud for 10 minutes.
3.7.3.3 **SET** the heater thermostat to 150^o F.
3.7.3.4 **OPEN** Valve HOV-312 (hot gas supply valve).
3.7.3.5 **CLOSE** the Valve HOV-310 (GN_2 bypass).
3.7.3.6 Switch **ON** the GN_2 heater.
3.7.3.7 Allow the shrouds to warm to ambient temperature. This typically takes two hours.
3.7.3.8 Switch **OFF** the heater.
3.7.3.9 **SET** the thermostat to **OFF**.
3.7.3.10 Allow the GN_2 to flow an additional 5 minutes to cool the heater.
3.7.3.11 **CLOSE** Valve HOV-312 (hot gas supply valve).
3.7.3.12 **CLOSE** GN_2 Warm-up System GN_2 Supply Valve (HOV-202).

3.7.3 **High Vacuum System Shutdown**.

The following switches are on the *iFIX* control screen unless indicated otherwise.

Turbo Pump System

3.7.4.1 **CLOSE** the Turbo Hi-Vac Valve.
3.7.4.2 Switch **OFF** Turbo Pump Controller.
3.7.4.3 **STOP** the Turbo Backing LN_2 Controller.

3.7.4.4 **OPEN** the GN_2 Turbo LN_2 Cold Trap Purge Valve.
3.7.4.5 Allow the turbo backing cold trap to purge for 30 minutes, and then **CLOSE** the Turbo Backing Cold Trap Purge Valve.
3.7.4.6 Switch **OFF** the Turbo Backing Pump.
3.7.4.7 **OPEN** the Backing Line Vent.

Cryo Pump System

3.7.4.8 **CLOSE** the Cryo Hi-Vac Valve.
3.7.4.9 Switch **OFF** the Cryo Compressor 1 or Cryo Compressor 2.
3.7.4.10 **STOP** the Cryo Pump Shroud LN_2.
3.7.4.11 Switch **ON** the **REGEN CRYO PUMP**. The **REGEN CRYO PUMP** button will switch off when regeneration of the cryo pump is complete.

3.7.5 Chamber Venting

The following switches are on the *iFIX* control screen unless indicated otherwise.

3.7.5.1 **OPEN** the Chamber Vent**.**
3.7.5.2 Verify the side clamps on the man entry are open.
3.7.5.3 **OPEN** the Air Chamber Backfill Supply Valve (HOV-207) on the inside air panel.
3.7.5.4 Verify the 2nd Stage Air is at 9 psig, +2 / -0 psi. Adjust if necessary.
3.7.5.5 When the chamber reaches 600 torr, **CLOSE** the LN2 valve on the scavenger panel
3.7.5.6 **CLOSED** the LN_2 Input Valve (ROV2) to Sunspot on the LN2 control system computer.

3.7.6 After the man-door is opened, and before other activities, an ETF electrical technician shall check for potential on all of the ETF's bare electrical parts energized at 50 volts or greater. The customer shall check for potential on the test article's bare electrical parts energized at 50 volts or greater.

3.7.7 The test article may now be removed from the chamber. When removing the test article through the top hatch, operate the crane in accordance with ET24-Crane-SOP-001.

3.8 WEATHER EMERGENCY SHUTDOWN

If the chamber must be abandoned because of requirements to evacuate during a weather emergency, and if there is adequate time, perform the following steps. These steps are to prevent over cooling of the test article should a loss of electrical power occur while the chamber is abandoned. If no cooling is being performed, skip this section and proceed to a protected area.

3.8.1 **CLOSE** the Shroud LN_2 Inlet.

3.8.2 **OPEN** the warm-up system GN_2 supply valve HOV202 and the GN_2 bypass valve HOV303 in the south east corner of the pit to purge the LN_2 shrouds.

4.0 EMERGENCY SHUTDOWN PROCEDURE

4.1 WATER FAILURE IN HIGH VACUUM OPERATIONS

4.1.1 **CLOSE** the Cryo Hi-Vac Valve.
4.1.2 **STOP** the Cryo Pump Compressor.
4.1.3 **CLOSE** the Turbo Hi-Vac Valve.
4.1.4 Switch **OFF** the Turbo pump.
4.1.5 Begin system shutdown if water flow cannot be resumed.

4.2 WATER FAILURE IN ROUGH VACUUM OPERATIONS

4.2.1 **CLOSE** the Roughing Valve.
4.2.2 **STOP** Blower 2.
4.2.3 Wait 15 seconds, than **STOP** Blower 1.
4.2.4 Wait another 15 seconds, and then **STOP** the Microvac Pump.
4.2.5 **VENT** the roughing line by opening the roughing line vent valve HOV-303, located in the pit on the roughing line.
4.2.6 Wait for the water flow to resume.

4.3 AIR FLOW FAILURE IN HIGH VACUUM OPERATIONS

4.3.1 The cryo high vacuum valve and the turbo high vacuum valves will fail closed upon loss of control air pressure. Go to Section 3.7 and begin system shut down if airflow does not resume within 30 minutes.

4.4 AIR FLOW FAILURE IN ROUGH VACUUM OPERATIONS

4.4.1 Chamber Roughing Valve will fail closed. If air flow does not resume in five minutes **STOP** Blower 2
4.4.2 Wait 30 seconds, then **STOP** Blower 1.
4.4.3 Wait 30 seconds, and then **STOP** the Microvac.

4.5 POWER FAILURE IN HIGH VACUUM OPERATIONS

4.5.1 The cryo high vacuum valve and the turbo high vacuum valves will fail closed upon loss of electrical power.
4.5.2 Switch **OFF** the Cryo Compressor at the *iFIX* control computer.
4.5.3 If power is not re-energized in 5 minutes, begin cryogenic system shutdown in Section 3.7.3.
4.5.4 On the inside pneumatic panel **OPEN** the Warm-up System GN2 Supply Hand Valve HOV-202.

4.5.5 **OPEN** the GN_2 Bypass Valve HOV-310. This hand valve is located above the heater in the southeast corner of the pit.

4.5.6 Start system shutdown by completing applicable parts of Sections 3.7.

4.6 POWER FAILURE IN ROUGH VACUUM OPERATIONS

4.6.1 The roughing valve will fail closed upon loss of electrical power. **OPEN** the chamber roughing line vent valve HOV-303.

4.6.2 Continue roughing shutdown by completing applicable parts of Sections 3.2.4.13 through 3.2.4.16.

4.7 ELECTRICAL EMERGENCY

**********CAUTION**********

First try to de-energize circuits with normal switches. The sudden shutdown of equipment **may cause damage to test article and facility equipment**. The following procedures shall only be used **to protect personnel from injury**.

****

4.7.1 **CONTROL POWER**. Switch **OFF the System Power** on the front of controls rack Bay 3. If this does not de-energize the failed circuit **OPEN Breaker 1, 3, and 5 in Panel NP** located in the control room.

4.7.2 **PHASER POWER**. **PRESS the Emergency Stop Button** on the left panel of the phaser power racks.

4.7.3 **MAIN ROUGHING PUMPS. OPEN Breakers 5 and 7 in Panel HP** located in the pit.

4.7.4 **CRYO COMPRESSORS. OPEN Breakers 1 and 3 in Panel HP** located in the pit.

4.7.5 **TURBO ROUGHING PUMP. OPEN Breakers 4 in Panel HP** located in the pit.

4.7.6 **SHROUD HEATER**. **OPEN Breakers 2 in Panel HP** located in the pit.

4.7.7 **CRYO ROUGHING PUMP. OPEN Breakers 9 and 11 in Panel LP** located in the pit.

4.7.8 **TURBO PUMP and CONTROLLER. OPEN Breaker 11 in Panel NP** located in the control room.

4.7.9 **120 volt RECEPTACLES around Sunspot. OPEN Breakers 1 through 20 in Panel HNP** located in the control room; and **Breakers 8, 10, 12 through 16, and 18 in Panel LP** located in the pit.

4.7.10 **120 volt RECEPTACLES in the Pit. OPEN Breakers 22 and 29 in Panel LL** located in Room 167B, **Breaker 8 in Panel PB** located in the control room, and **Breaker 4 in Panel RP-1** located on the north east of Room 167.

4.7.11 **208 volt RECEPTACLES** around Sunspot, **UNPLUG** the receptacle.

Sunspot As-run Buy-off Sheet

Test Number _____ Customer Contact _____

TPS or Work Instructions _____ Start Time & Date _____

Test Description_____ End Time & Date _____

Data Process Rate _____

Initial each step once completed. If test exceeds one day, date the first step each new day.

3.1 Facility Preparation

3.1.1 _____

3.1.2 _____

3.1.3.1 _____

3.1.3.2 _____

3.1.3.3 _____

3.1.4.1 _____

3.1.4.2 _____

3.1.4.3 _____

3.1.4.4 _____

3.1.4.5 _____

3.1.4.6_____

3.1.4.7 _____

3.1.4.8 _____

3.1.4.9 _____

3.1.5_____

3.1.6 _____

3.1.7 _____

3.1.8 _____

3.1.9 _____

3.1.10 _____

3.1.11 _____

3.1.12 _____

3.1.13 _____

3.1.14 _____

3.1.15 _____

3.1.16 _____

3.1.17.1 _____

3.1.17.2 _____

3.1.17.3 _____

3.1.17.4 _____

3.1.17.5_____

3.1.17.6 _____

3.1.17.7_____

3.1.17.8 _____

3.1.18.1 _____

3.1.18.2 _____

3.1.18.3 _____

3.1.18.4 _____

3.1.18.5 _____

3.1.18.6 _____

3.1.19.1 ____

3.1.19.2 ____

3.1.19.3 ____

3.1.19.4 _____

Sunspot As-run Buy-off Sheet

3.1.20 _____

3.1.21 _____

3.1.22.1 _____

3.1.22.2 _____

3.1.22.3 _____

3.1.22.4 _____

3.2 System Startup

3.2.1 _____

3.2.2 Roughing Prep.

3.2.2.1 _____

3.2.2.2 _____

3.2.3 Rough &Starting Cryo

3.2.3.1 _____

3.2.3.2 _____

3.2.3.3 _____

3.2.3.4 _____

3.2.3.5 _____

3.2.3.6 _____

3.2.3.7 _____

3.2.3.8 _____

3.2.3.9 _____

3.2.3.10 _____

3.2.3.11 _____

3.2.3.12 _____

3.2.3.13 _____

3.2.3.14 _____

3.2.3.15 _____

3.2.3.16 _____

3.2.3.17 _____

3.2.3.18 _____

3.2.3.19 _____

3.2.3.20 _____

3.2.3.21 _____

3.2.3.22 _____

3.2.3.23 _____

3.2.4 High Vacuum Operation

3.2.4.1 _____

3.2.4.2 _____

3.2.4.3 _____

3.2.4.4 _____

3.2.4.5 _____

3.2.4.6 _____

3.2.4.7 _____

3.2.4.8 _____

3.2.4.9 _____

3.2.4.10 _____

3.2.4.11 _____

3.2.4.12 _____

3.2.4.13 _____

3.2.4.14 _____

3.2.4.15 _____

3.2.4.16 _____

3.2.4.17 _____

3.3 Contamination Monitoring

3.3.1_____

3.3.2 _____

3.4 Thermal Conditioning

3.4.1 Cryogenic Wall Operation

3.4.1.1 _____

3.4.1.2 _____

3.4.1.3 _____

3.4.2 Hot Wall Operation

3.4.2.1 _____

3.4.2.2 _____

3.4.2.3 _____

Sunspot As-run Buy-off Sheet

3.4.2.4 _____

3.4.2.5 _____

3.4.3 Infrared Lamp Operation

3.4.3.1 _____

3.4.3.2 _____

3.4.3.3 _____

3.4.3.4 _____

3.4.3.5 _____

3.4.3.6 _____

3.4.3.7 _____

3.4.3.8 _____

3.5 Unattended Operation
NA if not required

3.5.1 _____

3.5.2 _____

3.6 Regen Cryo

3.6.1 _____

3.6.2 _____

3.6.3 _____

3.6.4 _____

3.7 System Shutdown

3.7.1 _____

3.7.2 _____

3.7.3 Cryogenic System Shutdown

3.7.3.1 _____

3.7.3.2 _____

3.7.3.3 _____

3.7.3.4 _____

3.7.3.5 _____

3.7.3.6 _____

3.7.3.7 _____

3.7.3.8 _____

3.7.3.9 _____

3.7.3.10 _____

3.7.3.11 _____

3.7.3.12 _____

3.7.4 High Vacuum System Shutdown

3.7.4.1 _____

3.7.4.2 _____

3.7.4.3 _____

3.7.4.4 _____

3.7.4.5 _____

3.7.4.6 _____

3.7.4.7 _____

3.7.4.8 _____

3.7.4.9 _____

3.7.4.10 _____

3.7.4.11 _____

3.7.5 Chamber Venting

3.7.5.1 _____

3.7.5.2 _____

3.7.5.3 _____

3.7.5.4 _____

3.7.5.5 _____

3.7.5.6 _____

3.7.6 _____

3.7.7 _____

3.8 Weather Shutdown

3.8.1_____

3.8.2 _____

QA _____
NA if not required

Research Incorporated Set-point Dial Settings VS Temperature

DEG F	0	1	2	3	4	5	6	7	8	9
-300	0.									
-290	6.9	6.2	5.5	4.8	4.1	3.4	2.7	2.0	1.3	0.7
-280	14.0	13.3	12.5	11.8	11.1	10.4	9.7	9.0	8.3	7.6
-270	21.4	20.6	19.9	19.1	18.4	17.7	16.9	16.2	15.5	14.7
-260	29.1	28.3	27.5	26.7	26.0	25.2	24.4	23.7	22.9	22.1
-250	37.0	36.2	35.4	34.6	33.8	33.0	32.2	31.4	30.6	29.8
-240	45.2	44.3	43.5	42.7	41.9	41.0	40.2	39.4	38.6	37.8
-230	53.6	52.7	51.9	51.0	50.2	49.3	48.5	47.7	46.8	46.0
-220	62.3	61.4	60.5	59.6	58.8	57.9	57.0	56.2	55.3	54.5
-210	71.2	70.3	69.4	68.5	67.6	66.7	65.8	64.9	64.0	63.2
-200	80.4	79.5	78.5	77.6	76.7	75.8	74.9	73.9	73.0	72.1
-190	89.8	88.9	87.9	87.0	86.0	85.1	84.1	83.2	82.3	81.3
-180	99.5	98.5	97.5	96.6	95.6	94.6	93.7	92.7	91.7	90.8
-170	109.4	108.4	107.4	106.4	105.4	104.4	103.4	102.4	101.5	100.5
-160	119.6	118.6	117.5	116.5	115.5	114.5	113.4	112.4	111.4	110.4
-150	130.0	128.9	127.9	126.8	125.8	124.8	123.7	122.7	121.6	120.6
-140	140.6	139.6	138.5	137.4	136.4	135.3	134.2	133.2	132.1	131.0
-130	151.6	150.4	149.4	148.3	147.2	146.1	145.0	143.9	142.8	141.7

Research Incorporated Set-point Dial Settings VS Temperature

DEG F	0	1	2	3	4	5	6	7	8	9
-120	162.7	161.6	160.4	159.3	158.2	157.1	156.0	154.9	153.8	152.7
-110	174.1	172.9	171.8	170.6	169.5	168.4	167.2	166.1	165.0	163.8
-100	185.7	184.5	183.4	182.2	181.0	179.9	178.7	177.5	176.4	175.2
-90	197.6	196.4	195.2	194.0	192.8	191.6	190.4	189.2	188.1	186.9
-80	209.7	208.5	207.2	206.0	204.8	203.6	202.4	201.2	200.0	198.8
-70	222.0	220.8	219.5	218.3	217.0	215.8	214.6	213.3	212.1	210.9
-60	234.5	233.3	232.0	230.8	229.5	228.2	227.0	225.7	224.5	223.2
-50	247.3	246.0	244.7	243.5	242.2	240.9	239.6	238.4	237.1	235.8
-40	260.3	259.0	257.7	256.4	255.1	253.8	252.5	251.2	249.9	248.6
-30	273.5	272.2	270.8	269.5	268.2	266.9	265.5	264.2	262.9	261.6
-20	286.9	285.5	284.2	282.8	281.5	280.1	278.8	277.5	276.1	274.8
-10	300.4	299.1	297.7	296.3	295.0	293.6	292.3	290.9	289.6	288.2
-0	314.1	312.8	311.4	310.0	308.6	307.3	305.9	304.5	303.1	301.8
0	314.1	315.5	316.9	318.3	319.7	321.1	322.5	323.8	325.2	326.6
10	328.0	329.4	330.8	332.2	333.6	335.0	336.4	337.8	339.2	340.6
20	342.0	343.4	344.9	346.3	347.7	349.1	350.5	351.9	353.3	354.8
30	356.2	357.6	359.4	360.6	362.1	363.5	365.0	366.4	367.9	369.4
40	370.8	372.3	373.8	375.2	376.7	378.2	379.6	381.1	382.6	384.1
50	385.5	387.0	388.5	390.0	391.5	393.0	394.4	395.9	397.4	398.9

Research Incorporated Set-point Dial Settings VS Temperature

DEG F	0	1	2	3	4	5	6	7	8	9
60	400.4	401.9	403.4	404.9	406.4	407.9	409.4	410.9	412.5	414.0
70	415.5	417.0	418.5	420.0	421.6	423.1	424.6	426.1	427.7	429.2
80	430.7	432.3	433.8	435.3	436.9	438.4	439.9	441.5	443.0	444.6
90	446.1	447.7	449.2	450.8	452.3	453.9	455.5	457.0	458.6	460.1
100	461.7	463.3	464.8	466.4	468.0	469.6	471.1	472.7	474.3	475.9
110	477.5	479.0	480.6	482.2	483.8	485.4	487.0	488.6	490.2	491.8
120	493.4	495.0	496.6	498.2	499.8	501.4	503.0	504.6	506.2	507.8
130	509.5	511.1	512.7	514.3	515.9	517.6	519.2	520.8	522.4	524.1
140	525.7	527.3	529.0	530.6	532.2	533.9	535.5	537.2	538.8	540.5
150	542.1	543.8	545.4	547.1	548.7	550.4	552.0	553.7	555.4	557.0
160	558.7	560.3	562.0	563.7	565.4	567.0	568.7	570.4	572.0	573.7
170	575.4	577.1	578.8	580.5	582.1	583.8	585.5	587.2	588.9	590.6
180	592.3	594.0	595.7	597.4	599.1	600.8	602.5	604.2	605.9	607.6
190	609.3	611.0	612.8	614.5	616.2	617.9	619.6	621.3	623.1	624.8
200	626.5	628.3	630.0	631.7	633.4	635.2	636.9	638.6	640.4	642.1
210	643.9	645.6	647.4	649.1	650.8	652.6	654.3	656.1	657.9	659.6
220	661.4	663.1	664.9	666.6	668.4	670.2	671.9	673.7	675.5	677.2
230	679.0	680.8	682.6	684.3	686.1	687.9	689.7	691.4	693.2	695.0
240	696.8	698.6	700.4	702.2	704.0	705.7	707.5	709.3	711.1	712.9
250	714.7	716.5	718.3	720.1	721.9	723.8	725.6	727.4	729.2	731.0

Research Incorporated Set-point Dial Settings VS Temperature

DEG F	0	1	2	3	4	5	6	7	8	9
260	732.8	734.6	736.4	738.3	740.1	741.9	743.7	745.5	747.4	749.2
270	751.0	752.9	754.7	756.5	758.4	760.2	762.0	763.9	765.7	767.5
280	769.4	771.2	773.1	774.9	776.8	778.6	780.5	782.3	784.2	786.0
290	787.9	789.7	791.6	793.5	795.3	797.2	799.1	800.9	802.8	804.7
300	806.5	808.4	810.3	812.1	814.0	815.9	817.8	819.6	821.5	823.4
310	825.3	827.2	829.1	830.9	832.8	834.7	836.6	838.5	840.4	842.3
320	844.2	846.1	848.0	849.9	851.8	853.7	855.6	857.5	859.0	861.3
330	863.2	865.1	867.1	869.0	870.9	872.8	874.7	876.6	878.5	880.5
340	882.4	884.3	886.2	888.2	890.1	892.0	894.0	895.9	897.8	899.7
350	901.7	903.6	905.6	907.5	909.4	911.4	913.3	915.3	917.2	919.2
360	921.1	923.0	925.0	927.0	928.9	930.9	932.8	934.8	936.7	938.7
370	940.6	942.6	944.6	946.5	948.5	950.5	952.4	954.4	956.4	958.3
380	960.3	962.3	964.3	966.2	968.2	970.2	972.2	974.1	976.1	978.1
390	980.1	982.1	984.1	986.1	988.0	990.0	992.0	994.0	996.0	998.0
400	1000.0									