National Aeronautics and
Space Administration

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

FACILITY OPERATING PROCEDURE
FOR
V6 THERMAL VACUUM CHAMBER

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

CHECK THE MASTER LIST—
VERIFY THAT THIS IS THE CORRECT VERSION BEFORE USE

FACILITY OPERATING PROCEDURE
FOR
V6 THERMAL VACUUM CHAMBER

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Release Date: 8 / 4 / 2005	**Marshall Space Flight Center Specification/Document Change Instruction** Spec. / Doc. No. ET24-V6-FOP-001	Page 1 of 1 Copy No.:

Change No./ Date	SCN/DCN No./Date	Replacement Page Instructions
Baseline/ 8-4-2005		Initial issue for the ET24 organization. Supersedes MFOP-FA-ETF-406.

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1.0 GENERAL INFORMATION

1.1 PURPOSE

This document describes the procedures for the operation of Thermal Vacuum Chamber V6 located in MSFC Building 4619.

1.2 SCOPE

The procedures and practices outlined in this document are to be followed in the operation of chamber V6. This document provides a record copy of chamber V6 operations.

1.3 APPLICABLE DOCUMENTS

MPR 8715.1	Marshall Safety, Health, and Environmental (SHE) Program
MWI 8715.1	Electrical Safety Program
ET24-UnattnOps-SOP-001	Unattended Operation of the Environmental Test Facility
ET24-LOTO-SOP-001	Control of Hazardous Energy (Lockout/Tagout) Procedure for the Environmental Test Facility
ET24-ETF-OWI-001	Environmental Test Facility Test Operations
ED26 (02-01)	Memorandum for Record, Safety Assessment for the ETF (soon to be re-issued 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 should be aware of the possibility of freeze burns by contact with cold surfaces or liquids. Protective clothing including eye protection and gloves must be worn by all personnel involved in handling of cryogenics or when making repairs/modifications to cryogenic facilities. Repairs/modifications to cryogenic systems must be performed by certified cryogenic handlers. In the event of a cryogenic spill, line ruptures, or similar emergencies, personnel must first ensure there is no possibility of asphyxiation due to oxygen displacement. Use a portable oxygen monitor to verify the spill area is safe before entering.

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 removing the test article in order to minimize the extreme temperature hazard.

ET24 Safety Assessment, Memorandum of Record ED26 (02-01) (soon to re-issue as an ET24 memo, number unknown) delineates the procedures, personal protective equipment (PPE)

requirements and job hazard analysis (JHAs) for hazards associated with operation of this chamber. Operators must follow procedures, implement the risk mitigation methods listed in the JHAs and use the required PPE to minimize risk from potential hazards during chamber operations.

1.5 EMERGENCY TELEPHONE NUMBERS

Dial **911** for all emergencies.

Medical	911
Ambulance	911
Fire	911
Security	911
Chemical Spills	911

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

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

1.6 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 to determine program set-points for the thermal controllers and safety devices. The "dummy" test article should provide an accurate thermal simulation of the actual test article.

1.7 HAZARDS LIST

- 208 and 120 volts AC electrical power.
- Extreme temperatures (hot and cold)
- Liquid nitrogen (LN_2)
- High kinetic energy in turbo pumps
- Vacuum pump oil

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

Prior to performing maintenance on any equipment, lockout and tag the equipment in accordance with Lockout/Tagout Procedure MSOP-FA-ETF-413 (soon to be superseded by ET24-LOTO-SOP-001). Maintenance shall be performed by qualified technicians only.

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1.7.1 Minimizing Electrical Shock Hazards

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

1.7.1.2 All bare electrical parts inside the chamber with a potential to ground of 50 volts or greater should 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.

1.7.1.3 Personnel must 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 must never blindly reach into an area that may contain energized bare electrical parts.

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

1.7.1.5 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.

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

1.7.1.7 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.

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

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

1.7.1.10 Any de-energized electrical parts that are not locked-out, tagged-out, or unplugged will 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.

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

1.7.1.12 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.

1.7.1.13 Locking type connectors shall be properly secured after connection.

1.7.1.14 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.

1.7.1.15 Over-current protective devices shall not be modified.

1.7.2 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 removing the test article in order to minimize the extreme temperature hazard.

1.7.3 Minimizing LN_2 Hazards

Personnel should be aware of the possibility of freeze burns by contact with cold surfaces or liquids. Protective clothing including eye protection and gloves must be worn by all personnel involved in handling of cryogenics or when making repairs/modifications to cryogenic facilities. Repairs/modifications to cryogenic systems must be performed by certified cryogenic handlers. In the event of a cryogenics spill, line ruptures, or similar emergencies, personnel must 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.

1.7.4 Minimizing Turbo Pump Hazards

The turbo pumps have several rotors with many thin blades that rotate approximately 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 expose the pumps to mechanical shock or move them when they are operating.

1.7.5 Minimizing Vacuum 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 safety glasses 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.

There is a risk that the test article could be contaminated with roughing pump oil. To minimize the risk of oil contamination, only allow trained personnel to operate the chamber. Also, ensure the cold trap between the roughing pump and chamber is operational to reduce the contamination risk.

1.8 RESPONSIBILITIES

ETF personnel will be responsible for the operation of the V6 Thermal Vacuum Facility. The designated operator of the chamber will be responsible for the safe operation and conduct of the facility. The operator will record his name in the chamber logbook.

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

2.0 FACILITY DESCRIPTION

2.1 CHAMBER DESCRIPTION AND DIMENSIONS

Chamber V6 is a stainless steel vessel with polished interior surfaces. The inside dimensions are 35” diameter and 6' length. The chamber is equipped with a thermal shroud, which has a 28” diameter and is 51" long. The thermal shroud provides heating and cooling of the test article.

2.2 VACUUM SYSTEM

The vacuum system consists of a 10-inch turbomolecular (turbo) pump with a foreline valve and a backing pump, a pneumatic high vacuum gate valve for the turbo pump, and a chamber roughing pump with pneumatic roughing valve. There is a cryogenic cold trap located between the chamber and the roughing pump.

2.3 CONTROL SYSTEM

The control system consists of a control panel of switches for operating valves and mechanical pumps. The turbo pump has its own controller. A Dimension Controller is used to control thermal conditioning. Pressure monitoring instrumentation is a convectron gauges and an ion gauge. These pressure gauges are connected to a Granville Phillips GP307 controller. The GP307 controller converts gauge signal to torr units and has the control capability to close the high vacuum valve and switch off the infrared lamps in the event of a pressure rise. This control capability must be selected and de-selected manually.

2.4 THERMAL SYSTEM

Chamber thermal conditioning is provided by a GN_2 thermal shroud. The GN_2 is thermally conditioned in a heat exchanger, which can provide temperature extremes from -168^{O}C to 150^{O}C (-270^{O}F to 302^{O}F). Infrared lamps may be installed in the chamber to provide radiant heating.

2.5 PERFORMANCE

Pumping speeds will vary depending on the pumps used, test specimen, gas load, and internal chamber conditions.

The chamber has an adjustable temperature range of -270°F to +302°F (-168°C to +150°C). Temperatures within this range can be maintained to ± 3.6 deg F (± 2 deg C) of nominal value.

Heating and cooling rates vary depending on the thermal load presented by the test specimen. An empty chamber will perform approximately as follows:

Maximum Heating Rates	
-200°F to 250°F (-129°C to 121°C)	60 minutes
Maximum Cooling Rates	
70°F to -285°F (21°C to -176°C)	15 minutes

NOTE

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

3.0 FACILITY OPERATION

The operations of Chamber V6 will vary 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 with either or both high vacuum pumps, but does not cover every possible scenario. Operating personnel should be thoroughly familiar with vacuum chamber operation, the thermal conditioning software and the data acquisition software.

Complete the As-run Buy-off Sheets 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), 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.

3.1.3 Visually inspect the level and condition of the oil in the turbo backing pump, and the chamber roughing pump. Add or change oil as needed. Oil should be changed whenever it is darkened, contaminated, milky, or if the pump performance has degraded. Wear safety glasses 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.

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

Prior to performing maintenance on any equipment, lockout and tag the equipment in accordance with Lockout/Tagout Procedure MSOP-FA-ETF-413 (soon to be superseded by ET24-LOTO-SOP-001). Maintenance shall be performed by qualified technicians only.

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3.1.4 CALIBRATION

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

3.1.4.2 Verify that the calibration will not expire before the expected test conclusion date.

3.1.5 Place all switches on the control panel to the off, safe or normal position.

3.1.6 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.

3.2 VACUUM SYSTEM OPERATION

3.2.1 Photograph the test article and test setup. Take as many photograph 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. This section shall be omitted if the customer requests no photographing of the test article.

3.2.2 Closed and secure the chamber door.

3.2.3 If using PACRATS, switch **ON** the data acquisition computer and **START** recording data.

3.2.4 Switch the GP model 307 "OFF-SP-ON" to the **SP** position. Also, verify the auto set point SP setting.

3.2.5 Turn mechanical roughing pump switch **ON** and allow pump to warm.

3.2.6 **OPEN** the chamber-roughing valve.

3.2.7 Switch **ON** LN_2 supply the roughing cold trap.

3.2.8 Loosen bolts that are securing chamber door.

3.2.9 Switch **ON** the turbo-pump backing pump.

3.2.10 **OPEN** turbo pump's foreline valve.

3.2.11 Switch **ON** the controller power to turbo pump.

3.2.12 Allow the turbo pump time to come to operating speed.

3.2.13 Allow the chamber to rough pump to 8.0×10^{-2} torr $\pm 20 \times 10^{-2}$ torr (100 to 60 millitorr) as indicated on the convectron gauge. Never rough the chamber to less then 50 millitorr.

3.2.14 Turn the GP model 307 "OFF-SP-ON" switch to the **ON** position.

3.2.15 **CLOSE** the chamber-roughing valve.

3.2.16 **OPEN** high vacuum valve No. 2.

3.2.17 Switch **ON** the ion gauge.

3.2.18 Verify the ion gauge is **ON**.

3.2.19 Ensure LN_2 supply to roughing pump cold trap is switched off.

3.2.20 After allowing time for the roughing pump cold trap to defrost and warm, then switch **OFF** the mechanical roughing pump.

3.2.21 After the system is in a high vacuum state, and pressure is lower than the set-point of the GP 307 (about 10 times the operating pressure), switch the OFF-SP-ON switch to the **SP** position.

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

IF AT ANY TIME THE CHAMBER PRESSURE CLIMBS ABOVE THE GP307 SETPOINT, THE HIGH VACUUM VALVES WILL CLOSE AND SECURE THE CHAMBER.

********** **********

3.3 THERMAL CONDITINING

Thermal conditioning is accomplished using the thermal shroud system. The heat exchanger components are controlled either by a Dimension process controller or by Intellution Dynamics iFIX software. If the Intellution Dynamics iFIX software is being used for controlling thermal conditioning, request a qualified Intellution programmer set up the program.

3.3.1 Ensure that the gaseous nitrogen (GN_2) used for thermal conditioning is regulated to no more than 45 psig. There is a gauge GNP42 at the GN_2 Panel on the west side of V5. The regulator GNR47 is located on GN_2 Panel LPP-1A

3.3.2 **OPEN** the V6 thermal shroud GN_2 system valve on the gas panel located behind Chamber V5.

3.3.3 If a RI Limiter is being used, switch **ON** the R.I. limiter at the toggle switch labeled "LIM" located to the left of the limiter

3.3.4 If a RI Limiter is being used, **PRESS** the R.I. limiter reset button

3.3.5. If the Dimension controller is being used, switch **ON** the Dimension controller at the toggle switch labeled "DIM" located to the right of the controller.

3.3.6 If the Dimension controller is being used, **SET** the Dimension Loop 1 set-point to the desired temperature.

3.3.7 If a RI Limiter is being used for hot temperature control, **ADJUST** the Hot R.I. limiter dial to that maximum temperature at which cutoff is to occur. If a RI Limiter is being used for cold temperature control, **ADJUST** the Cold R.I. limiter dial to the minimum temperature at which cutoff is to occur. The Cold Temperature Bypass must be in the OFF position for Cold Limiter to operate. Refer to Attachment B for set point dial settings.

3.3.8 Verify test article temperatures on data system, and adjust the set-point accordingly.

3.4 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.

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

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

3.5 THERMAL CONDITIONING SHUTDOWN

Thermal conditioning can be accomplished using infrared lamps to heat, a cold plate to cool or the shrouds to heat and/or cool. The following instructions are for the Dimension controller. If the Intellution Dynamics iFIX software is being used for controlling thermal conditioning, request a qualified Intellution programmer set up the program and omit the following Section 3.5 instructions.

3.5.1 **SET** the temperature controller being used to the ambient temperature.

3.5.2 **OPEN** the shroud purge if using the shroud to cool.

3.5.3 Wait for the chamber and test article to return to ambient temperatures $\pm$ 10 degrees C ($\pm$18 degrees F) and above the dew-point.

3.5.4 **CLOSE** the V6 GN2 shroud purge valve located on the west side of V5.

3.6 VACUUM SYSTEM SHUTDOWN

3.6.1 Verify thermal conditioning is **OFF**.

3.6.2 Switch **OFF** the ion gauge.

3.6.3 **CLOSE** THE hi-vac valve.

3.6.4 Switch **OFF** turbo pump controller power.

3.6.5 **CLOSE** the turbo pump's foreline valve.

3.6.6 **STOP** turbo foreline pump.

3.6.7 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 1.7.1 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 1.7.1. Minimizing Electrical Shock Hazards.

3.6.8 Verify thermal conditioning is **OFF** and the test article and chamber are at ambient temperature $\pm$ 10 degrees C ($\pm$ 18 degrees F) and above the dew point.

3.6.9 **OPEN** the chamber MGA Repress valve.

3.6.10 Allow the chamber to reach atmospheric pressure, which should take about 30 minutes.

3.6.11 **CLOSE** the chamber MGA Repress valve.

3.6.12 After the 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.

3.6.13 Test article may now be removed from the chamber.

4.0 EMERGENCY SHUTDOWN

_____ 4.1 **OPEN** the V6 disconnect switches 1 and 2 to switch off system power.

_____ 4.2 Switch **OFF** the DIM, HOT LIM, and COLD LIM switches to the right of the Dimension controller.

_____ 4.3 Vent chamber and remove test article only when there is no significant risk of injury to personnel.

V6 **As-run Buy-off Sheet**

Test Number _____ Customer Contact _____

Calling TPS or Work Instructions _____Start Time & Date _____

Test Description_____ End Time & Date _____

Data Process Rate _____

Test Operator(s) (Print name and initial) _____ _____

3.1 Facility Preparation

3.1.1 _____

3.1.2 _____

3.1.3 _____

3.1.4.1_____

3.1.4.2_____

3.1.5_____

3.1.6_____

3.2 Vac Sys Operation

3.2.1 _____

3.2.2 _____

3.2.3 _____

3.2.4 _____

3.2.5 _____

3.2.6 _____

3.2.7 _____

3.2.8 _____

3.2.9 _____

3.2.10_____

3.2.11_____

3.2.12 _____

3.2.13 _____

3.2.14 _____

3.2.15 _____

3.2.16 _____

3.2.17 _____

3.2.18 _____

3.2.19 _____

3.2.20 _____

3.2.21 _____

3.3 Thermal Conditioning

3.3.1 _____

3.3.2 _____

3.3.3 _____

3.3.4 _____

3.3.5 _____

3.3.6 _____

3.3.7 _____

3.3.8 _____

3.4 Unattended Operation
(N/A if not applicable)

3.4.1 _____

3.4.2 _____

3.5 Thermal Cond. Shutdown

3.5.1 _____

3.5.2 _____

3.5.3 _____

3.5.4 _____

3.6 Partial Shutdown

3.6.1 _____

V6 **As-run Buy-off Sheet**

3.6.2 _____

3.6.3 _____

3.6.4 _____

3.6.5 _____

3.6.6 _____

3.6.7 _____

3.6.8 _____

3.6.9 _____

3.6.10 _____

3.6.11 _____

3.6.12 _____

3.6.13 _____

QA _____(N/A if not applicable)

Research Incorporated Temperature Limiter
SETPOINT 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 Temperature Limiter
SETPOINT 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 Temperature Limiter
SETPOINT 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 Temperature Limiter
SETPOINT 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									