akrometrix

ThermoiRé AXP 2.0

User Manual

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Contents

1 Introduction

1.1 Overview

The Akrometrix TherMoiré AXP 2.0 is a system designed for measuring sample surface warpage as a function of temperature. It uses a full-field, non-contact optical technique called shadow moiré in combination with automated image processing. Samples are measured inside a computer-controlled oven chamber with a temperature range from ambient to 300°C.

This manual describes the system hardware of the TherMoiré AXP 2.0. Data acquisition is described in the Surface Measurement User Manual and analysis is described in the Surface Analysis User Manual. Surface Measurement requires system hardware to operate and, thus, will only be installed on the AXP 2.0. Surface Analysis may reside on the AXP 2.0 computer and/or on a remote computer.

The main body of this manual emphasizes the system hardware and its operation. A user unfamiliar with shadow moiré and its application in the TherMoiré system is advised to first read Akrometrix Optical Techniques and Analyses 101, and **Section 1**, Troubleshooting in order to make best use of the system.

Before operating the system, the user should carefully read **Section 1.2.2**, which describes safety and health hazards associated with the system. The TherMoiré AXP 2.0 system contains a high temperature oven, motorized sample stages, and electrical systems, all with the potential to injure if used or maintained carelessly.

Sections 1.3 and **1.4** identify system components and controls. **Section 2** describes basic procedures for system setup and shutdown. **Section 3** describes setting up samples for measurement under thermal test. **Section 4** describes PLC logic conditions and **Section 5** describes basic troubleshooting.

Appendix A describes recommended procedures for maintenance, transport and disassembly of the system. This section also contains equipment ratings and technical support material. **Appendix B** describes the Blower system and its operation.

1.2 Warnings and Precautions

1.2.1 Warnings and Notes in this Manual

Warnings and Notes are marked throughout the manual with these icons:

Figure 1.1 Warning Icon

Figure 1.2 Note Icon

Warnings are specific health hazards for the operator or potential sources of damage to the AXP 2.0 system. Notes highlight system limitations or automatic responses that may require corrective action by the operator for successful operation.

1.2.2 Health and Safety Hazards

- The AXP 2.0 system has been designed to minimize the potential for user injury. Safety systems, including the oven and electrical enclosure interlocks, should not be tampered with, circumvented, or left in a permanent over-ride state.
- Staring into the oven while a profile is running increases the risk of eye damage from IR radiant energy. Even though the oven has been designed to mitigate this risk, the TherMoiré oven requires the use of IR energy. The only sure way to eliminate this risk is to not look into the oven while a profile is running.
- Surfaces both inside and outside the oven chamber can reach extreme temperatures during system operation and can harm the user without proper precautions. Care should be taken in opening the oven after a temperature cycle. The user should only touch the oven lid by its handle or use hand protection. Internal oven surfaces can remain at extreme temperatures even after the sample reaches room temperature. The user should exercise care before touching the sample, sample supports, or other internal surfaces after a temperature cycle.
- The system should not be used with samples that can catch fire or emit toxic gases during sample heating.
- Motorized translation of the sample support stages can create the potential for pinch-points between moving and stationary components, especially the sample support arms and the oven walls. Keep hands out of the oven during sample stage translation. Keep the stage translation path free from obstruction.
- Close the oven lid carefully to avoid catching fingers or damaging the glass grating.
- External electrical and compressed air connections must be installed safely and meet all relevant requirements and building codes.
- Do not operate the light sources with the fiber optic bundle connectors removed from the light source housings.
- Do not sit or stand on any part of the system enclosure, including the electrical box. Do not place loads greater than 25 kg (55 lbs) on top of the system.
- Lock system casters when not being moved. Follow transport procedures described in **Appendix A.3** when moving system. Do not move system on surfaces with a tilt greater than 10 degrees from horizontal.
- Special care should be used when operating the system manually or using specialized diagnostic programs. Temperatures or motions outside the normal range of operation may be possible under these conditions and the system should be monitored carefully.
- Do not position the system such that the electrical interlock is inaccessible.
- MSDS data sheets for all supplied chemicals are available upon request.

1.2.3 System Operating Precautions

- Do not install additional software on the TherMoiré computer, change computer system settings, or upgrade system software or hardware without consulting Akrometrix. Unauthorized modifications can cause problems in normal system operation.
- Close the oven lids with care. Make sure there is adequate clearance between the glass grating and sample supports or samples before closing the oven lid. If the grating is discolored by outgassing products, clean it using rubbing alcohol or glass cleaner before performing another temperature cycle.
- Do not touch the heating elements in the IR heater bank. Clean any debris that falls onto the heater elements as soon as possible. Heat cycles can “bake” oils and other organic materials onto the oven bank surfaces making them harder to clean as more heat cycles are applied.
- The sample support should not be loaded with a sample weighing greater than 10 lbs (4.5 kg). Loads exceeding 10 lbs may cause harm to the stage motion components.
- In order to eliminate any eye, hand, or back strain, adjust the monitor and keyboard cart for ease and comfort of use. The monitor can be tilted and raised on its pedestal. The cart can be raised and lowered for proper hand position on the keyboard.

1.2.4 Warning labels used on the TherMoiré AXP 2.0

Figure 1.3 Danger High Voltage Label

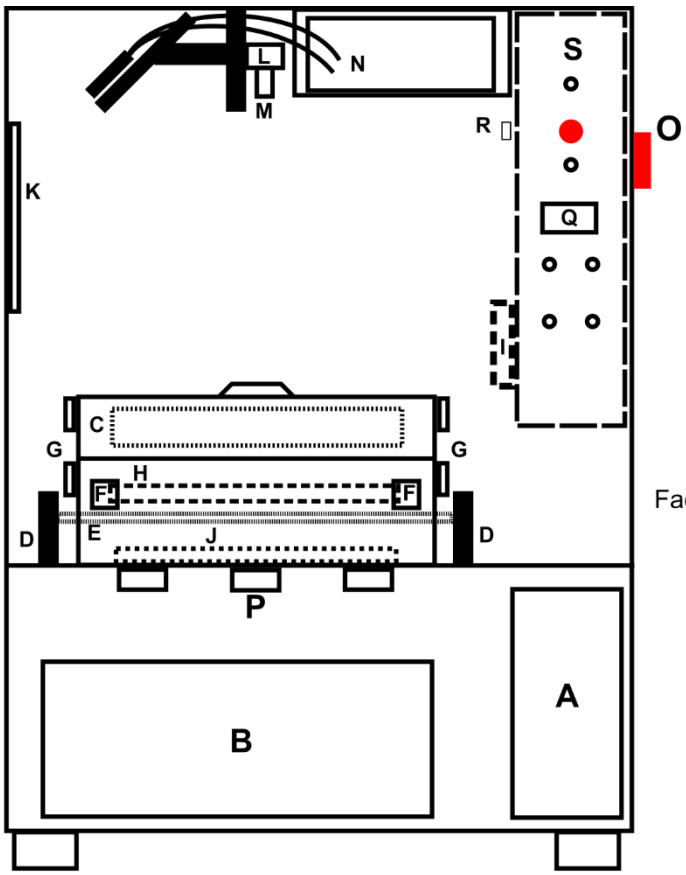
Figure 1.4 Danger Arc Flash Label

These labels are mounted to the electrical panel as a reminder that the voltages inside the enclosure are lethal.

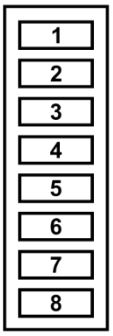
Figure 1.5 Warning Burn Hazard Label

This label is mounted by the oven handle as a reminder that the contents of the oven can be hot after a sample run is complete.

1.3 System Configuration



Thermocouple Locations
Facing Inside Right Side of Electrical Cabinet



A Computer	**H** Grating	**O** Main Power Disconnect
B AC Units for Blower	**I** Thermocouple Connectors	**P** Exhaust Fans
C Oven Top Heaters	**J** Oven Lower Heater Bank	**Q** HMI Screen
D Sample Translation Stages	**K** Mirror	**R** Exhaust Speed Control
E Sample Support	**L** Camera	**S** Electrical Cabinet
F Grating Tilt Adjusts	**M** Lens	
G Oven Interlocks	**N** Light Source	

Figure 1.6 Overall System Components

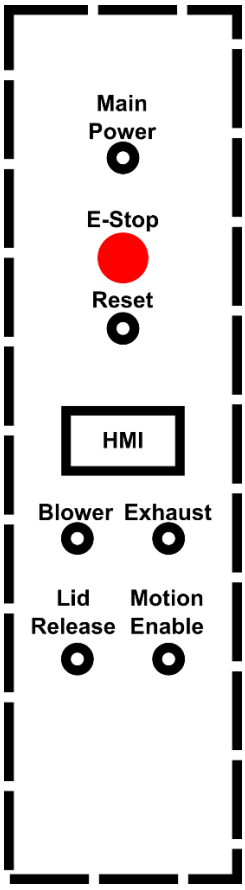


Figure 1.7
Electrical Cabinet Buttons

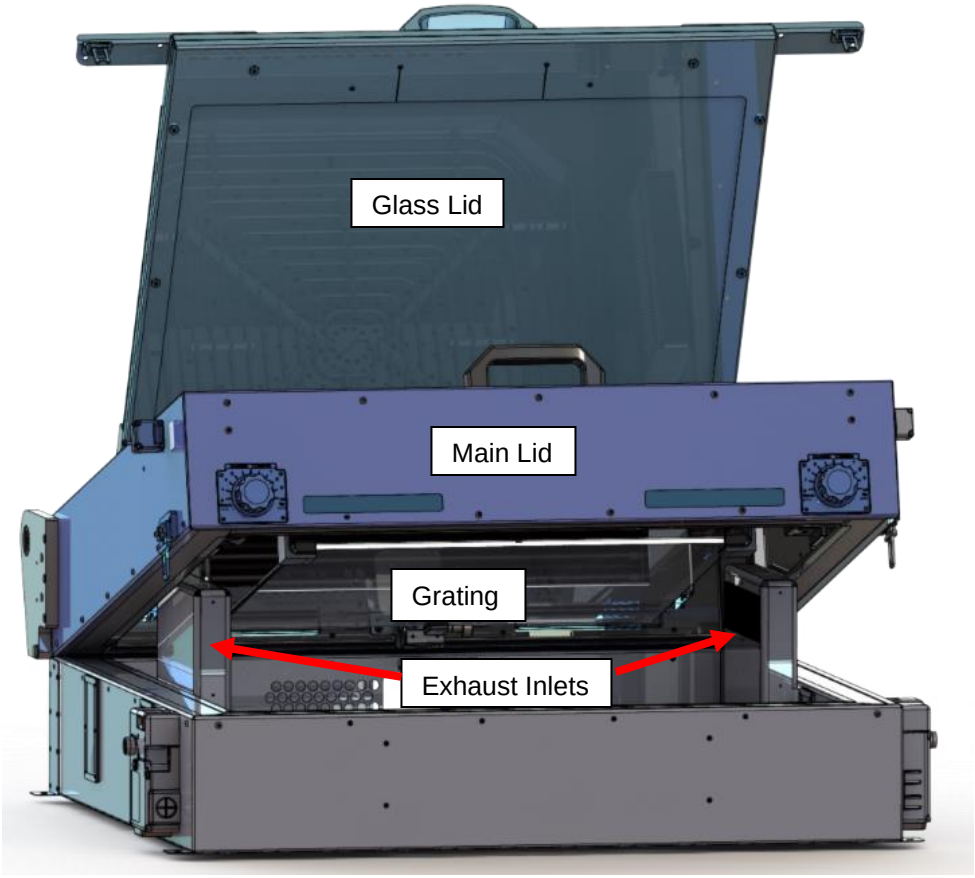


Figure 1.8 Oven Components

1.4 System Components

Every TherMoiré system consists of three main hardware components. In essence, these components do not change for different sized TherMoiré systems. These include:

- an Oven
- a Grating and Linear Motion Stage
- a Camera and Light Source

It is important to understand the basic design and operation of these components in order to fully utilize the system's capabilities. See the following sections for a brief description of each component.

1.4.1 Oven

The AXP 2.0 oven is an infrared oven consisting of both bottom and top heater elements. The bottom heater element is composed of two zones (**Figure 1.9**), one inner, and one outer. The bottom heater power to each zone can be controlled as a percentage when running a thermal profile. The top heater elements are positioned at the front and back of the oven, above the grating. These elements can be turned on or off and the

feedback thermocouple can be set to either TC1 or TC2, depending on how the user has the test set up. PID control to follow an input profile is provided by a PLC unit located in the electrical cabinet. In addition, cooling is provided by Exhaust fans which pull air out of the oven chamber from towers on the left and right sides and through holes in the bottom of the oven. Blower units force sub-room temperature air into the oven through holes in front and back of the oven, below the grating. Additionally, when cooling is enabled, air inlets in the front and back of the oven lid allow air to enter into the oven when pulled by the exhaust. The oven is sealed so that fumes, which may be generated from samples inside the oven, are directed out of the system exhaust.

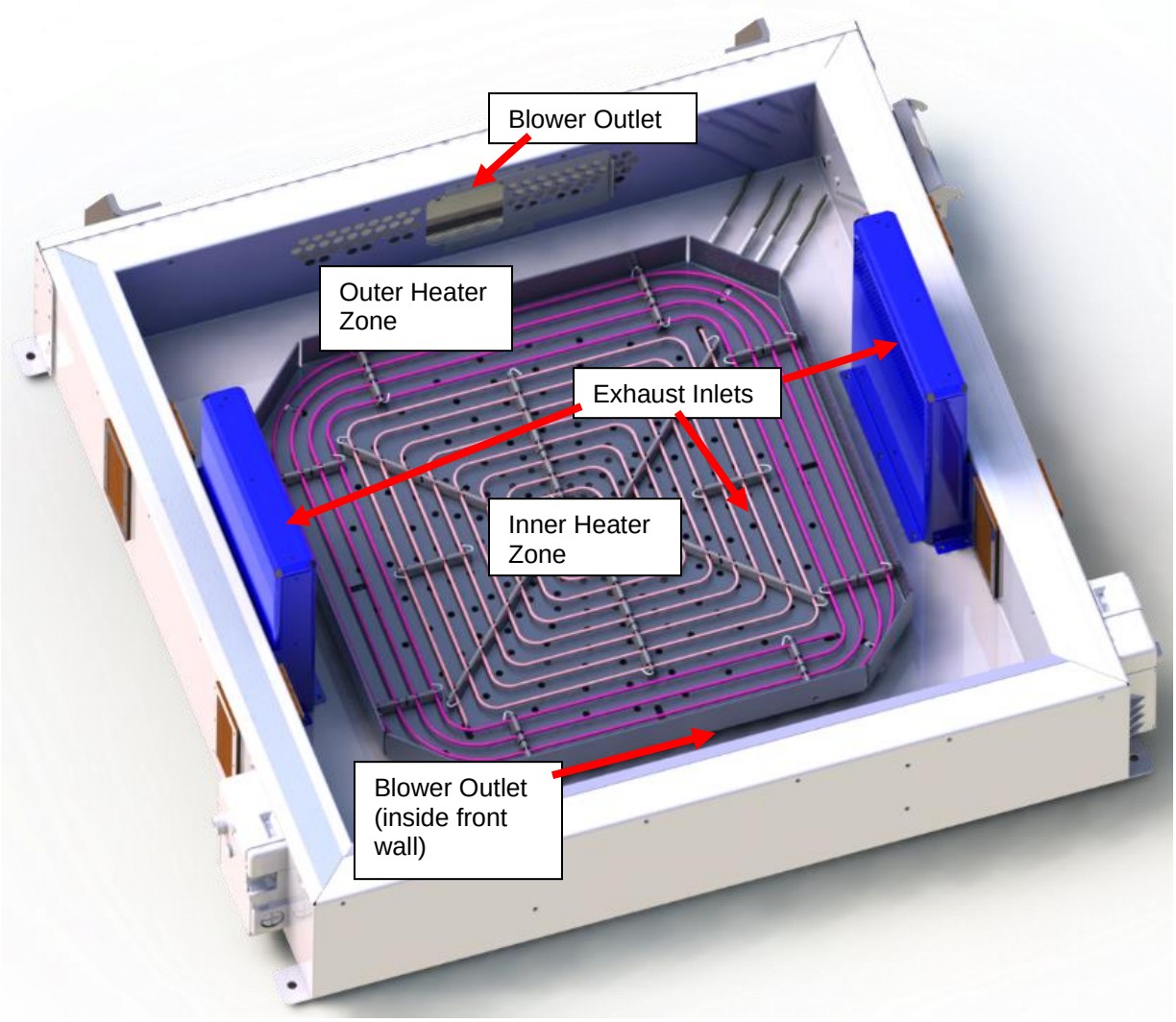


Figure 1.9 Oven Bottom Components

Temperature control can be operated manually, or automatically, via the Thermal Profiler software. Please see the Thermal Profiler User Manual for instructions on automatic or manual temperature profiling.

1.4.2 Grating and Linear Motion Stage

In standard configuration, each AXP 2.0 system is provided with a Ronchi ruled 100 lines per inch grating. Akrometrix has found that this frequency grating provides a good compromise between working distance and accuracy. Other grating frequencies are available but there are trade-offs associated with their use. Please see the Akrometrix Optical Techniques and Analyses 101 document for more details.

A linear motion stage drives the sample support up and down to achieve phase stepping in the AXP 2.0. Two motors are used, one on each side of the oven, and are tied together so that they move as one unit. They are attached to linear motion stages that provide a 2 inch (5.08 cm) range of travel. Limit switches prevent the motors from operating past the stage travel limits. Control over these motors is done exclusively using the Surface Measurement software. Please see the Surface Measurement User Manual for instructions on their use.

1.4.3 Camera and Light Source

The system is equipped with a single 1.4 megapixel camera to capture image data through the oven window. This camera is paired with a 12.5 – 75 mm zoom lens to provide either a full 375 x 375 mm or variable field of view.

An LED light source feeds light to a pair of fiber optic line lights which are pointed at the mirror on the left side of the unit. The light source should be set to maximum intensity for shadow moiré tests and can be set to a lower intensity for DIC focusing purposes.

1.5 Technical Support

For technical support, contact Akrometrix:

Akrometrix	404-486-0880	support@akrometrix.com
2700 NE Expressway	404-486-0890 (fax)	http://www.akrometrix.com
Building B, Suite 500		
Atlanta, GA 30345		

When contacting Akrometrix, please provide the system serial number, the version numbers of the Akrometrix software being used, a description of the problem or question, and contact information for reply. If the question concerns a particular measurement or analysis, please provide electronic copies of the phase images, reference images, and final results and a description of data acquisition and/or analysis conditions. If the problem concerns changes or failure in general system operation, please describe any events or system modifications that occurred immediately before the problem arose.

2 System Set-up and Use

2.1 System Set-up

1. Turn the AXP 2.0 system on.
   a. Make sure the Main Power Disconnect switch on the right side of the unit is in the ON position.
   b. Press the Main Power switch.
   c. Turn on the light source. For shadow moiré measurements, make sure that it is set to 100% power.
2. Run Surface Measurement by clicking the Surface Measurement button in the Studio Manager bar on the left side of the screen. A start-up splash screen appears while the software initializes. Refer to the Surface Measurement User Manual for operating procedures.
3. Attach the Process 1 K-type thermocouple to the sample. This thermocouple is located at the very top position of the thermocouple connector block. Typically, this 36awg Teflon-coated thermocouple with bare junction is attached to the sample bottom with Kapton tape and supplied thermal grease.
4. If top/bottom uniformity is of concern, Process 2 should be attached to the top of the sample and control of the top heaters should be set to feedback from this thermocouple. TC2 can be found just below the Process 1 thermocouple position on the thermocouple connector block.
5. Optionally, more thermocouples can be attached to other points on the sample or other samples. Process 3-8 can be recorded during the sample run, but do not play a role in temperature control. The AXP 2.0 can accommodate up to 8 total thermocouples. See **Figure 1.6** for thermocouple locations.
6. Open the main lid, and position the sample between the two sample support rails. Typically, samples should be supported on their edges by the sample support rails, but test accuracy should be considered as sample deflection can and does affect the warpage result. In general, samples should be supported as they are in the process that is being simulated in the AXP 2.0. However, the support method should be adjusted if it would result in significant shielding of the sample from the IR energy produced by the heater bank. The oven heater coils will only heat what is in direct line of sight so areas shielded by sample support structures will be colder than those areas that are unshielded.
7. Close the main lid. The system is now ready to begin operation.

Note: Unlike the original AXP, the AXP 2.0 does not require the user to press the Reset button in order to resume program operation after the lid is closed.

2.2 System Shutdown

The Main Power switch will turn off all devices in the electrical cabinet while leaving power on for the PLC and computer. This is useful for leaving the AXP in an idle mode without having to turn off the computer. However, the interlock/disconnect switch on the electrical cabinet will remove all electrical energy from the AXP, the computer and monitor as well. Before using this switch or unplugging the system from main power, close all programs and shut down the computer. The HMI screen will go blank, indicating all power has been removed from the unit.

Note: In the event of an emergency, press the EMO pushbutton. This action will remove power from the heaters, stage motors, blower, and exhaust while leaving the PLC functional for monitoring the temperature inside the oven and troubleshooting.

2.3 Replacing a Grating

The standard 100LPI grating can be swapped out for other frequency gratings in case application requirements change. In order to swap gratings, the main lid of the unit must be closed and the glass lid on the very top of the oven must be open. Pressing the Motion Enable and Lid Release buttons together will unlock the glass lid so that it can be opened. Once it is opened, the current grating can be lifted out by its edges, being careful to angle it such that it does not hit the top heater reflectors. The opening between the top heaters is sized such that the grating usually has to be lowered one side at a time.

Warning: The top heater housings and reflectors can remain quite hot for a considerable time after a profile finishes. TC9 mounted to the rear top heater housing must be below 50C before the glass lid is allowed to open.

Store unused gratings in their cases to protect them from damage.

2.4 Cleaning a Grating or Glass Window

Maintaining a clean grating when using the shadow moiré technique, or glass window when using any of the optional measurement modules, is critical to optimizing measurement resolution and reducing measurement noise. Gratings and windows should be cleaned on an as needed basis, when any forms of contamination or clouding become apparent.

Gratings and windows should only be cleaned when below a safe to touch temperature of 50°C. As a safety precaution, the AXP 2.0 will disable the main lid release functionality when thermocouples 1 and 2 are above 50°C. The AXP 2.0 will disable glass lid release functionality when thermocouples 1, 2, or 9 (attached to rear top heater housing) are above 50°C. Keep in mind that the grating or window temperature may be higher than these thermocouple locations.

Frequent cleaning of these surfaces is critical to avoiding staining, or more permanent residue deposits. The grating or window should be cleaned shortly after cooling to near

room temperature, whenever contamination is observed. Allowing a contaminated grating or window to be heated without cleaning can lead to more permanent grating surface stains.

Gratings and windows should be cleaned with a lint free cloth or wipe and typically with a mild glass cleaner or 30-70% IPA solution. The etched lines in the grating surface are not easily removed. Users are free to press firmly on the grating and wipe in multiple directions to clean the grating surface effectively. More stubborn deposits can be taken off with Acetone or even Oven Cleaners (typically sodium hydroxide, aka Lye). If these products are required, be sure to exercise appropriate safety precautions including hand and eye protection as well as adequate ventilation of the work area.

Note: Refer to the cleaning product precautions for any personal protection equipment needed and for disposal of soiled cloths.

3 Temperature Control

3.1 Manual Temperature Control

See the Thermal Profiler User Manual for Manual Temperature Control.

3.2 Automatic Temperature Control

Automatic temperature control is achieved through the use of a piece of Akrometrix software called Thermal Profiler. Please see the Thermal Profiler User Manual for a description of its procedures and usage.

3.2.1 HMI Screen

The HMI (Human Machine Interface) Screen is used primarily to display thermocouple setpoints and values. When the Main Power switch is off, it will display AKROMETRIX AXP 2.0. This will also be displayed if communication with the PC is lost during a profile.

When the Main Power switch is on, and communication with Studio is active, it will display a profile screen with dual temperatures and setpoints for profiles with active top heating, and a single setpoint and value for TC1 when only bottom heaters are active.

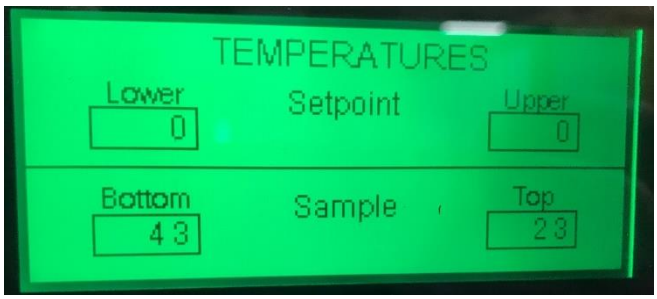


Figure 3.1 HMI Profile Run Screen

There is also a diagnostic display mode that shows all active thermocouples values, including TC9, which is permanently mounted to the rear top heater enclosure as over-temperature protection. This mode can be entered by holding down the Motion Enable button and pressing the Reset button.

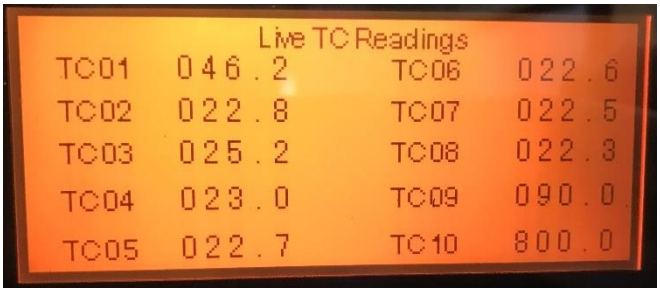


Figure 3.2 HMI Diagnostic Screen

3.3 Removing and Changing Samples

1. Allow the oven to cool until temperatures are safe for handling.

Warning: The AXP 2.0 oven takes time to return to safe-handling temperatures. Use extreme caution in handling samples as they can retain significant heat long after the thermal cycle is complete. In addition, the HMI screen shows the *sample temperature*, which may not be an accurate indicator of the temperature of other oven components.

2. Open the main lid while pressing the Oven Lid Release button.
3. Remove the tested sample carefully. Detach the thermocouple(s) by removing the Kapton tape. Do not remove the thermocouple by pulling on the thermocouple wire, which may damage the wire.
4. Set up the new sample as described in **Section 2.1**, Steps 3-7.

Warning: Before closing the lid, check that clearance between the sample and grating will be maintained after closing. Lower the sample height before closing, if necessary. Severe sample-grating contact may damage the grating, sample, or sample support structure.

4 PLC Logic Conditions

In place of a standalone temperature controller the AXP 2.0 has moved to a PLC (programmable logic controller) based control scheme. This allows more flexibility to the overall system design and operation of the various electro and electro-mechanical devices used for temperature control and safety protections. In this section, the logic conditions for each device and safety precaution are described.

4.1 E-Stop Alarms

The following conditions will trip an E-Stop Alarm, shutting down power to the heaters and stage motors. The reset light will light up solid white when in E-Stop, indicating that the user needs to press it once the E-Stop condition has been cleared.

1. TC1 or TC2 is open (i.e. TC > 400C, condition is considered open)
2. Any active TC reads over 310C while a profile is running

Note: Installing or removing a thermocouple while a profile is running will trip this alarm.

3. TC1 or TC2 is shorted

During an active profile, the following steps happen:

Once every ten seconds TC1 & TC2 temperature readings are saved. During this ten second window the TCs are monitored for a change of 1° for TC1 or 0.1° for TC2. If this change does not happen a 60 second timer is started. If this timer expires then the TC is considered shorted. The timer is cleared any time both TC1 & TC2 have made their prescribed change in the 10 second window.

TC1 is checked when the lower heaters are running, the difference in temperature from setpoint is larger than 5°, and the combined heater output is > 55%. TC2 is checked when the upper heaters are running, are being controlled by TC2, the difference in temperature from setpoint is larger than 10°, and the combined heater output is > 55%.

4. EMO pushbutton depressed. This pushbutton serves as the means for the user to activate an emergency shutdown of the machine. With this button pressed, the heaters, stage motors, blower and exhaust will not function. However, the PLC is still alive such that temperature information can be obtained for troubleshooting. Once this button is pressed it will need to be twisted to release.
5. Over-temperature switch mounted in the back right corner of oven. This switch will de-energize the heaters, blowers, and exhaust when the inner walls of the oven reach a temperature over 150C. Pressing the reset button will clear the alarm when this switch temperature is cooled below 110C.

4.1.1 Resetting an E-Stop condition

1. Allow internal oven temperatures to fall below the temperatures indicated above. The Emergency Stop condition cannot be reset until this occurs.

Warning: Objects within the oven may remain dangerously hot even after the over-temp controller unlocks the oven.

2. Press the Reset button on the front control panel.

4.2 Lid Operation and Lockouts

Unlike its predecessor, the AXP 2.0 now has two lid opening mechanisms. These are known as the Main lid and Glass lid. The Main lid is used for day to day sample setup and testing while the Glass lid is used for grating swaps, module installations, and maintenance/troubleshooting.

Both heater power and motion system power are cut when either of these lids are open. However, holding down the Motion Enable button will re-establish power to the motion system in case it is needed while a lid is open.

4.2.1 Main Lid

The main lid is opened by pressing the Lid Release button. The lid interlock will be locked closed in the following conditions to protect the operator and equipment:

1. TC1 or TC2 > 50°C (lockout can be defeated if either of these thermocouples are unplugged)
2. Glass lid open (reset light will blink)

Note: The lid cannot be opened (using the Lid Release button) until TC1 or TC2 fall below 50°C. In the event the operator needs emergency access to the oven, the oven lid interlock can be opened with a mechanical over-ride key.

4.2.2 Glass Lid

The glass lid is opened by pressing the Lid Release and Motion Enable buttons at the same time. While this lid is open the Reset light will flash. Because the top heaters can remain much hotter than the sample long after it has returned to room temperature, a 9th thermocouple is attached to the frame of the back top heater to monitor its temperature. The glass lid will lock under the following conditions:

1. TC1 or TC2 > 50°C (lockout can be defeated if either of these thermocouples are unplugged)
2. TC9 > 40°C
3. Main lid open (reset light will blink)

Note: The glass lid cannot be opened (using the Lid Release and Motion enable buttons) until TC1 and TC2 fall below 50°C, and TC9 falls below 40°C. In the event the operator needs emergency access to the oven, the oven lid interlock can be opened with a mechanical over-ride key.

4.3 Heater/Blower/Exhaust Controls

4.3.1 Heating/Cooling Mode

Because some of the logic for the Exhaust/Blower is dependent on whether the system is currently supposed to be heating or cooling, the following definitions for those modes are defined. This definition is based on a comparison between the last setpoint (SP) and the current setpoint.

1. If the last SP < current SP then the mode is heating.
2. If the last SP > current SP then the mode is cooling.
3. If the last SP = current SP then the mode is not changed.
4. At the end of a profile the mode is set to cooling.

Also, because the PID will force the output on after an extreme time of not meeting the setpoint, the heater outputs are forced off if in cooling mode and TC1 > SP.

4.3.2 Heaters

The top heaters should most typically be controlled by TC2 attached to the top of the sample under test. Alternatively, they can be controlled by TC1. This setting is chosen during profile setup. Also, unlike the bottom heater bank, the top heaters are run in On/Off mode.

1. If TC2 is the feedback
    a. On when TC2 < Upper SP + Offset
    b. Off when TC2 > Upper SP + Offset
2. If TC1 is the feedback
    a. On when TC1 < Upper SP + Offset
    b. Off when TC1 > Upper SP + Offset

For safety precautions to both the operator and equipment, the top heaters will be turned off:

1. While TC9 > 350°C (or 375°C when running Studio 8.5 PLC code)
2. Or if they run continuously for more than 8 minutes. This timer restarts from zero every time the heater is turned on.

The bottom heater is divided into two zones with two PID loops. Feedback for both zones is TC1. If TC1 goes 2°C above the current setpoint the max allowed power output

is cut by 75%. Also, when the Exhaust turns off the max allowed power output is cut by 75% for 10 seconds.

4.3.3 Exhaust

The following conditions apply to Exhaust on/off commands. Anytime the Exhaust turns on, the damper valve on the back of the system opens.

During a profile depressing the Exhaust pushbutton will behave differently depending on whether the profile is in heating or cooling mode.

1. In Heating mode the Exhaust will run when TC1 > SP+6°C
2. In Cooling mode the Exhaust will run when TC1 > SP+4°C or TC1 < 50°C

During a profile the Exhaust on command will only run when TC1 > SP-3°C. If a profile is not running, the Exhaust simply turns on and off when the pushbutton is depressed. The Exhaust pushbutton light will turn on or off depending on the conditionals above.

4.3.4 Blower

The following conditions apply to Blower on/off commands. Anytime the Blower turns on, the Exhaust will also run to prevent fumes from going anywhere but the facility Exhaust. While a profile is running, the Blower will not turn on if the profile is in heating mode. It will also not turn on if power output to the heaters is over 50%.

The Blower will turn on in the following conditions, either from the pushbutton being depressed or the Blower command in a profile:

1. TC1 > SP+15 and run until TC1 < SP-2°C
2. If the lower heater SP < 50°C

If a profile is not running, the Blower simply turns on and off when the pushbutton is depressed. Once the Blower has turned off it will not restart for 7 seconds to prevent excessive wear and tear on the compressors and large current draw from the facility power. The Blower pushbutton light will turn on or off depending on the conditionals above.

4.3.5 PLC Troubleshooting

If the system is plugged in, the Main Power Disconnect is on, and the PLC is up and running, the Main Power switch light will come on when the Main Power button is depressed. If it does not, the PLC has probably crashed or died. To reset the PLC, the Main Power Disconnect needs to be turned off for about 15 seconds and then back on.

5 Troubleshooting

5.1 Troubleshooting Data Acquisition

As with any measurement system, the AXP 2.0 has its limitations. These limitations exist because:

1. The shadow moiré technique with phase stepping analysis is sensitive to the optical properties of the samples measured, and
2. The desired thermal profile (generated on a production tool, such as a conveyorized reflow furnace) may be difficult to reproduce in a small thermal chamber where the sample position is fixed.

The optical and analytical limitations of the system include:

- Failure to obtain good fringe phase information.
- Loss of resolution on samples with a wide range of reflectivity.

The thermal limitations of the system include:

- Temperature gradients across/through the sample.
- Limits on heating and cooling ramp rates.

5.2 Troubleshooting Oven Operation

5.2.1 Minimizing Temperature Gradients

An important goal in many industrial thermal processes is achieving uniform temperatures across the product. Minimizing thermal gradients in the AXP 2.0 is now made easier by the addition of top side radiant heaters. However, the top side heaters have finite power and transmission of their energy through the grating is somewhat blocked. As a result, achieving good thermal uniformity can require some creativity for samples that are thick or have poor thermal conductivity. In general, the use of high radiant flux sources rather than forced convection heating in TherMoiré systems originated from the need to duplicate the high ramp rates of belt reflow ovens. There are three simple approaches to reducing top-to-bottom thermal gradients:

1. Use the Top/Bottom Uniformity heating mode in Thermal Profiler:

This mode applies 100% power to the bottom outer heater zone and 0% to the inner, sacrificing some heating rate. As a result, IR energy is bounced off of the grating and IR reflective coating on the lid glass and onto the top of the sample under test.

2. Reduce Ramp Rates:

The highest ramp rates for heating tend to cause non-equilibrium temperature distributions because of finite conduction rates of heat throughout the part under test. More gradual temperature profiles allow the heat to spread through the part, thus reducing top-to-bottom gradients.

3. Increase Sample-Grating Distance

The distance between the grating and the sample affects the top-to-bottom temperature gradient. A narrow gap enhances cooling of the top sample surface through

convection between the sample and the (relatively) cool grating and prevents flow of heated air across the top of the sample.

4. Measure During Cooling

Near isothermal conditions can be achieved on a transient basis by raising the sample temperature above the temperature point at which the measurement is to be made, and turning off power to the IR heater bank, e.g., setting the temperature controller set point to zero for several seconds. During the cooling period, the temperature gradient is significantly reduced within a few seconds as the temperature across the sample equilibrates in the absence of radiant flux. As a general corollary, gradients can be less during the cooling portion of the cycle than during the heating portion.

5.2.2 Increasing Rates of Heating and Cooling

A second issue that repeatedly arises during simulation of production time-temperature profiles is reproducing heating and cooling rates. A belt system that transports a sample through pre-equilibrated zones of different temperature is intrinsically faster at changing sample temperature than a batch system that must allow time for the heat source and the surrounding chamber to reach a new thermal equilibrium.

The TherMoiré system uses a PID (proportional-integral-derivative) temperature control loop to minimize the error signal between sample temperature and desired set point. While effective at that task if properly tuned, PID control can reduce the maximum achievable ramp rates for heating and cooling if the set point temperature is varied gradually. The highest heating rates are achieved when the set point is set far above the sample temperature, while the fastest cooling rates are achieved if the temperature set point is set to zero. In this mode, the temperature control loop is essentially an on-off switch.

Heating rates can also be increased by maximizing IR absorbance of the sample surfaces exposed to the radiant heater bank. A thin coat of high temperature flat black paint on the bottom surfaces provides much higher absorbance than a shiny metallic surface.

Cooling in the AXP 2.0 system is primarily limited by the cooling of the infra-red heater bank, rather than the sample itself. The airflow provided by the blower and Exhaust fans is designed to sweep room-temperature air across the sample and then down through the heater bank to maximize cooling. Exhaust speed can be adjusted to vary cooling rate.

Appendix A - Miscellaneous Information

A.1 Equipment Ratings

Electrical	
Supply Voltage	230VAC, 50/60 Hz, 3Φ Delta
Full Load Amp Rating	45 A
SCCR	10kA @ 230VAC
Mechanical	
Footprint	1285 (w) x 1025 (d) x 1780 (h) mm
Weight	575 kg, 800 kg crated for shipment
Condensation drain from Blower system, Ø 3/8” OD flexible tube	
Pneumatic	
Clean dry air, min. pressure 1.4 bar, flow rate 250 lpm at STP, 3/8” NPT connection	
Oven Exhaust	
Port Diameter	150 mm
Maximum Temperature	100°C
Maximum Flowrate	14,286 LPM

A.2 Installation and Assembly

1. The AXP 2.0 is designed to be installed in a room with a temperature between 20–26C and humidity between 20-80% non-condensing. The lighting should not be overly bright while not so dim these instructions cannot be read.
2. The AXP 2.0 can be lifted by its base plate (forklift, pallet jack, etc.) or wheeled to its operating location.
3. Once in position, adjust the AXP 2.0 caster standoff thumbscrews such that the equipment feet are in firm contact with the floor.
4. Remove any packing materials attached to the equipment.
5. Assemble the monitor and stand. Place the keyboard and mouse on the stand.
6. Install the graphics card in the system computer, if applicable, then install the computer in its position beneath the electrical cabinet. Connect all relevant cables according to the installation instructions shipped with the machine.
7. Connect the AXP 2.0 power cord to an appropriate power outlet for the voltage and current rating stated in A.1.

Please see the TherMoiré AXP 2.0 Installation Procedure document for more details.

A.3 Transport

When transporting the TherMoiré AXP 2.0 system to a new location, Akrometrix recommends that certain components be removed from the system and packed separately. These include:

- Gratings
- Computer, graphics card, monitor, keyboard and mouse
- Camera lenses (place lens caps on lenses, both ends, and a cap over the exposed camera element)
- System Mirror
- Sample Support structure

Other moving parts should be either restrained from movement with zip-ties or removed and shipped separately, including:

- Oven and computer compartment doors (the entire system should be wrapped in plastic and this would serve as restraint for these doors)
- Light source
- Vertical translation stage. There are two straps that are shipped installed on the stages. These should be saved and reused in the event the system needs to be moved again. See **Figure A.1** for an example of how the stage strap is attached for shipment. This view is of the top of each stage on the left and right sides of the oven.

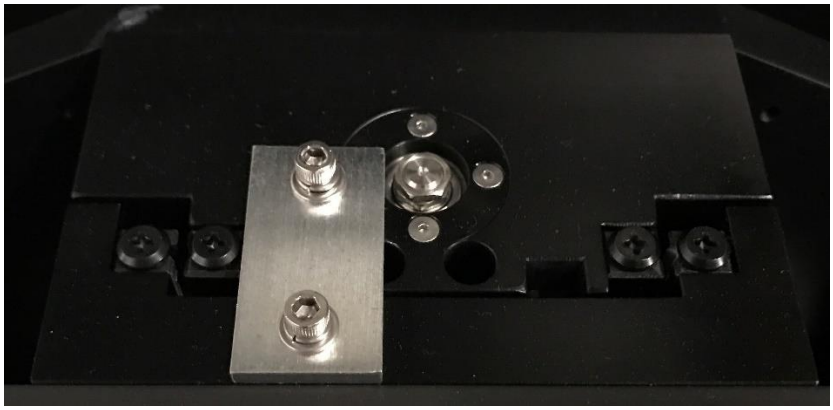


Figure A.1 Stage Strap installed for shipping

A.4 Disassembly

No special precautions or procedures are required for disassembly or final disposal, beyond normal care in handling the heavier components. No materials incorporated in the TherMoiré AXP 2.0 are known to require special handling or disposal. The metals used are aluminum and steel. The outer door and face panels are acrylic.

Note: The blower AC units do contain refrigerant that should be reclaimed before opening the closed loop system.

A.5 Ventilation

The AXP 2.0 itself requires no specialized ventilation. However, some sample types will emit gasses when heated to reflow temperatures. These gasses should be vented through the Exhaust port on the system, which is preferably connected to an outside ventilation system.

A.6 Maintenance

A.6.1 Stage Lubrication

A syringe of lubricant called Lubriplate (see **Figure A.2**) is supplied with each Akrometrix system. This lubricant should be applied to the stage leadscrews at 6 month intervals. The procedure to do so is as follows.

Figure A.2 Lubriplate Stage Lubricant

1. Remove the left and right system panels to expose the sides of the motor/stage assemblies. Remove the right motor/stage assembly cover as well.
2. Using the Surface Measurement application, lower the stages to their bottom position. The leadscrews will be visible as shown in **Figure A.3**.
3. Apply a small bead of Lubriplate along the visible portion of both left and right stage leadscrews. A small flathead screwdriver or wooden coffee stirrer can be used, just take care to not damage the leadscrew.
4. Raise the stages to their top position.
5. Apply another small bead of Lubriplate along the visible portion of both left and right stage leadscrews.
6. Jog the stages up and down to their limits several times to ensure that the lubricant is adequately spread onto the leadscrews.

Warning: Avoid contact with skin and do not inhale. This product has a NFPA Health rating of 1. In the event of skin contact, wash with warm water and soap. A full MSDS is available upon request.

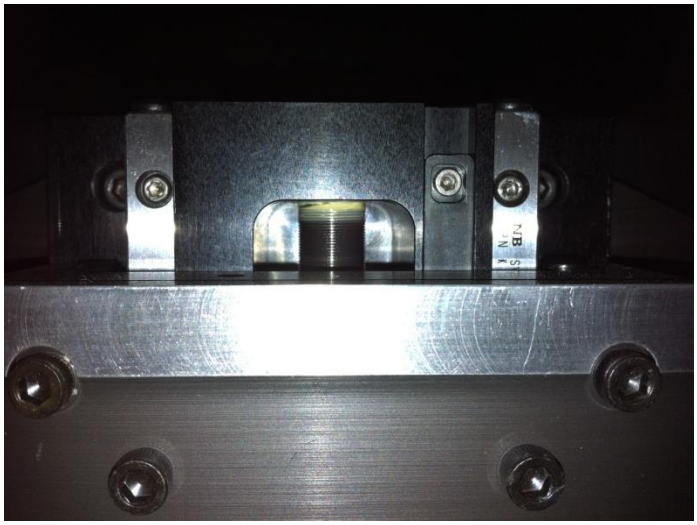


Figure A.3 Leadscrew Visible with Sample Support at Bottom Position

A.6.2 Servicing the Light Source

The LED light source in the AXP 2.0 has a serviceable life of ~50,000 hours. If any problems are encountered with this light source, contact your local Akrometrix representative for repair or replacement.

A.6.3 Replacing Thermocouples

1. Unplug the thermocouple from the electrical cabinet socket.
2. Open the connector by removing the two small screws on the outside of the connector.
3. Loosen the two screw terminals inside the connector body
4. Replace using standard K-type thermocouples, making sure the new thermocouple is connected with the correct polarity, yellow to the positive terminal, red to the negative.
5. Replace the thermocouple connector cover.
6. Reconnect the thermocouple to the electrical cabinet socket.

A.6.4 Gas Line Maintenance

Periodically inspect all compressed air hose connections for leaks or other wear. Tighten connections and repair/replace hoses when necessary.

A.7 Oven Lid Interlock Bypass

The lid interlocks ship from the factory in the Locked position, in which they remain locked until power is applied to the solenoid (using the Lid Release button). However, in the event that power is not available (i.e. the AXP 2.0 main power is off), the powered lock is defeated by setting the interlock mechanism to Unlocked:

Warning: Opening the Oven Lid Interlock using the mechanical over-ride key can expose the operator to harm. The interlock should never be left in the mechanical over-ride position during system operation.

1. Insert the appropriate Interlock Key (**Figure A.1**) into the side of the solenoid interlock mechanism. (**Figure A.2** and **Figure A.3**)
2. Rotate the key to the Unlocked position.

Note: An interlock in the unlocked state is seen as an open lid by the PLC, so the Reset light will flash in this case.

3. To restore the factory Locked position, rotate the key in the opposite direction.

Figure A.1 Interlock Keys

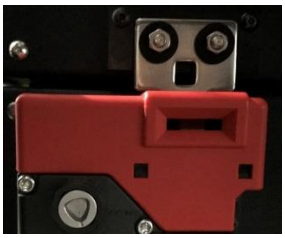


Figure A.2 Main Lid Interlock

Figure A.3 Glass Lid Interlock

A.8 Oven Over-Temperature Switch

Over-temperature switch functionality can be tested whenever the stage lead screws are lubricated. Using a heat gun, apply heat to the area in the oven just above where the lower heater wires pass through the inner wall of the oven. Keep applying heat until the Reset Light changes from blinking to solid on. Then let the area cool for 15 to 30 minutes and press the Reset pushbutton to clear the alarm. The Reset Light will return to blinking. If this does not happen, the Over-temperature Switch has failed to reset and the oven will not heat until the switch is replaced.

A.9 EMO Pushbutton

Once every six months, press the EMO pushbutton and check for a solid Reset Light. Twist to clear the EMO and press the Reset Pushbutton to clear the Reset Light. If the reset light does not turn on once the EMO pushbutton is depressed, then repair is required.

A.10 Camera Lens

Clean the lens as needed. The recommended product for cleaning the camera lens is Tech Spec Lens Cleaner. An eight fluid ounce bottle is included in the accessories kit. When using this product read and follow all directions and precautions on the bottle.

Warning: Avoid contact with the eyes. This product has a NFPA Health rating of 1. In the event of eye contact, rinse immediately with plenty of water for at least 15 minutes. Seek medical attention if irritation develops or persists. A full MSDS is available upon request.

Appendix B – Blower A/C Units

B.1 Overview

The AXP 2.0 Blower system consists of two 2500BTU/hr A/C units forcing air into the sample chamber via holes in the front and back walls of the oven. The Blower A/C units cool the incoming air to below room temperature before entering the thermal chamber to aid in the cooling process (see **Figure B.1**). By forcing sub-room temperature air into the oven instead of room-temperature air, the cooldown to room temperature is substantially improved.

Figure B.1 Blower A/C Units under oven

B.2 Facilities Requirements

Be aware that the Blower A/C units will produce condensation during use, particularly in more humid environments. Akrometrix uses a hose to route the condensation from each A/C Unit to the rear of the system where a 3/8” quick disconnect fitting is located. This port should typically be plumbed on installation to drain into a pan or drain of some kind.

Figure B.2 Drain Hose Routing

Figure B.3 Condensation Drain Hole

B.2.1 Ambient Air Filter

It is recommended that the ambient air filter be checked and cleaned regularly, at least every 6 months, or more frequently depending on dust levels. To check the condition of the air filter, remove the lower left side panel from the AXP 2.0. Locate the filters as pictured in **Figure B.4**.

Figure B.4 A/C Unit Air Filter

Next, check the condition of the filters. If they are significantly covered in dust, they should be cleaned or replaced. To do so, remove the four screws holding the filter onto the AC unit. The filter can be cleaned by soaking it in warm soapy water and then rinsing in clean water. Use a shop vacuum to remove excess water from the filter before reinstallation. Replace the filter if it is showing signs of deterioration.

It is recommended to have a spare, clean filter in stock in order to prevent prolonged cooling system downtime. The dirty filter may be cleaned at a more convenient time.