7. Calibration Procedures

This section of the manual describes the procedures used in calibrating the mechanical and control functions of GNIRS. Some operational procedures, such as focusing the slit onto the detector, will be covered here, but general observational procedures, such as flatfielding, wavelength and flux calibration, are covered in the User's Manual.

7.1 Mechanism Calibration

With the exception of the acquisition mirror and environmental cover, which travel between two fixed locations defined by limit switches, the GNIRS mechanisms operate by moving relative to a "home" or "datum" location. The motion itself is open-loop, generated by moving the motor a predetermined number of steps. Backlash is removed by approaching all locations from the same direction (overshooting in the "negative" direction by a predetermined amount, then reversing direction to finish at the target location).

NOTE: For completeness, this section will refer to both GNIRS and OIWFS mechanisms. However, the details of any calibration or maintenance of the OIWFS mechanisms will not be covered here, and the reader is referred to the OIWFS manual.

7.1.1 Establishing a Datum

Because there is no absolute encoding of the mechanisms, it is necessary to re-establish the datum after powering up the control electronics or rebooting the controller.

7.1.1.1 OIWFS Mechanisms

The OIWFS mechanisms use a Hall effect (magnetic proximity) sensor, with a small magnet in the moving part and the sensor at a nearby location in the housing. Datuming consists of moving the mechanism at fairly high speed while monitoring the voltage output of the Hall sensor. After a peak has been sensed, the motion reverses and the peak is traversed several times at decreasing speed. Since the peak itself is difficult to determine, the datum is defined as the point midway between two points at a particular fractional amplitude on either side of the peak. Because the mechanism has no knowledge of its position on powerup, it will initially move in the wrong direction half the time. As a result, this process can be lengthy.

Each sensor has two outputs for redundancy. Normally, both outputs are recorded. In the event of a failure of one of the sensors, the backup sensor can be used (see the OIWFS manual). The datum established by the primary and backup sensors should be in the same location, although the peak voltages themselves will be different.

7.1.1.2 GNIRS Mechanisms

The GNIRS mechanisms use a bearing follower activated microswitch to sense a mechanical step on the mechanism wheel or turret. Datuming is done by moving the mechanism until the transition occurs; because the home is a high-low transition, the computer knows the proper direction of the initial motion after powerup. The mechanism is then moved to a position a short distance on the negative side of the step and then in the positive direction at a very slow speed until the transition occurs.

There are two home switches for redundancy. One may select either the primary or the backup home switch, but because of mechanical tolerances, the home positions of the two will differ by a small amount. The position difference is in the configuration table, so operation should not be significantly affected.

7.1.2 Mechanism Configuration

There are three types of mechanism operation. The environmental cover and acquisition mirror, as noted above, travel between two extremal positions defined by limit switches or hard stops. Some (OIWFS gimbal mirror, focus drives) can be configured at any position between the limits as part of normal operation. Others (filters, slit, decker, prism, cameras) have a finite number of well-defined configurations. The grating is a hybrid in that it has a few defined windows within which the 10, 32, and 110 l/mm gratings can be continuously positioned.

Discrete mechanisms use a configuration table to translate the named positions into motor steps relative to the home location. Since the named positions have well-defined relative locations defined by machining, calibration consists of measuring the location of one of the positions, determining any offset from the value in the existing configuration table, and applying this offset to all entries in the configuration table. Such a procedure may be necessary in the event of any wear in a home switch and will almost certainly be necessary if one re-installs the mechanism for some reason. Replacement of the slit mask by a new one, for example, will require a more detailed calibration, since the relative slit locations must be remeasured.

The grating accepts input in the form of desired grating, center wavelength and order, and converts this information to a motor step location. Unless the gratings have been moved (e.g., removed and installed), calibration should be no more than re-establishing the zero point, as with the discrete mechanisms.

Continuous functions such as the detector focus will be calibrated as part of the instrument operations, so there is no “correct” position. The relative positions of the four camera foci may be sufficiently invariant that focusing with one camera may permit the observer to move the detector a set amount so it will be focused for another camera.

7.1.2.1 Slit and Decker Calibration

The exit mask for the preslit bench has a cutout sufficient to pass the acquisition field (wide “slit” + acquisition bulge). One may verify its position by imaging the acquisition

slit on the sky or calibration flatfield and ensuring that it is not vignetted by the mask. Since the decker for the acquisition field is the same size and shape as the slit, one must carry out this process iteratively for the two mechanisms to ensure that they are aligned with each other and not vignetted.

- Set up GNIRS in imaging mode, with the acquisition mirror in the beam, pointed at the flatfield in the calibration unit, with a short wavelength filter (Order 4, for example). The short blue camera will permit the entire slit to be imaged.
- Set both the decker and slit to the acquisition position and take an image. NOTE: If there appears to be vignetting from the filter wheel, move the filter wheel until an unvignetted image of the slit can be obtained, then carry out the filter wheel calibration in section 7.1.2.5 after this procedure has been completed.
- Move the slit by small amounts and examine the images for vignetting between the slit and decker. Adjust until the slit and decker are aligned with each other. NOTE: Vignetting between the slit and decker will be sharp. Vignetting by the exit mask will be more gradual, since it is about 100 mm from the slit plane.
- Move the slit and decker together (in space, not motor steps) back and forth until the vignetting envelope of the exit mask can be determined on the detector. Calculate the midpoint of the envelope and move the slit and decker to this point. This should define the step position relative to home for the acquisition locations.
- If necessary, edit the configuration file for the slit and/or decker for the new zero point, redatum, and move both to the acquisition location again. Verify they are at the previously determined position on the detector.
- Move the decker to all of the other locations in turn and verify that the envelope in the dispersion axis is the same (i.e., the relative positions are correct)
- Determine the midpoint of the acquisition slit on the detector in both axes. This fiducial will be used for the cross-dispersion and grating calibrations as well. Move to all of the slit positions and verify that the slit images are centered at this point. NOTE: If the image of the slit is significantly decentered in the spatial direction, the camera calibration (section 7.1.2.2) may need checking.
- If a new slit mask had been installed, determine the stepper motor locations which center the slit images at the fiducial and enter these into the configuration file.

7.1.2.2 Camera Turret

The relative locations of the four cameras should not change, but recalibration may be needed in the event of switching to the backup home switch or if the instrument has been disassembled. The primary symptom would be a significant decenter in the spatial axis of the slit image during the slit calibration procedure in section 7.1.2.1.

Because of the optical path through the long camera fold mirrors, the image motion through the long cameras is (nearly) along the dispersion axis as the camera rotates, whereas that for the short cameras is along the spatial axis. In addition, rotation of the camera turret results in a focus change with the long cameras.

- Carry out the slit/decker calibration (section 7.1.2.1), using the short blue camera.

- If the image of the slit is significantly decentered in the spatial axis, move the camera turret until the image is centered.
- Move the slit to the multiple pinhole target location and take an image. Verify good (or at least symmetric) image quality at the ends of the slit.
- Note the actual motor position of the camera and edit the camera positions in the configuration file.
- Redatum, move to the short blue camera, and verify position. Move to the long blue camera and a short decker (LCXD, Wollaston) and verify that the image is centered horizontally. If necessary, verify and/or determine the red camera positions as well.

7.1.2.3 Prism Turret

This will assume that the fiducial point on the detector array is known or has been interactively determined as in section 7.1.2.1.

- Set up GNIRS in spectroscopic mode, with the acquisition mirror out of the beam, pointed at the flatfield in the calibration unit, with a short wavelength filter (Order 4, for example).
- Set the slit to any long slit and the decker to the shortest height.
- Prism to longslit position (mirror)
- Grating to 110 l/mm, 1.50 microns
- Examine the continuum spectrum. It should be centered on the column coordinate of the fiducial point. If not, move the prism mechanism until the spectrum is properly centered, note the motor step position.
- Edit the configuration file, redatum, and confirm that the longslit (mirror) spectrum is still centered

7.1.2.4 Grating Turret

Before carrying out this step, the slit/decker (section 7.1.2.1), camera (section 7.1.2.2) and prism (section 7.1.2.3) should be known to be calibrated.

- Set up GNIRS in spectroscopic mode, with the acquisition mirror out of the beam, pointed at the calibration unit with an emission line source in the beam. Plan on using an easily-identified portion of the line source spectrum and select the appropriate order separating filter.
- Move the slit to the 2-pixel slit and the prism to the mirror position. The decker position is not critical, so one may use the longest one.
- Enter the wavelength of a strong emission line and move the 32 l/mm grating to that position. Take an image and identify the line in the spectrum. It should be centered on the array in the dispersion axis.
- If necessary, move the grating until the line is centered and note the offset. Edit the configuration file, redatum, and move again to the line position to verify the calibration.
- If there is any doubt about the line identification, go to another prominent emission line wavelength, preferably in another order, for verification.

- Repeat this process for the 10 l/mm and 110 l/mm gratings.

7.1.2.5 Filter Wheel Calibration

Calibration of the filter wheels assumes that the slit/decker calibration exercise (section 7.1.2.1) has been carried out.

There are two filter wheels. The first (FW1) contains inserts (pupil viewer, focus mask) referenced mechanically to the apertures in the wheel which are thus useful in determining proper centering. The second (FW2) contains only the order-separating filters, so the best technique for centering is to equalize the offsets from the nominal position which give equal vignetting of the field.

- Set up the instrument in acquisition mode as for the slit/decker calibration procedure (section 7.1.2.1). Acquisition mirror in; slit/decker in acquisition positions; short blue camera.
- Set FW1 to an open position and FW2 to a short-wavelength filter such as Order 4.
- Take an image. If the entire acquisition field is visible, move the filter wheel 50 steps and repeat. Continue until the edge of the filter blocks half of the field. Note the motor position.
- Repeat this procedure on the other side of the filter aperture. Average the two motor positions, move the filter to that location. Edit the configuration file if necessary.
- Move FW1 to the pupil viewer location. The (defocused) aperture should be centered in the slit. If not, move until it is centered and edit the configuration file. Redatum and check the pupil viewer centering.
- Alternatively, take images at each of the two focus mask locations. They should block off each half of the slit equally. If not, move the wheel until this condition is satisfied and edit the configuration file.

7.1.3 Focus Calibration

Because the detector focus is continuous, it is not really calibrated, although the motor step values which give the optimum focus for each camera should not change much. One can focus interactively for the minimum width of a sharp emission line, but since the centroid of a line can be measured more consistently than its width, we suggest using the focus masks built into the filter wheel. These two masks block off the alternating halves of the beam and act, in effect, as a two-element Hartmann mask. Spectra of a sharp emission line taken through each mask will be centered at the same wavelength if the slit is properly focused on the array.

- Set up GNIRS in spectroscopic mode pointed at the calibration unit with an emission line source selected. Go to an order separator filter (FW2) appropriate for the camera in use and set the prism to the longslit (mirror) position.
- Select the narrowest slit and the long decker
- Move the grating to the wavelength of an appropriate line and verify that the line is centered on the array.

- Move one of the focus masks (FW1) into the beam and take a spectrum. Repeat for the other focus mask.
- Measure the centroids of the line in the two images. If they are precisely the same, the slit is properly focused. In the more likely case that they are different, move the focus 50,000 steps (long camera) or 20,000 (short camera) and repeat the process. Continue this interactively until the position of the best focus can be determined. Move to that position and verify.
- Repeat this process for the other wavelength/camera combinations which are of interest.

7.1.4 Pupil Viewer Centering

The rate of pump-down depends somewhat on the set-up available. Initially, the pump should be throttled back using the vacuum valve, so that the rate is 50 T/min or less. Once the pressure reaches 100-200 T, you will probably be able to open the valve all the way. The time to reach a pressure of ~1 T should be about half an hour (depends on pump). The pressure should be well below 1 T after another half hour or so.

7.2 Software Configuration

This section discusses how to make changes to the instrument lookup tables in responses to minor configuration changes.

These are organized by configuration change:

- Filter change
- Position optimization
- Slit mask change
- Home switch change
- Grating optimization

All files discussed below are located in

{BASE}`/control/CC/pv`

You must run a `gmake` after completing editing files, and then re-boot the components controller.

7.2.1 Filter Change

If you change filters in the filter wheels, but do nothing else to the wheels, then all that needs to be changed is the entry or entries in the `fw1.lut` and/or `fw2.lut` files (for FW1 and FW2 respectively).

7.2.2 Position Optimization

This situation occurs when the nominal position for a mechanism configuration needs to be "tweaked". For filters, and filters only, the file giving positions is `gnirsFilters`. The names tabulated are generic names, which are matched to actual names in the `fw1.lut` and `fw2.lut` files. For the position you want to modify, you must know the new position in steps. Edit the appropriate entry in `gnirsFilters`, then run `gmake` and reboot the components controller.

For other mechanisms, except the grating turret, the positions are located in the `gnirsMechanisms` file. Again, edit the appropriate entry, run `gmake` and reboot the components controller. *Do not* change the name associated with the position!

7.2.3 Slit Mask Change

If you are changing the slit mask, you will probably want to re-name some of the positions since the slits are presumably different. The new names must be changed in both the `gnirsMechanisms` file *and* the `mechanisms.pv` file. Make sure the names match. As long as all you want to do is change names, no other files need to be changed. Adding positions (going from 12 to 13 or more) requires more changes; see the Software Manual if you must do this.

Since the exact positions of the new slits will doubtless be slightly different, the positions in the `gnirsMechanisms` file should be changed at the same time.

7.2.4 Home Switch Change

This section discusses the changes required if the home switch has changed in some way, perhaps due to wear or disassembly. Changing from the primary home to backup (or back) is discussed in 6.2.1. If the home switch has changed, the location of one or both of the primary and backup switches will have changed relative to all the mechanism positions. Since these are all measured from home, you need to determine the offset of the primary home relative to its old position (calibrate one or two mechanism positions, see 7.1). Then apply that offset to the positions in `gnirsMechanisms` or `gnirsFilters`, as appropriate (see 7.2.2). For the backup switch, determine the offset from the primary (use the `homeTest` procedure after changing home via the `useAlt` command, see section 6.2). Then edit the appropriate entry ("aux offset") in `gnirsConfig` for that mechanism.

7.2.5 Grating Optimization

The grating position is controlled either by specifying tilt (from zero order) or wavelength with or without specifying order. All the relevant parameters are specified in the gnirsConfig file.

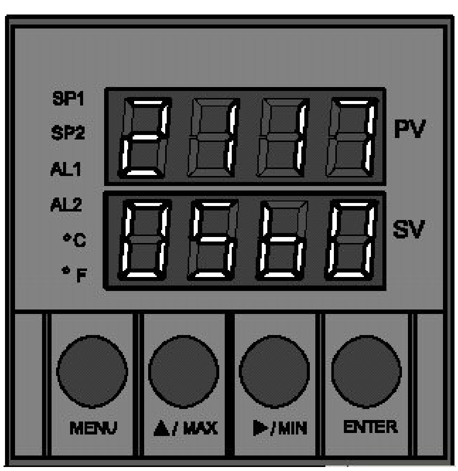
If there have been changes to the home switch, but the configuration is otherwise optimal, then the zero point values should be changed, but nothing else. The correspondence between the grating number in the `gnirsConfig` file, and the grating name can be obtained from the `gnirsMechanisms` file. The positions listed in the `gnirsMechanisms` file are *not* used for positioning the grating except as a named position, which is not very useful.

The positioning as a function of wavelength is based on a solution of the grating equation, converting steps to angle. The only parameters are therefore the grating constant and the zero point. The zero point corresponds to zero order (you can check this by setting order or wavelength equal to zero). If the turret drive was absolutely circular, all specified wavelengths would fall exactly at the same place on the detector as zero order. But because there are some eccentricities in the drive, there will be small deviations, and the values used have been tweaked to give a best fit over the useful wavelength range defined by the grating blaze. If you feel a *compelling* need to adjust this fit, you can do so by editing the grating constant and zero point values. Increasing the grating constant value will cause the turret to move more steps for a given wavelength change. You should normally decrease the zero point somewhat to compensate.

7.3 Programming the Bench and Warmup Temperature Controllers

GNIRS has two temperature control functions, the optical bench temperature is controlled to approximately 77K with a Process Controller located in crate 4, and a small stand-alone box also with a Process Controller and 4 power relays provides the instrument warm-up power. Both PC's are CN77-series (trade name "MICROMEGA") 1/16 DIN Process Controllers from Omega Engineering, Inc. The users manual for the CN77 PC's is available at: www.omega.com/ppt/pptsc.asp?ref=CN77000

The CN77's have many options that allow the user to select several input types, including 10 types of thermocouples or platinum RTD's, analog voltage or analog current. The voltage/current inputs are fully scalable to engineering units, with selectable decimal point. GNIRS uses a voltage in the range of 0 to 1V as the process variable. A 2-point calibration has been entered that scales the V_f of 1N914 diodes to Kelvins for display on the front panel as the Process Value (PV, red LED display). The Setpoint Value (SV, green LED display) is preset and is the 'target' value that the P-I-D control algorithm attempts to attain.



The CN77's have a dual LED display and 4 front panel configuration or programming buttons. They also have two control outputs (only one is used by the Warmup Controller) and a single alarm output. The bench control CN77 has analog voltage output and the RS-232 communications port option, while the warmup CN77 has an off/on relay output and the remote setpoint selection

option. The remote setpoint feature allows 1 of 3 alternative preprogrammed SV's to be selected by simple contact closure. Toggle switches on the front-panel of the Warmup Controller implement the remote setpoint selection.

The CN77 process controller is completely programmable from its 4 front-panel push buttons. The left-most MENU button is for entering the programming mode and moving through the menus. The red and green LED displays show various prompts to tell the user which function or sub-menu they are currently programming. If a menu topic has sub-menus, they are entered by pressing the right-most button, ENTER, once.
If a menu item has two or more settings, pressing MAX will toggle through them sequentially and repeatedly. Pressing ENTER selects that setting and moves the menu on to the next in line. If a menu item is a number, the left-most digit will begin flashing. Pressing MAX will toggle that digit from 0 to 9 sequentially and repeatedly. When the desired number is displayed, or if it is already correct, then pressing MIN will move the selected digit (flashing) to the next significant digit. When the number is correct, pressing ENTER selects that entry and moves the menu on to the next in line.

If you err and progress too far into a sub-menu, pressing MIN should return the programming to the last main menu topic and you can then re-enter the sub-menu.

The CN77 begins operating as soon as power is applied. There are 2 ways by which the outputs can be disabled while the CN77 is powered, (1) enter programming mode as described above, (2) place the CN77 in standby mode. Standby mode is entered by pressing the ENTER button twice, and is exited by pressing ENTER once more. While in standby mode, the letters "Stby" appear on the SV LED display.

MS-Excel spreadsheets for recording the programming of the CN77's have been provided for both temperature control functions, see Sec 6.5.

7.3.1 Bench Temperature Controller

Output 2 of the CN77 is used to control AC power to the Acopian 28VDC power supply within crate 4. Output 2 is programmed as an OFF/ON output and is turned off if the PV exceeds the value of SV2. Thus if the bench temperature is above SV2 for any reason, including a full-ON failure of the bench temperature controller, the +28V will be disabled and bench heating from this source terminated.

The proportional PID term in the Omega process controller is not a gain term, but is the magnitude of the band of the Process Value over which the PID is active. For example, our CN77 is scaled in Kelvins, so a Prop Band value of 01.00 means the proportional band is 1K. If the SV is 62.00, then the Prop Band is from 61.00 to 62.00. Below 61K the PC output is full scale and maximum heating is applied to the bench; above 62K the PC output is zero and minimum heating is applied. Within the Prop Band the PID is actively controlling the bench temperature. If a non-zero I term (called Reset by Omega) is used then the Prop Band is still 1K but it's shifted by the PC from the 61-62 range so as to cause the PV to match the SV with less error.

Using the wrong P-I-D terms can result in unsatisfactory performance or even oscillation. The best recipe for PID selection for the Omega PC's is found at: www.omega.com/manuals/index.html?s=c and selecting the manual for the CN2116 (an obsolete product).

By pressing combinations of MENU-ENTER-MENU one can move through all the CN77 menu items in sequence. Several specific settings the user may want to verify or change are described below.

1) New Setpoint Values. The SV1 for output 1 is the first main menu item and the SV2 for output 2 is the second. Press MENU once for SV1, then change the digits with the MAX and MIN buttons. Press ENTER when the new SV is displayed. And to get to SV2, just press MENU twice and then ENTER as before.
2) New values for the Alarm limits. Settings for the Alarm 1 function are the 6^{th} main menu selection. After entering ALARM 1, the low value is the 7^{th} sub-menu item and the high value is set at the 8^{th} sub-menu item.
3) New P-I-D values. The PID constants are set in the Output 1 main menu item, 9^{th} in order. Enter the sub-menu and skip past the first eight items. The proportional band item is the 9^{th} sub-menu item, the PV display will be "ProP" and the SV display will be "bAnd". Enter and change the value if necessary. The integral term (the units are seconds of time) is next. The PV display will be "rESt" and the SV display will be "StuP". Enter and change the value if necessary. Similarly the differential term is next, the PV display will be "rAtE" and the SV display will be"StuP". We've never found the D-term to be useful and it should be left at 000.0.

7.3.2 Dewar Warmup Controller

By pressing combinations of MENU-ENTER-MENU one can move through all the CN77 menu items in sequence. Several specific settings the user may want to verify or change are described below.

1) New Setpoint Value. The SV for output 1 is the first main menu item. Press MENU once, then change the digits with the MAX and MIN buttons. Press ENTER when the new SV is displayed.
2) New values for the Alarm limits. Settings for the Alarm function are the 6^{th} main menu selection. After entering ALARM 1, the low value is the 7^{th} sub-menu item and the high value is set at the 8^{th} sub-menu item.

3) RAMP time. The RAMP and SOAK functions are the 11th main menu item. When at this item the PV display will show “rAMP” and the SV display will show “SoAc”. Enter the sub-menu and go to the “rAMP” item; enter the new ramp time in the HH:MM format. Be sure to leave the ramp function in the enabled, “EnbL”, mode.
4) New alternative setpoint variables. The remote setpoint programming is the last main menu item. When at this item the PV display will show “r.SEt” and the SV display will show “Pont”. Enter the sub-menu and go to the first remote setpoint entry, the SV display will be “rSP1”. Entry for the 2nd and 3rd remote setpoint values follow.

7.3.3 Temperature Sensor Locations

See drawings 89-NOAO-4201-0811 through 0816 for the locations of the 1N914 temp-sensing diodes on the optical bench and on the mechanisms.

7.3.4 Temperature Diode Calibration

The temperature diodes used for sensing the science detector and OIWFS detector are Lakeshore DT-470s, which come with a calibration curve. The OIWFS detector temperature is controlled by an Omega CYC3211, which was included in the OIWFS deliverables and is beyond the scope of this manual.

The other temperature sensors in GNIRS are 1N914 diodes. A generic voltage-temperature curve derived from laboratory testing of several 1N914 diodes against calibrated Lakeshore diodes is used as the calibration. Individual diodes are further calibrated by applying an offset to the generic relation. For selected critical temperature sensors, this offset was determined by dipping the sensor in LN_2 and adjusting the relation to read the local temperature of LN_2 (76.7 K). This temperature is close to that of the bench when the instrument is cold. The other less critical sensors were calibrated using the mean LN_2 offset, except for the shell and passive shield diodes, which were calibrated to room temperature. Use of an average LN_2 offset was found to give less scatter than use of room temperature offsets.

7.4 Flexure Compensator Adjustment

This section describes the theory behind the flexure compensation mechanism, and the procedures for making adjustments. Note that excess flexure may well be a symptom of an underlying problem, in which case the correct approach is to identify and solve the problem, not try and correct for it.

7.4.1 Coordinate Systems

The instrument coordinates used for most procedures in this manual are described in section 8.2.2. However, a more rigorous set of coordinates was used in developing the instrument solid models, including flexure modeling. This is a standard Cartesian coordinate system, with its origin at the intersection of the ISS mounting surface and the telescope optical axis. The Z axis runs parallel to the optical axis, with Z increasing to the rear of the instrument. The X axis is horizontal when the instrument is side-looking, and increases to the starboard side (see Figures. 3.5, & 3.6). The Y axis is vertical when in the same orientation, increasing upward.

Although the detector is more or less in the YZ plane (there is a tilt of a few degrees about the Y axis), it is more convenient to consider displacements in the coordinates defined by the detector readout. The images are stored in a format where X, column number, corresponds to displacement along the slit (perpendicular to dispersion), which corresponds to the instrument Y axis. Detector Y, in the dispersion direction, corresponds approximately to the instrument Z axis (neglecting the tilt mentioned above). The focus direction corresponds approximately to instrument X, but focus flexure is very small and well within tolerance; it is not considered further here.

If flexure within the instrument is entirely due to elastic deformations, the motion of an image of a point on the slit will be displaced on the detector as a function of gravity vector by an amount which, for each coordinate on the detector, is simply the dot product of a flexure vector and the gravity vector:

$$\Delta_x = \mathbf{F_x} \bullet \mathbf{g}$$

$$\Delta_y = \mathbf{F_y} \bullet \mathbf{g}$$

The components of the **F** vectors are simply the flexure as a function of gravity in that particular cardinal direction.

7.4.2 Flexure Measurement

Flexure is most easily measured using the flexure rig while imaging the slit onto the detector. Since the long camera configurations show the most sensitivity, one should use one of these (probably blue long camera). The choice of grating and prism should have only a modest effect. Ideally, the slit mask with a series of pinholes should be used to get accurate flexure in both directions.

An arc lamp should be used to provide a series of line images.

The centroids of the lines as a function of instrument orientation will provide displacements, which can be determined relative to a particular orientation or to the average position. These displacements can be used together with the orientation of the

flex rig to determine the components of the **F** vectors. The flexure as a function of rotation about an axis of the flexure rig should fit a function of the form

$$\Delta = A \cos(\theta) + B \sin(\theta)$$

where A will be the dependence for gravity in the direction θ=0 and B will be the dependence in the orthogonal direction. One obviously needs to perform the imaging sequence for more than one rotational configuration, in order to get all three components for each direction on the detector. A global fit should be used to verify that the different measurements are consistent. It is also a good idea to repeat some measurements, including reversing the direction of rotation, in order to identify any hysteresis or other inelastic effects. Any fit to the data should attempt to average these out, since the compensator cannot correct for them.

7.4.3 Flexure Correction

Assume that the flexure coefficients described above have been determined, and assume as well that they are different enough from zero to warrant correction. (This, hopefully, may never be the case.) What is now necessary is to adjust weights on the compensator mechanisms, which produces small tilts in the instrument collimator as a function of gravity.

The collimator is mounted on three flexures. One of these provides a fixed pivot point, while the other two can be deformed in the Z axis. If both flexures deform by the same amount, the collimator is tilted about the Y axis, while if the flexures deform by equal and opposite amounts, the tilt is about the X axis. The deformation is accomplished by three sets of adjustable weights mounted on flex pivots above each flexure; each set of weights is sensitive to gravity in a particular cardinal direction. One adjusts the pair of weights for that particular gravity component for each direction on the detector.

Figure 7.4.3.1 Collimator Compensator Assembly

As an example, for flexure as a function of gravity in X in the dispersion direction on the detector, one would adjust the X weights on both flexures by the same amount; for flexure along the slit, the adjustments would be opposite. (Since there would probably be flexure in both directions on the detector, one would add the two adjustments before carrying them out.)

The table below gives the adjustments required to correct for flexure of 10 microns in response to 1 gravity. Note that this is the correction required to move the image in a specified direction; hence any correction is in a direction *opposite* to the observed flexure.

Table 7.4.1 – Compensator Adjustment Values

		10 microns in Detector's Y (parallel to slit)			**10 microns in Detector's Z (lateral to slit)**		
	Counter Weight	Sense of weight motion w.r.t. pivot	Magnitude of weight motion (inch)	Equivalent no. of turns	Sense of weight motion w.r.t. pivot	Magnitude of weight motion (inch)	Equivalent no. of turns
1.0 Grav X	**AX pri**	in	0.175	4.2	out	0.322	7.7
	BX pri	out	0.175	4.2	out	0.322	7.7
	AX sec	out	0.296	7.1	in	0.546	13.1
	BX sec	in	0.296	7.1	in	0.546	13.1
1.0 Grav Y	**AY pri**	in	0.175	4.2	out	0.322	7.7
	BY pri	in	0.175	4.2	in	0.322	7.7
	AY sec	out	0.296	7.1	in	0.546	13.1
	BY sec	out	0.296	7.1	out	0.546	13.1
1.0 Grav Z	**AZ**	in	0.0474	0.95	out	0.0874	1.75
	BZ	out	0.0474	0.95	out	0.0874	1.75

The X and Y adjustments should be made with *either* the primary or secondary weight in each group, but not both; it is OK to move the primary weight on one group and the secondary weight on the other (by the respective tabulated amounts). If the primary weight has been replaced by another secondary weight, that secondary weight should be adjusted in the same direction as indicated for the primary weight, but by the amount indicated for the secondary weight.

7.4.4. Correction Procedure

To access the flexure compensator, perform the following steps:

- The instrument must be warm and at ambient pressure (4.2.5,4.2.6)
- Remove the rear truss (8.3.4), if present.
- Remove the thermal enclosures and thermal enclosure trusses (8.3.2).
- Remove the rear dewar shell and molecular sieve (8.4.2). You can bake the molecular sieve while adjusting the collimator (5.1.3). Flow dry nitrogen into the dewar backfill port (4.2.6) so as to protect the detector.
- Remove the aft bulkhead (8.4.3).
- Remove the aft active shield (8.4.4)
- Remove the cover for the collimator assembly (see 8.5.2). The cover unscrews from the assembly; do not remove the assembly from the bench.
- Identify the individual weights to be adjusted (see Fig 7.4.1). Make the adjustments as calculated from the observed flexure and Table 7.4.1. In general, the simplest procedure is to count turns of the weights rather than trying to measure displacements along the compensator arms. Note that screws on the weights must be loosened to carry this out. In same cases, an alternate screw position must be used after the weight is adjusted, since the head of the original screw will not be accessible. To minimize resonant behavior, the Z compensation weights are not secured to the threaded shafts, but are safety wired to each other. If adjustment of either Z weight is necessary, undo the safety wire, move the weight(s) as required, and resecure with the safety wire.
- Replace the collimator cover.
- Replace the aft active shield (8.4.4) and aft bulkhead (8.4.3).
- Replace the molecular sieve and aft dewar shell (8.4.2).
- Start evacuating the dewar (4.2.2).
- Install the thermal enclosure trusses, thermal enclosures (8.3.2) and the rear dewar truss (8.3.4) if required.