THE ISAAC NEWTON GROUP OF TELESCOPES

WILLIAM HERSCHEL TELESCOPE

PFIP

A REPORT ON WORK CARRIED OUT ON THE WHT PRIME FOCUS INSTRUMENT PLATFORM

and

A NEW CALIBRATION PROCEDURE FOR THE PFIP AUTOGUIDER X-Y PROBE

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Introduction

During the last WHT prime focus run and occasionally on previous runs, there have been numerous problems with the PFIP autoguider's inability to find guide stars. This has resulted in lost observing time with many engineers spending time trying to solve the problem. When PFIP is mounted on the WHT prime focus, it is also very difficult to gain access to the autoguider probe X-Y slide mechanisms.

With this in mind, it was decided after the last observing run to bring PFIP down to the SLO electronics workshop so that these problems could be analysed in 'slow time' and the autoguider re-calibrated to bring it back to specification.

History

In retrospect, this instrument has never worked 100% satisfactory since it was delivered from RGO Cambridge: *circa* 1994. The problem being that the specification of autoguider positioning repeatable to 10 microns was never reliably met. Howard Stevenson and Paul Martin who were the primary design engineers on the project had considerable problems in achieving stability with the Penny Giles linear encoders that were selected for PFIP.

These problems in encoder value changes are mainly due to temperature fluctuations and possibly also due to noise pickup in the long signal cables that carry data back to the Encoder Processor modules in the 4MS crate mounted on the top end ring. Howard spent a long time trying to solve this and after getting in contact with the encoder manufacturer, it was suggested that a filter circuit be fitted to reduce and cleanup the encoder signals. This was installed; the noise reduced considerably, but he never managed to totally eliminate the problem.

It was the general consensus after PFIP was commissioned that the linear encoders employed were a bad choice, but the project had progressed too far for these to be changed.

The bottom line being that unless a lot of effort and money is spent in re-designing the autoguider encoding system, we have to make the best of what we have.

Known problems

From day one, an annoying feature when using PFIP is the ICL sending error messages occasionally saying that a "Mechanism has unexpectedly moved", when in fact it hasn't!

This problem is due to flags being set by the PFIP FORTH software when an encoder value changes over a period of time due to the problems mentioned above.

In fact, the "*WHT Prime Focus Duty Tech Document*" even states that some of the flags can be set due to encoder temperature changes.

After an autoguider move, the ICL mimic will show a green status, but after an in-determinate time, the autoguider X, Y or focus encoder values will change to red and the "Mechanism unexpectedly moved" message displayed. On checking the engineering mimic, the Mechanism Error status will have changed from a '0' to a 'B'. This signifies a problem with the encoder EM-2 module, but in reality, no problem exists. In time, if no change in position is demanded, all three autoguider values will have changed to red status! A noise glitch has probably caused this bit to have been set.

These error messages have never indicated that a REAL un-expected movement has occurred. For this to happen, the mechanism's brake would first need to be released and a motor activated. This operation would be heard over the control room PFIP sound monitors.

Although annoying to the observer, it can be disregarded. It should be possible to change the ICL software to ignore these flags so preventing endless lines of meaningless messages.

It should also be noted that these messages only refer to mechanisms using the Penny Giles encoders. These being: autoguider X; autoguider Y and autoguider focus mechanisms. Other PFIP mechanisms such as the main filter wheel and the Atmospheric Dispersion Corrector; which use a different encoding system, don't suffer with this problem.

Autoguider requirements

As stated earlier, the biggest problem with PFIP is that the autoguider has problems in finding guide stars. Guide stars are located (as is the case with all ING telescopes and foci using offset autoguiders) by using X/Y autoguider probe coordinates supplied by the Guide Star Server (GSS).

The GSS requires:

- The telescope and focal station in use
- The sky PA position (rotator angle)
- The R.A. and DEC positions of the target

The GSS will then generate a list of suitable guide stars with X and Y coordinates (in microns) relevant to the focal station selected. The criteria being that the mechanical range (and linearity) of autoguider probe movement needs to be accurate for the guide star to be located.

This is particularly important with PFIP as the autoguider uses a coherent fibre optic bundle with imaging optics producing a capture area of just 25 square arc seconds. A small error in the positioning of the X/Y slide will fail to put a guide star on to the coherent fibre optic bundle.

Initial findings

The work carried out in the SLO has been as follows:

- To measure distance travelled over the autoguider’s X and Y motion extremities
- To check the linearity across the range in X and Y motion
- To check and measure the repeatability of probe positioning
- Attempt to adjust the reference datum sensors to eliminate error messages

To perform accurate measurements, a MITUTOYO digital Vernier Gauge (serial number 7036613) was borrowed from the mechanical workshop. This can read down to an accuracy of 10 microns (0.01mm)

The scale size of the WHT prime focus (with corrector lens) is: 17.55 arcsec/mm
The autoguider FOV is: 25arcsec square, thus: 25/17.55 gives a value of 1.424 mm

Using the value above, an autoguider X or Y position error of < +/- 712 microns (*i.e.* 1.424/2) will not position the guide star within the fibre bundle.

On checking slide movement in the X axis, it was found that a movement of 110,000 microns (the maximum distance of travel) <u>the measured distance was 114,120 microns</u>. This is a LARGE error and certainly would explain the inability to find guide stars.

Moving the Y axis slide between 0 and 20,000 microns, the measured distance was 2,086 microns which is well within the required accuracy needed.

Adjustments

The output from each encoder goes to a Penny Giles EM-2 processor module located in the 4MS crate. There are two preset potentiometers, ZERO and GAIN on the front panel which set the encoder zero point and span (range). However…

The problem we found is that the encoder calibration instructions as stated in the “WHT Prime Focus Duty Tech Document” for re-calibration of the encoders cannot be followed literally?

The procedure relies on a FORTH word “WHERE” during the calibration set-up to read the number of steps actually moved and this command doesn’t exist! Perhaps this command was available in an earlier version of the PFIP software or during development at RGO, but its certainly not recognised now; neither in the compiled EPROM code or on the FORTH source code discs.

The manual states that it is much easier to change values in the source code and re-program new EPROMS than attempting to physically adjust the mechanisms to the values stored in the ROMMECH table. However, due to the problem stated above, we had no other option but to start from first principles and adjust the electronics/mechanisms manually to achieve the best results.

The instructions in the manual for adjusting the ZERO point of reference can be followed. That is to move each mechanism to its mechanical limit and adjust the ZERO preset pot on the EM-2 modules to the value "Offsetenc" stored in the ROMMECH table for each mechanism.

As the mechanisms have never been removed and the default values unchanged in the firmware, it should be possible to restore the original zero reference positions. These values are the DIRECT encoder readings:

- Offsetenc = **1357** (autoguider X slide - **APX**)
- Offsetenc = **5478** (autoguider Y slide - **APY**)
- Offsetenc = **20553** (autoguider focus - **AFS**)

In the case of the X and Y slides, this involved putting PFIP into "Transparent Mode" to release the brake and move the mechanism by hand until the mechanical limit was reached. It should be noted that the LOWER limit switch is activated doing this operation. There is no mention of this given in the manual.

n.b. As the AFS mechanism doesn't have a brake (and is less critical in positioning), the mechanical end-stop can be acquired by simply turning the lead screw by hand until the slide stops moving. The procedure was done as follows; (X and Y slides) :

To enable Transparent Mode and release the brake on the motor, the keyboard sequence is :

T (select Transparent Mode)
1 (enable Transparent Mode= ON)
0 (select PFIP)
Y (YES to continue)

Transparent mode is now selected. *n.b.* All transparent commands must be preceded with a period '**.**'

APX zero point calibration

SMCM(0,1) select channel 2
SMCM(0,21) select multiplexer 4 (APX)
SMCM(0,14) release brake

1. Move the mechanism by hand until it reaches its mechanical LOWER limit and note the DIRECT encoder reading from the VT200 dynamic Help display.

2. Adjust the ZERO pot on the APX encoder EM-2 module to obtain the value - **1357**

In practice this is very difficult to achieve as the values change occasionally due to encoder instability. Just get the value as close as possible.

3. Move the mechanism by hand back past the LOWER limit so the switch is NOT activated.

4. Reset the LIMPIT (and brake) with: SMCM(0,64)

5. Return back to normal engineering mode by typing: T followed by: 0

APY zero point calibration

The procedure for calibrating APY is the same as above except after entering transparent mode, the command sequence for releasing the brake is :

SMCM(0,1)	select channel 2
SMCM(0,19)	select multiplexer 2 (APY)
SMCM(0,14)	release brake

1. Move the mechanism by hand until it reaches it mechanical LOWER limit and note the DIRECT encoder reading from the VT200 dynamic Help display.

   Note. *It is VERY difficult to do this as the coupling between the motor and lead screw is buried deep within the mechanism. I found it just possible to insert two fingers (one from the top; the other from the side before I could move the lead screw. It was necessary also to move the AFS slide to give more 'finger' space!*

2. Adjust the ZERO pot on the APY encoder EM-2 module to obtain a value as close as possible to **- 5478**

3. Move the mechanism by hand back past the LOWER limit so the switch is NOT activated.

4. Reset the LIMPIT (and brake) with: SMCM(0,64)

5. Return back to normal engineering mode by typing: T followed by: 0

AFS zero point calibration

The can be adjusted in normal engineering mode as follows:

1. Move the mechanism by hand until it reaches its mechanical LOWER limit and note the DIRECT encoder reading from the VT200 dynamic Help display.

2. Adjust the ZERO pot on the AFS encoder EM-2 module to obtain a value as close as possible to - **20553**

3. Move the mechanism by hand back past the LOWER limit so the switch is NOT activated.

Setting the range (span) of the encoders

Having established a zero reference point for each mechanism, the aim now is to adjust the encoder GAIN so that its range between minimum and maximum values equates to a known value. The specification for PFIP is:

- **APX** 0 to 110,000 microns
- **APY** 0 to 20,000 microns
- **AFS** 0 to 14,100 microns

As mentioned earlier, with APX moving between 0 to 111,000 microns, the travel measured was 114,120. To correct for this, the GAIN preset potentiometer on the APX EM-2 module was adjusted in increments to remove this error.

The same adjustments were made to APY and AFS. Although these mechanisms were reasonably accurate in range measurements, there were some errors found with respect to the zero point reference values.

As the ZERO and GAIN preset controls are somewhat interactive, measurements were re-made to check that the Offsetenc value was close to the values stored in the firmware. Small adjustments were needed to the ZERO preset controls whilst setting the GAIN.

One of the biggest problems found was finding surfaces where repeatable measurements could be made. In the case of the APY and AFS mechanisms, the digital Vernier gauge was placed in such a way that it could read squarely off a moving and fixed surface of the encoder barrel itself. To measure the Y encoder, it is necessary to remove the side panel else the Vernier cannot be positioned correctly. In the case of APX, measurements were taken between a machined part of the enclosure and the focus motor flange. The repeatable accuracy obtained was ~ +/- 50 microns.

Datum reference sensors

All mechanisms are fitted with a reference sensor (proximity switch) which serve as fiducial markers to allow the mechanism to be set to a known value and thus give confidence that encoder calibration is correct. These values (which were changed in Charles Benneker's 1997 firmware upgrade - V1.07) are also stored in the ROMMECH table. These being:

- APX = **55870**
- APY = **8280**
- AFS = **10580**

To drive a mechanism to a datum switch, the '102' command is used *e.g.*

APX102 will move the X slide until the datum switch is found.

The mechanism moves until the UPPER limit switch is activated then moves back until the proximity sensor is detected. On detection, it steps out a small amount then moves back at a very slow speed until the sensor is triggered.

In practice, to set up these proximity switches is **VERY DIFFICULT**. One can easily appreciate why the PFIP manual states that the best option is to record the values and change them in the firmware. An indiscernible move of the sensor will alter the returned value by orders of +/- 100's of microns.

Sometime ago, C. Benneker opened up the size of this window in the FORTH code and generated a new set of EPROMS for the 4MS (version 1.07), but in practice this hasn't made any difference.

It is just the case of making small adjustments by moving the switches (which are located in slotted holes) until the values returned are as close as possible to those stated above. When a '**0**' is returned in the Mechanism Error field, the returned value is very close to the reference value stored in the ROMMECH table. Other mechanism error flags returned can be:

20 (datum position warning)
D (encoder calibration at datum exceeds limit)

The **20** flag indicates a small datum error ~ +/- 100 microns. The **D** flag is set if the datum value returned exceeds a limit value set in the firmware.

Although I have adjusted the switches NOT to produce a Mechanism error = **0**, due to general encoder instability and temperature changes, the **20** flag will be more than often set. The results below give some idea how these values 'wander' over time.

This is just something we will have to live with.

Results

The tables below show how the Offsetenc and Datum values change after PFIP is powered on and how they change during the course of the day. The reference values (in **bold** type) were set up the previous day (19/3/2002) by adjusting the ZERO pot for the Offsetenc value and moving the proximity switches manually to achieve a Datum mechanism Error = **0**

A small change of the datum value (**20** flag set) is not so important, but a large change in Offsetenc could effect guide star acquisition if it wanders too far away from the ROMMECH table values.

It should be noted that the temperature change in the SLO during the day varied from 25 to 31^{o} C. In practice, PFIP will be working at a much lower temperature, so its important to re-check the calibration values when the instrument is back on site.

Changes in ZERO (Offsetenc) values over time				
Date 20/3/2002	10:00hrs switched on	12:00hrs	14:00hrs	16:00hrs
APX Offsetenc Set to **1357**	1412	1334	1320	1355
APY Offsetenc Set to **5478**	5518	5472	5486	5491
AFS Offsetenc Set to **20553**	20441	20561	20553	20545

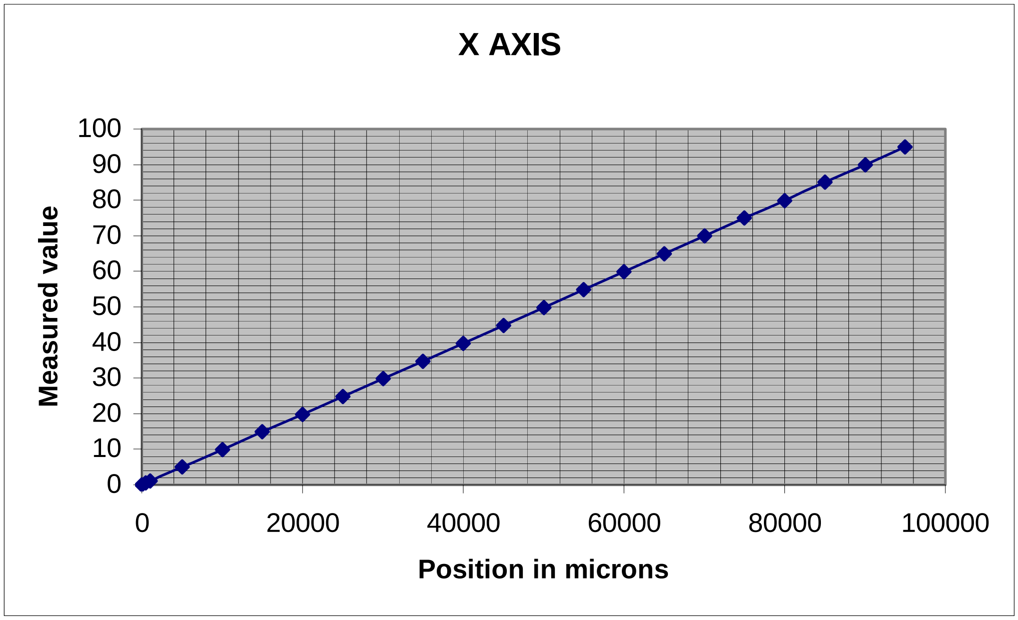
Changes in Datum values over time				
Date 20/3/2002	10:00hrs switched on	12:00hrs	14:00hrs	16:00hrs
APX datum Set to **55870**	56170 (20)	55800 (20)	55830 (0)	55950 (0)
APY datum Set to **8280**	8200 (20)	8150 (20)	8230 (0)	8210 (20)
AFS datum Set to **10580**	10250 (20)	10490 (20)	10500 (20)	10490 (20)

X axis calibration

(SLO 22/3/02)

X AXIS CALIBRATION

		References	**datum**	**55870**	**Offset**	**1357**
Position	Measured	Pre-check	datum	55890 (0)	Offset	1363
0	0					
500	0.52					
1000	1.09					
5000	4.97					
10000	9.92					
15000	14.89					
20000	19.82					
25000	24.81					
30000	29.81					
35000	34.76					
40000	39.8					
45000	44.82					
50000	49.82					
55000	54.84					
60000	59.84					
65000	64.84					
70000	69.89					
75000	74.97					
80000	79.94					
85000	85					
90000	90.01					
95000	95.04	Post-check	datum	55900 (0)	Offset	1363
100000	100.02					
105000	105.05					
110000	110.02					



Notes
These values show a small drop-off around 35,000 microns, but improving again towards the maximum travel of the encoder. However, in practice this should not present a problem. The error at 35,000 being ~ 240 microns. * Why this is the case is unknown. However, multiple readings taken between 0 – 110,000 microns always averaged out around +/- 30 microns.

Measurements were taken between the Focus motor flange and the machined case.

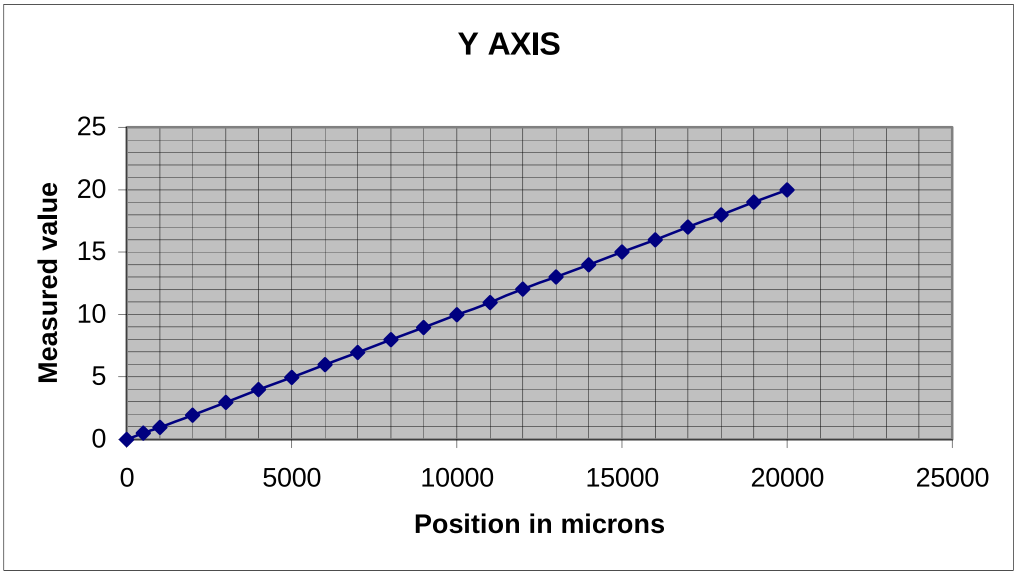
n.b. This encoder was later changed on site when it failed completely so the data above is no longer valid. I have kept the data above purely for historical reasons. See page 15 for the new encoder data.

Y axis calibration

(SLO 22/3/02)

Y AXIS CALIBRATION

		References	**datum**	**8280**	**Offset**	**5478**
Position	Measured	Pre-check	datum	8240 (0)	Offset	5497
0	0.01					
500	0.49					
1000	0.97					
2000	1.97					
3000	2.99					
4000	3.99					
5000	4.98					
6000	5.99					
7000	6.98					
8000	7.99					
9000	8.98					
10000	9.98					
11000	10.98					
12000	12.02					
13000	12.99					
14000	13.98					
15000	15.01					
16000	15.98					
17000	17					
18000	17.98					
19000	18.99					
20000	19.99	Post-check	datum	8230 (0)	Offset	5491



Notes

These values are very close to the demanded positions. The measured values returned were within +/- 20 microns.

The Vernier was able to read directly from the encoder body and plunger which was not possible to do with the X axis.

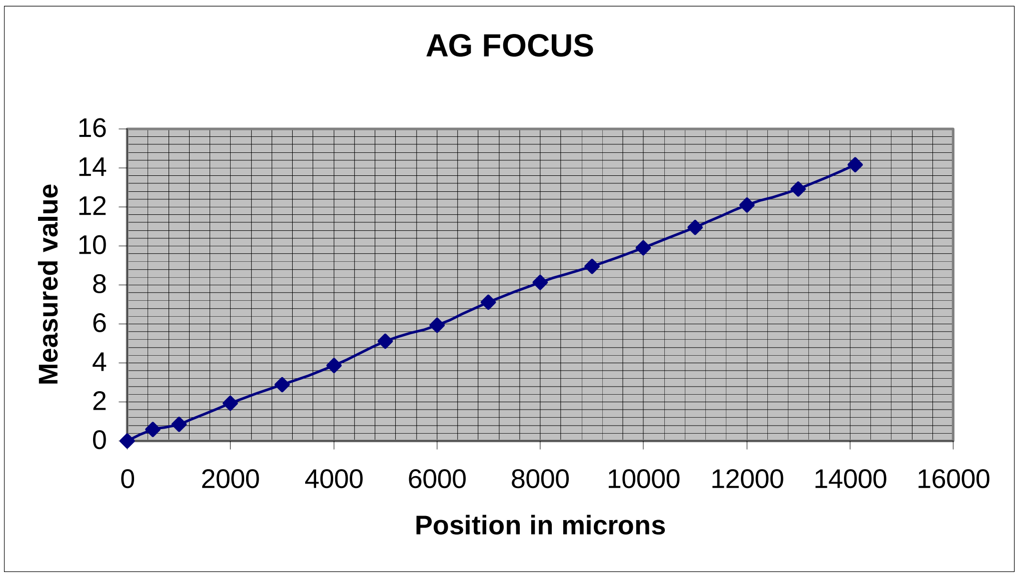
Autoguider Focus calibration

(SLO 22/3/02)

AG FOCUS CALIBRATION

References	**datum**	**10580**	**Offset**	**20553**
Pre-check	datum	10470 (20)	Offset	20553

Position	Measured
0	0
500	0.58
1000	0.85
2000	1.92
3000	2.87
4000	3.86
5000	5.12
6000	5.94
7000	7.13
8000	8.14
9000	8.95
10000	9.91
11000	10.95
12000	12.09
13000	12.92
14100	14.15



Post-check	datum	10500 (20)	Offset	20560
	re- adjusted	10560 (0)		

Notes

These values are not as close as I would have liked, but they all average within +/- 150 microns.

The Vernier was able to read directly from the encoder body in this case.

Tests on site

Wednesday 27th March

PFIP was set up in the aluminising area to recheck that the calibration had not changed and to see if working in a lower temperature would have any detrimental effects. *n.b.* * signifies that either the Offset value was re-adjusted or the datum sensor moved.

An hour after powering on, the values were:

Mechanism references	**Offset**	**Datum**
APX O=1357 D=55870	1418 * 1354 after 1hr	55680 (20)
APY O=5478 D=8280	5432	**5475 (D)**
AFS O=20553 D=10580	20564	10560 (0)

Mechanical Work needed

The large change in the APY datum value was later found to be caused by the steel target that the proximity sensor detects having slipped. In fact, this caused damage and broke the bracket that holds the X datum sensor. It should be noted that the steel target is used by BOTH the X and Y datum sensors.

It was necessary to drill and tap the Y slide to fit a second screw for the steel target and to remake a new bracket for the X datum sensor. As the Y sensor was very difficult to adjust, a new mounting plate with a slotted hole was also made; the plate now being moved to achieve sensor alignment and NOT the switch itself.

Friday 29th March

Mechanism references	**Offset**	**Datum**
APX O=1357 D=55870	1375	55840 (0) *
APY O=5478 D=8280	5469	8230 (0) *
AFS O=20553 D=10580	20555	10540 (0)

More checks done and the X and Y datums adjusted so as not to give a mechanism error. PFIP was switched off over the weekend

Tuesday 2nd April

Mechanism references	**Offset**	**Datum**
APX O=1357 D=55870	1375 *1357	55680 (20) *55840 (0)
APY O=5478 D=8280	5481	8130 (20) *8260 (0)
AFS O=20553 D=10580	20563	10530 (0)

It can be seen from the preceding table just how unstable the encoder values are over time and the re-adjustments made to return : Mechanism error = **0**

Thursday 4th April

With PFIP going on the WHT the next day, final measurements were taken of the distance travelled by the autoguider X, Y slides and focus. After the remedial work was carried out in the SLO (and on site up to this time), all three mechanisms were within specification and measurements taken corresponded well to the calibration graphs shown within this document.

However, on measuring the distance covered by the X slide, I found this had changed considerably, with the **mechanism moving 108,000 microns when the maximum value of 110,000 microns was demanded**. I also found that the ZERO offset had changed to a very high value and it was impossible to adjust this below 32,000 units…

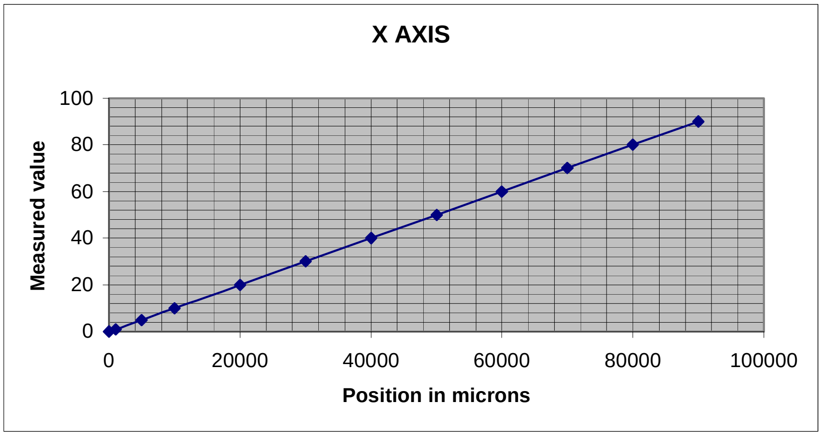
I changed the APX EM-2 module, but this made no difference. I came to the conclusion that the Penny Giles encoder had failed and needed to be replaced. Worked started on removing this immediately and when released from it's mounts, was found to be far from smooth and 'lumpy' in operation. Once the replacement encoder was cabled in, I checked that I could adjust the EM-2 module to the required ZERO value and that the encoder read correctly over its range. All was working correctly again.

After re-fitting the new encoder, I then had to go through the entire procedure of adjusting the ZERO and GAIN presets and re-aligning the datum. The results of the encoder change are shown in the graph below.

X AXIS CALIBRATION (after encoder replacement)

References Datum **55870** Offset **1357**

Position	Measured
0	0
1000	0.92
5000	4.95
10000	9.96
20000	19.93
30000	30.02
40000	40.08
50000	49.99
60000	60.06
70000	70.11
80000	80.12
90000	90.1
100000	100.07
105000	105.05
110000	110.08



Post check Datum 55830 (0) Offset 1365

Final checks

Friday 5th April

The table below shows the datum values and mechanism error status just before PFIP was taken from the aluminising area to be fitted at 11:00 hrs.

Datum values (T = 16^o C)	
Datum	Actual value & mechanism status
APX (55870)	55820 (0)
APY (8280)	8370 (20)
AFS (10580)	10600 (0)

The table below shows how the datum values have changed after PFIP was fitted. At this time, the temperature difference between the aluminising area and dome was only 2^o C . The small changes in datum values are probably due to flexure within PFIP, but I would have expected with the telescope at zenith, the datum values would have been closer to those in the table above.

Datum values with respect to position of telescope tube (T = 14^o C)			
Datum	AP3	45^o	Zenith
APX (55870)	56330 (20)	56240 (20)	56240 (20)
APY (8280)	8610 (20)	8590 (20)	8610 (20)
AFS (10580)	10410 (20)	10480 (20)	10460 (20)

The table below shows well the effect of a small change of encoders value due to a gradual drop in temperature after the dome has been opened. This is to be expected.

Datum values with respect to temperature over time			
Datum	21:00 hrs T = 13^o C	22:00 hrs T = 12^o C	24:00 hrs T = 10^o C
APX (55870)	56200 (20)	56220 (20)	56250 (20)
APY (8280)	8600 (20)	8610 (20)	8630 (20)
AFS (10580)	10460 (20)	10440 (20)	10430 (20)

n.b. The temperature measurements were taken using the 5- HUM engineering command and read from the PFIP help display. A temperature sensor is mounted in the PFIP enclosure.

Appendix

1. The ability to find guide stars

n.b. . Most of the text below was taken from Juerg Rey's comments via email the following day. When these problems have been solved and correction offsets added to the GSS, these notes will no longer apply.

On the first attempt we couldn't find guide stars. One of the problems being the GSS's inability to handle aperture offsets. As the prime focus camera now uses the 2EEV CCD mosaic, it is important that this problem is addressed.

Without aperture offsets applied *i.e.* The target object effectively falling at the centre of the gap between the 2 chip array, an offset of +3000 microns in X had to be applied for a rotator position of ROT SKY 0.

On other rotator positions, the offset needed was slightly different by up to 1000 microns. Some offset in Y was needed too. However the pointing was probably off by a few arc-seconds as the sigma we got at the beginning of the night was in the order of 5 arc-second!

Without apertures (object coordinates correspond to centre of the gap between the chips), <u>we acquired guide stars accurately.</u>

So, here is the current recipe to find a guide star:

1. Which chip? Set aperture 0 is needed
2. Move to the source
3. Run GSS, don't use the aperture command here
4. Add +3000 to X
5. With CCD1 add 14300 to X, with CCD2 subtract 14300 from X
6. (14300 microns correspond to roughly 250", the chip apertures)
7. Send the AG probe to guide star: PGDXY xxxxx yyyyy
8. If there isn't a guide star on the autoguider fibre (~25" or 1400 microns in each direction), do a spiral search using increments of 15"
9. Once the guide star is found, go back in steps such you can see the movements and undo the handset offset just applied moving PGDXY at the same time
10. Note down the applied offsets as this will help you to find the next guide star

The autoguider focus needs to be set to maximum, this is 14000. Unfortunately the image is still a bit out of focus. John will address this problem. For the moment we have to work with 14000.

2. Autoguider Focus (AFS)

As was mentioned above, the AG focus was best at 14,000 microns and could have been even sharper if more movement was available on the mechanism. In previously runs, the best focus found was about 11,000 – 12,000 microns.

I've since heard that work had been done by the mechanical group on the prime focus rotator which has marginally shifted the WHT focus when working at prime? This shift in focus was also present when AF2 was last used. As the AG focus mechanism cannot be easily modified, either the autoguider head needs to be re-positioned or the fibre bundle mounting plate. The autoguider head fits into a 'dove tail' plate and is clamped with a single bolt. This ensures that if heads are replaced they can always be returned to the same position. So, I would recommend the second approach?

From what I recall, when PFIP was designed an error was made in that the focus was intended to be adjusted at the head and not the probe end of the fibre. Part of this earlier mechanism is still in place. It should be possible to move the fibre at the 'head end' to find the best focus. My idea being that if AFS is positioned at mid-range (~7000 microns), the fibre holder can be moved either backwards or forwards to achieve the best *course* focus. AFS will then have adequate +/- movement to find the best *fine* focus.

As this can only be performed on the sky (and the was weather bad for most of the PFIP run), it will have to be done the next time the instrument is used.

3. Recommendations

The problem regarding "Mechanism un-expectedly moved" messages on the ICL after a period of time <u>has NOT been resolved.</u>

As these 'B' flags in reality do not reflect a change in autoguider position or an EM-2 module problem, I recommend that the ICL software be changed to ignore this flag. The same applies to a '20' flag being set after a mechanism initialisation as this represents an error in the order of only ~ +/- 100 microns which makes very little difference.

I would recommend that the 'D' flag is still checked after a mechanism initialisation. If this flag is set, it shows a considerable error in X or Y alignment which may require probe re-calibration.

IMPORTANT ***Since this work has been undertaken, I strongly advise against changing the settings of the EM-2 module's ZERO and GAIN presets if calibration errors occur during future observing. Without following the instructions [verbatim] within this document, it is very easy to throw off the alignment of the autoguider thus making it non-linear. This is what probably caused the problems in the first place.***

4. Future Improvements

If autoguider problems still persist in the future then the only long term solution is to change the encoding system.

Mechanically this should not be too difficult. It should be possible to substitute the Penny Giles units for higher spec LVDT's. An example could be the SONY encoder as used for the fine focus encoder at the INT. These encoders have a greater accuracy and work over a larger temperature range. The effort required would be more in interfacing these encoders into the PFIP electronics and changing the firmware.

If it is planned in the future to change the 4MS systems in the WHT to EPICS based VME systems (and if PFIP is still considered to be a viable long-term instrument), work should be carried out in unison to change the encoders and their interface modules. I consider it a bad move if a lot of effort is put into changing the hardware/software system of PFIP and the old encoders are still used.

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