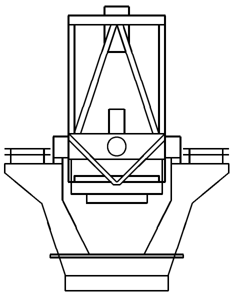
Isaac Newton Group, La Palma

The St Andrews RBS User Manual

R. Edwin

Version 2.0, September 1988

Scanned, OCR'ed & Latex'ified, February 1997. Sections labelled "Obsolete, uncorrected" are seriously out of date, and have not been checked after scanning.



The Isaac Newton Group of Telescopes at the Observatorio del Roque de los Muchachos del Instituto de Astrofisica de Canarias is operated by the Royal Greenwich Observatory on behalf of the Science and Engineering Research Council (UK) and the Nederlandse organisatie voor wetenschappelijk onderzoek (NL).

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Part I

1 Introduction

The Spectrograph is available at the f/15 Cassegrain focus of the 1.0m Kapteyn Telescope. The instrument was built at the University Observatory, St Andrews and is based on the original design by Richardson and Brealey (J.R.A.S. Canada 67, 165 (1973)). Both the camera and collimator optical systems are off-axis designs which produce high quality spectral images in a flat focal plane. The aluminium instrument casing has low flexure, is compact and is light in weight (18 kg). At the time of writing the Spectrograph is manually operated and uses photographic detection, although electronic detection may become available. The present instrument performance makes it suitable for medium and low dispersion spectroscopy of relatively bright objects. Two sets of optics are available to optimise efficiency in "red" or "blue" spectral regions and three gratings provide different dispersions.

The general construction, layout and facilities of the Spectrograph are described initially, followed by details of operational procedures and precautions. Figure 1 is a schematic diagram of the main optical components and their relative locations.

2 Acquisition and Guidance unit (A & G UNIT)

A separate manual is available for this unit and the associated TV system so that only a brief description will be given. The Unit contains systems to provide slit viewing and illumination of the slit by a comparison arc source. The movements of optics within the unit are remotely operated from the Control Console area and as far as spectrograph operation is concerned, it is used in two configurations.

2.1 Object acquisition mode

In this mode the Westinghouse SEC TV camera views the Cassegrain image directly after a 90°reflection by a plane mirror. Simultaneously, the spectrograph slit can be illuminated by the comparison arc source. In principle, an object can be acquired whilst the arc is exposed. However, arc exposures should be made with the telescope and spectrograph oriented close to the celestial exposure as is usual practice. Arc exposures are of the order of seconds. Cu-Ar and Cu-Ne hollow cathode lamps are available.

2.2 Slit viewing mode

In this mode the acquisition/comparison arc mirror system is withdrawn and the Cassegrain image formed directly on the spectrograph slit. The polished slit jaws are inclined with their normal 7.5°from the telescope axis so that the reflected beam has an axis inclined at 15°to the telescope axis. The slit viewing mirror enables the TV camera to view the reflected image. The slit can also be viewed via an eyepiece substituted for the TV camera. In practice the TV system is used because of its efficiency and convenience.

3 Filter spacer

Between the A&G unit and the Spectrograph is a mounting spacer, which locates the slit at the correct f/15 focal plane. The spacer is normally mated with the Spectrograph and it houses a simple filter unit. Details of the filters available are given in Appendix 5. Any one of the filters can be inserted in the convergent beam path to the slit. The image viewed by the the TV camera is necessarily filtered also, but a double pass is avoided.

The initial suite of three gratings are designed for first order operation. Thus, when working in first order blue, there may be a need to filter out second order ultra-violet radiation from the comparison arc. When working in first order red, filters will be required to remove second order blue for all spectra. The photographic emulsion will provide the red cut-off.

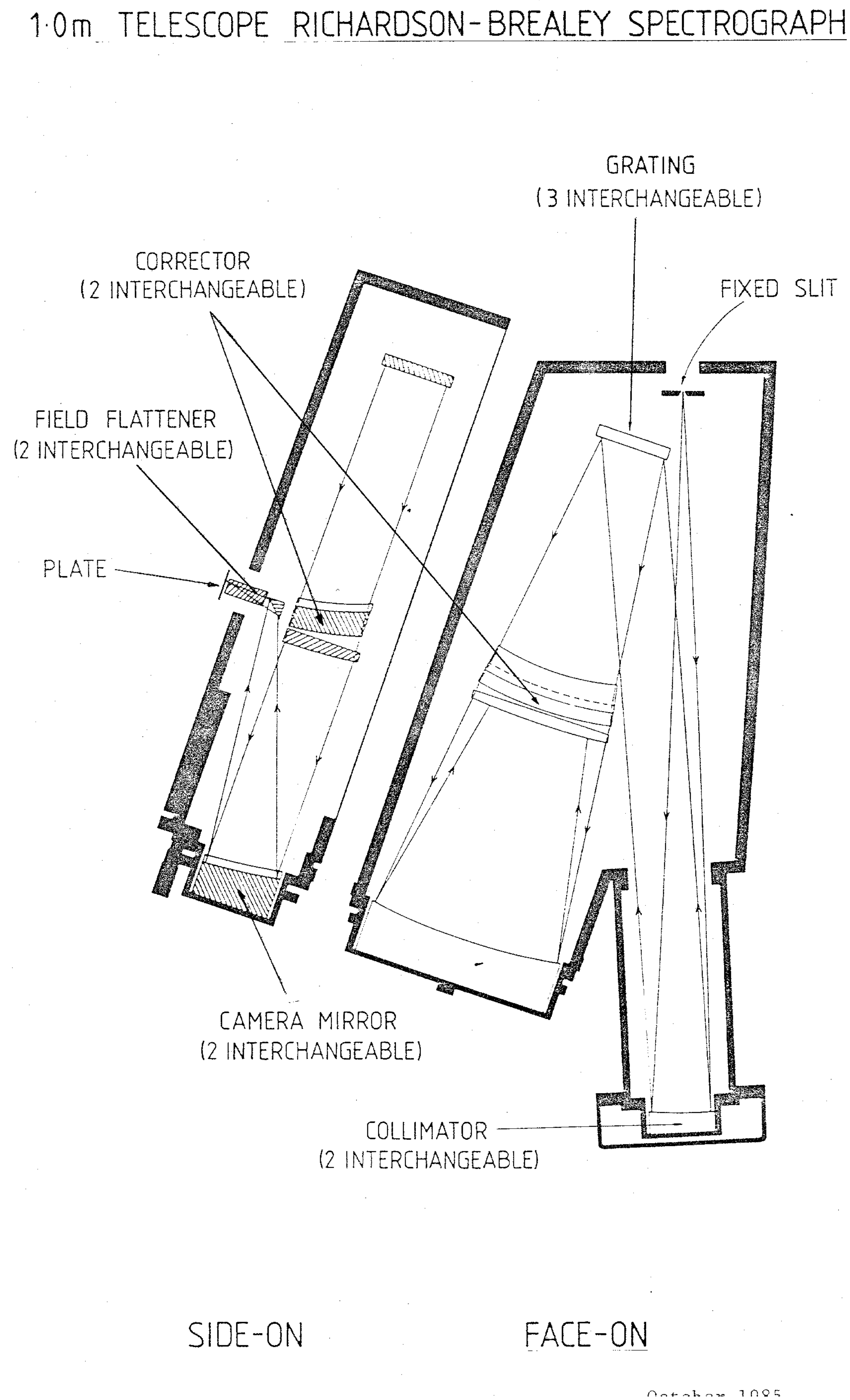

Figure 1: Schematic diagram of main optical components

The neutral density filters should not be required in photographic mode. However, some neutral filters (Kodak "Wratten" gelatin) can be inserted in front of the very sensitive TV camera. The filters should be used if objects brighter than $m_v = 6$ are in the field.

4 Spectrograph components

4.1 Slit and dekker assembly

The slit and dekker slide are mounted from inside the main casing as a single unit. A shutter mechanism is adjacent to the slit.

The dekker has four positions defined at follows:

1. Slide fully "in": whole slit covered.
2. Inner detented position: star slot uncovered in which the central 2 mm of slit is exposed.
3. Outer detented position: arc slots uncovered in which two 2mm portions of the slit each side of the central 2 mm are exposed.
4. Fully "out": the full length of the slit is exposed being some 20 mm. This position would normally only be used for acquisition purposes.

The dimensions and location of star and arc slots are arranged so that their respective spectra do not overlap. 20 mm slit lengths project to approximately 0.5 mm wide spectra at the camera focus.

The slit width is fixed but the whole unit can be replaced for a unit having a different width. Initially two units have been provided widths of $70\,\mu$m and $100\,\mu$m corresponding, to I and 1.5 arc seconds projected onto-the sky. During the commissioning period it was determined that slits of equivalent width less than 1 arcsecond would find less use than a 1.5 arc second slit. Additional slit units may be available in future, depending on demand.

The slit to detector reduction factor of 0.28 means that a slit width of 1 arc second projects to $20\,\mu$m at the detector (neglecting foreshortening effects). Geometrically the optics should produce images of width less than $10\,\mu$m for a zero width slit object.

4.2 Shutter – obsolete, uncorrected

The shutter consists of an aluminium blade which slides under solenoid control behind the slit. A foam rubber light seal is made between the, blade and slit unit. A d.c. power supply of 20 to 30Y is required ideally on the @ telescope but during commissioning the power supply was located on the dome floor.

4.3 Exposure meter – obsolete, uncorrected

Soon, after, leaving the slit, the divergent beam encounters the fuse silica beam splitter of the exposure meter. The beam splitter consists, of a thin (1mm) window inclined at 450 which is anti-reflection coated on one surface. Consequently a few percent of the radiation transmitted by the slit is fed to an exposure meter photomultiplier (EMI type 9 This tube has a bialkali photocathode and fused silica window. lent in the same system is also of fused silica which makes the exposure meter UV sensitive. A darkslide is provided in front of t

The abode current from the photomultiplier is integrated by the exposure meter control electronics located in the console Area and the n is displayed as four digits. The control electronics box also houses the EHT supply which should normally be set at 1100V.

4.4 Collimator

The collimator is an off-axis parabola of focal length 750 mm (nominal) aperture of 50 mm. The collimator can be removed from outside of the casing after removing the protective screw cap. As with other optics in the main optical train, two collimators are available, identical except for the coatings optimised for "red" or "blue" spectral regions. Information on the relative efficiencies of the two sets of optics is given in a later section. The "red" collimator is identified by a red painted disc on the collimator cell with a similar blue marking on the other unit.

4.5 Gratings

Four gratings of line spacings 300, 600, 1200 and 2400 L/mm provide nominal dispersions of 160, 80, 40 and 20 A/mm. The 600 and 1200 L/mm gratings are conventional replicas of ruled gratings and are blazed for 4400 A. The 2400 L/mm grating is a replica of a holographic grating and, although not blazed shows higher efficiency in the blue.

Each grating is mounted in a prealigned cell so that grating interchange is straightforward. The grating is accessed by removing the main casing lid.

Grating rotation is accomplished by a worm gear system with scales calibrated in 0.25 degree divisions.

4.6 Camera

The camera system is an f/4.1 off-axis Maksutov design comprising a two-element corrector, a spherical mirror and a field flattening element adjacent to the focal plane. A 45°flat mirror before the field flattener directs the convergent radiation to a focus outside of the spectrograph. Each element is interchangeable and ':identified as before by red or blue painted discs on the cells. The red and blue flatteners are of different optical design. Both the, camera casing and field flattener unit are accessed from outside of the casing.

Focusing of the spectrograph is achieved by movement of the camera mirror. The collimator position is not adjustable except by a small distance during alignment operations which are not the concern of the normal user. The camera mirror position is determined by a micrometer which is read from outside of the instrument. The mirror slide is additionally clamped by a nut which must be released before adjusting the micrometer. A Hartmann mask, located close to the slit dekker and thermometer allow Hartmann focus tests to be conducted. The camera position for best focus can be defined to within $\sim 50\,\mu$m routinely.

In normal operations the Hartmann mask is withdrawn from the optical path and held by a nylon clamp. In use the two operational positions of the mask are determined by being fully "in" or at a detented position. Adjacent halves of the collimator aperture are irradiated in the two positions.

4.7 Plate holder assembly – Obsolete, uncorrected

The Spectrograph is designed to use plates of size 76

5.@ x 255 (3" The plate ate is held in the plateholder under leaf spring pressure., The plateholder is kinematically located into a recess on the plate slide. Slide movement is controlled by a nut and screw defeats corresponding to O.5mm slide movement. The motion can be monitored on a pointer and mm scale.

Sets of spectra (comparison arc and astronomical exposures) occupy a
2mm strips of plate and it is recommended that the plate is racked
5 or five detents between exposures.,
Up to five sets can be accommodated: on: one plate. I A portion of the plate can not be user
c@16-Se geometry of the field flatterer to the plate
c Mechanical fouling
unless the 'plate movement Is tea

5 Spectrograph operation

5.1 Optical Configuration

Before the Spectrograph is used a choice should be made of optics, grating and slit. Although either set of optics can be used throughout the wavelength range 350 to 1000 nm, there is an efficiency penalty. The performance data should be consulted, but as a general guide, red optics should be used for wavelengths above 500 nm.

The choice of slit will depend on the seeing but it is anticipated 1that the 1 arcsec slit will be the normal choice.

The choice of grating will be governed by the observations and the dispersion and wavelength data should be consulted.

The "mounting" of the optics should only be attempted by someone familiar with the spectrograph.

New users can quickly learn the necessary procedures which, with everything to hand, takes about 20 minutes for a complete optics changeover. Many of the mounting screws mate with threads tapped into aluminium and care should be taken not to overstress the threads, i.e., a light hand is required. The grating should not be removed without having a protective cover in place. It is wise to cover the grating during most operations within the casing with the lid removed.

OBSOLETE:In such operations the EHT to the exposure 'C@: met stitched off and as an additional precaution the me or e c is now described

5.2 Slit replacement

For this procedure the grating has to be removed first. The 3 mm AF hex ball driver kept with the gratings should be used to loosen the three captive screws holding the grating base in place on the turntable. The grating may have to be rotated to gain access to the screws. Before rotating the grating, release the clamp nut (anti-clockwise rotation) by half a turn. This brass knurled nut is located on the rotation axis outside of the instrument. Each grating assembly should be held by the handle or base and not by the grating cell.

The shutter mechanism can be pulled away from the slit by holding onto the body of the mechanism NOT the shutter blade. The mechanism hinges about the end remote from the slit.

The dekker should be pulled to the fully out position. The two toggle clamps located at the edges of the slit assembly should be loosened (anti-clockwise rotation) whilst holding the assembly. The assembly can then be removed by rotating about 30°which releases the dekker control from the slide bar.

Mounting is the same procedure in reverse and the whole operation should become more obvious when the hardware is inspected. Before tightening (lightly) the toggle clamps ensure that the new slit is rotated anticlockwise against the rotation stop and that the dekker slide and control rod are correctly engaged. Check dekker and shutter operation.

5.3 Grating assembly mounting

Once a grating is removed as described in the previous section a different one can be mounted by reversing the procedure. As with the slit, before tightening the three holding screws ensure that the base is rotated anti-clockwise to contact the tangent screw against its stop. The grating angle can be set according to the observational requirements by reading the main scale (divided into whole degrees) and the control knob scale (which produces 2°grating rotation per one revolution and can be set to a precision of a quarter degree).

5.4 Removal and replacement of optics

5.4.1 Collimator

This component is accessed by removal of the protective screw cap as previously mentioned. Two toggle clamps hold the cell in place and rotation of the cell is defined by a tangent screw and stop. Removal and replacement procedures should be self evident.

5.4.2 Corrector Unit

Access is gained with the main casing lid removed. This unit is an expensive item and is held in place by two metal fingers which are spring loaded. Precise location of the cell is ensured by two cone sockets in the cell base which locate onto matching cones on the cell slide.

To remove the cell, hold the body of the cell (not the optical surfaces) and lift each finger away from the cell and to the side of the cell and not to the rear where the fingers might contact the optical surface. Mounting is the reverse of removal. Ensure that the cell base is correctly located on the cones.

5.4.3 Camera Mirror

From outside of the instrument identify the four Allen screws which hold the mirror cell adaptor plate on to the casing. Ensure that the three pairs of tilt screws are not disturbed. Mirrors can be interchanged by simple removal and replacement of the four screws after swapping the mirror assemblies.

5.4.4 Field Flattener Unit – Obsolete, uncorrected

The field flattener is accessed via the plateholder recess. The plateholder or dummy should be removed to expose the two M6 Allen screws located close to the outer surface of the field flattener element. Remove the screws whilst keeping a careful hold of the flattener cell. Movement of the plateholder slide may enable better hold of the cell to be established. When withdrawing the unit be careful to avoid fouling of the 45 degree mirror surface on the surrounding case plate. Replacement should be obvious.

6 Preparation for observations – Warning, needs to be updated

It is assumed that the Spectrograph is optically complete and that the instrument is mounted via the filter spacer onto the A and G Unit. The orientation of the Spectrograph relative to the A & G Unit must be such that the slit reflection is towards the TV camera. Check that the TV camera, the dekker knob, Hartmann mask control and thermometer are all on the same side of the telescope axis.

NEEDS TO BE UPDATED There are several electrical connections which must be made. The A & G Unit must be connected to its control unit and in turn the comparison arc connected to the power unit on the side of the A & G Unit. The exposure meter photomultiplier has two coaxial leads for EHT (HNC connector) and anode signal (BNC connector). These leads are routed to the Console Area for connection to the exposure meter control box. The shutter, controlled at present from the dome floor, has an electronic box mounted on the instrument casing and hand control paddle on a flying lead. A d.c. supply of 20 to 3O V is required to power the shutter mechanism. At the time of writing all cabling to the telescope instrumentation was in a temporary configuration.

NEEDS TO BE UPDATED Operation of the A&G Unit is simple. Buttons are pressed to bring either the slit viewing mirror or the comparison arc/direct view mirrors into position. Panel lights indicate the current status and interlocks prevent mechanical fouling of the mirrors and operation of the comparison arc when in the slit viewing mode. A separate push button controls the comparison arc.

OBSOLETE, uncorrected The exposure meter has very few controls. With the mains power 'on' -check the EHT voltage on the panel meter (normally 11OOV). Adjustment is achieved by turning the multi-turn potentiometer with a screwdriver through the hole in the front panel. The digital display can be zeroed or reset at any time by pressing the button under tile display.

OBSOLETE, uncorrected A useful daytime cheek that the exposure meter is functioning can be performed as follows. Illuminate the slit with the comparison arc by operation of the A&G Unit controls. Switch the exposure meter on and open the darkslide in front of the photomultiplier. With the dekker in. either the star or arc position and the slit shutter open, the digital display should count rapidly. With the darkslide or shutter closed, the count should stop (an insignificant count rate corresponding to the dark current will be registered).

Separate instructions are available for operating the TV system and the associated image integration system. It is necessary before observations are started to check that the slit is correctly focused by the

TV camera optics. With the A&G Unit in the slit viewing mode and the dome lights extinguished view the slit image on the console display. An assistant will be required to provide some field illumination of the slit area eg., the telescope secondary can be illuminated by a flashlight cautiously. A 1 arc second slit occupies about 2 raster lines of the display. The dull dekker mask should be seen readily against the bright background of the slit jaws. Adjustment of the TV focus must be performed at the telescope by moving the camera body relative to the A&G Unit. A screw system is provided. Careful adjustment at this stage will reduce frustration during observations.

7 Focusing the spectrograph

OBSOLETE, uncorrected With a plate loaded mount the plateholder on the Spectrograph noting that there is only one correct orientation for this unit defined by the three kinematic mounting locations and anti-fouling pins. The Plateholder slide should be moved to one end of its travel (with the I scale reading 22mm or 12mm). –exposures are normally conducted with @:t slide in positions 22, 19. 5, 17, 14. 5 and 12 mm. The '22mm' exposure., occurs near the middle of the plate and the 12-.mm exposure at the edge the plate.

NEEDS TO BE UPDATED Ensure the slit shutter is closed, the dekker is in the star position, the Hartmann mask is "in" and the plateholder darkslide "out". The focus micrometer should read 0.2 mm greater than the anticipated focus (5.0 mm for blue optics, 4.5 mm for red optics). With the slit illuminated by the arc source, the slit shutter should be opened for about 10 seconds thus exposing the plate. Without moving the plateholder a second, exposure should be made with the Hartmann mask in its detented location and the dekker in arc (double aperture) position. The plateholder can then be moved to the next location and the micrometer focus screw decremented by 0.1 mm. The exposure cycle is repeated keeping the mask and dekker in the same relative locations throughout i.e., mask "in" , dekker "in" and mask "out", dekker "out". The plate should show a total of five focus tests conducted at settings of e.g., 5.2, 5.1, 5.0 , 4.9 and 4.8 mm. The darkslide must be closed before removing the plateholder!

The resultant spectra should show a shift in the relative positions of the "arc" and "star" exposures as in the classical Hartmann test. The best focus should be determined and the micrometer set to the nearest 0.05 mm and the Spectrograph temperature noted. A change of more than 5° C will require a new focus to be set or determined depending on the calibration data available. Based on experience with a similar spectrograph in St Andrews the temperature coefficient of focus change will be about 0.025 mm/° C.

The Spectrograph should now be ready for astronomical observations. Any pre-slit filters should be prepared for use.

8 Photographic plates – Obsolete, uncorrected

The size of the plate required is no longer available from Kodak a I ad plates must be cut by the observer or arrangements made with the Photographic: technician. Special emulsions ,nay have to be supplied by the observer.

Hypersensitizing of plates is also possible provided adequate notice is given. Baking in forming; gas was used C¿ C¿ for the commissioning observations.

Plate processing with bubble burst agitation is performed in the build for the Kapteyn Telescope but plate cutting, hypering and storage T 7 facilities are located in the @@T building..

metric,).;:. calibration of plates requires the use of the calibration spectrograph also located in the INT building. There is insufficient room on the small plates for the calibration spectra. Calibration and astronomical spectra have to be exposed on their respective spectrographs, using.– plates from the same batch. The plates should then be cam simultaneously but the system is not ideal.

9 Astronomical exposures – Warning, needs to be updated

Astronomical exposures are straightforward compared with the setting operations.'

NEEDS TO BE UPDATED The loaded plateholder should be mounted onto the instrument and positioned ready to receive the first exposure. The good pointing of the telescope in combination with the versatile TV system enables objects within the magnitude range of the Spectrograph to be easily acquired, Although the comparison arc/direct view configuration of the A&G unit enables a larger field of sky to be viewed, the pointing is such that slit viewing imaging system is adequate for acquisition. The 2 mm apertures of the dekker correspond to 27 arc seconds at f/15 focus.

NEEDS TO BE UPDATED During stellar exposures, image trailing will be required. At this time the details of the trailing facility have not been finalised. Telescope focus and guiding are performed from the Console.

OBSOLETE, uncorrected The duration of comparison arc exposures can either be timed or 'counted' on. the exposure meter. At commissioning the hollow cathode source was unstable (old tube) a-,id the exposure meter method was preferred.'

The duration of the astronomical exposure can be estimated from the data in Appendix 4, but observers will have to modify their exposures to match their measurement goals.

OBSOLETE, uncorrected After use, the dummy plateholder should be mounted to protect the vulnerable field flattener. Unlike the plateholder, the dummy can he mounted in two orientations.

Part II
Appendices

1 Special Precautions Summary

1. Screws must not be overtightened, especially where aluminium thread, are involved.

2. Optical surfaces, particularly grating surfaces, must not be touched or contacted.

3. **OBSOLETE, uncorrected** The exposure ,meter darkslide must be closed before removing the case lid. As an added precaution the EHT should be switched off.

4. **OBSOLETE, uncorrected** The shutter should be swung away from the slit by holding the body of the mechanism not the shutter blade.

5. When adjusting the camera mirror focus with the micrometer, ensure that the clamp nut is released. For highest stability this nut should be tightened once best focus has been determined.

6. The grating rotation clamp must be released before the rotation knob is adjusted.

7. There is a possible fouling of the telescope pier by the collimator tube at declinations greater than +70 degrees when operating below the pole.

8. The grating should be protected by a cover during all operations within the casing.

9. Grating angles outside the range +60°to -30°should not be set to avoid mechanical fouling between casing and grating.

10. NEEDS TO BE UPDATED When not in use, the field flattener should be protected by either the plateholder or the dummy cover.

11. When removing a corrector unit lift each clamp finger and swing to the side of the cell and not to the rear where there is a danger of contact with the rear optical surface.

2 Wavelength Ranges and Dispersion Data

NEEDS TO BE UPDATED The two conventional gratings (600 and 1200 L/mm) are blazed for 4400 A. The gratings are mounted with the “blaze to collimator” i.e., angle of incidence greater than angle of diffraction. The 2400 L/mmm grating is used in a similar configuration but this type of grating is not specifically blazed.

The rotation angle given in the tables can be determined or set using the circular scale and control knob subdivisions. 0°on the scale corresponds to the grating being normal to the collimated beam. Because the angle between the collimated beam and camera axis is 23°, a setting of +11.5°puts zero order centrally in the camera field.

There are mechanical limits to the maximum grating rotation. The limits correspond to scale readings of +60°and -30°. At high angles of incidence (larger than 30°) the projected width of the 58 mm wide gratings is less than the collimated bean and so some light loss occurs.

The following three tables give for each grating the dispersions and wavelengths for the centre and edges of the camera field for a range of angle settings.

OBSOLETE February 1997: The tables are obsolete, and not reproduced in the Latex version.

3 Optical specifications

Collimator focal length	749.25 mm (f/15)
Camera effective focal length	208 mm (f/4.1)
grating apertures	58 mm x 58 mm
Slit width (1 second of arc)	70 μm
Slit width (1.5 second of arc)	100 μm
Slit height (star mode)	2 mm
Slit height (comparison ard mode)	2 x 2 mm
Angular field of camera (unvignetted)	13.7 °(∼6.85°)
Angle between collimated beam axis and camera axis	23°
OBSOLETE Photographic plate size	3" x 1" = 765 mm x 255 mm
OBSOLETE Plate thickness	0.04" nominal = 1 mm
Needs to be updated Focus setting at 20° C (blue optics)	5.0 mm
Needs to be updated Focus setting at 20° C (red optics)	4.5 mm
Temperature coefficient of focus setting	0.025 mm/° C

4 Performance data

The following data are preliminary results obtained at the time of commissioning. Modifications may be required with experience.

4.1 Exposure times

Since it is expected that the dispersion of 40A/mm (1200 L/mm grating) will be used the most, this dispersion is taken as the standard. It was found that to a good approximation exposure times are inversely proportional to dispersion. The exposure times for the comparison arc are independent of dispersion.

Exposure times are quoted which produce a density of 0.8 above fog in the middle of the spectral range (unless otherwise specified). Seeing conditions of 1 to 2 arc seconds are assumed using the 1 arcsec slit. Needs to be updated Image trailing uses the full 2 mm of slit exposed by the star aperture in the dekker. It is estimated that at the time of commissioning that there was 0.4 magnitudes of extinction at the zenith by dust.

The exposure times are quoted for stars of zeroth magnitude.

4.2 Radial velocity measurements

Laboratory tests on the spectrograph before commissioning and subsequent tests on the telescope yielded a flexure of 1 μm per hour for spectra (hour here refers to telescope/spectrograph RA motion during the course of an exposure).

Needs to be updated

4.2.1 IIaO – 3200 to 5000 A – Blue optics – 40 A/mm

a) Arc exposure	350 counts x 2 (15 seconds x 2 approx.)
b) Star exposure	1400 counts for all spectral types (1.9 seconds for a B = 0 mag star) (for H and K in a K type star, increase x 2) (for H and K in a M type star, increase x 5)
c) Red optics	Penalty – increase exposure x 2
d) Sensitization	Little improvement – decrease exposure by30%

4.2.2 IIIaJ – 3200 to 5000 A – Blue optics – 40 A/mm

a) Arc exposure	1000 counts x 2 (45 seconds x 2 approx.)
b) Star exposure	9000 counts for all spectral types
	(12 seconds for a B = 0 mag star)
	(for H and K in a K type star, increase x 2)
	(for H and K in a M type star, increase x 5)
c) Red optics	Penalty – increase exposure x 2 below 4500 A
	Same exposure for 4500 to 5500 A
d) Sensitization	Decrease exposure x 5

4.2.3 IIIaJ – 3500 to 6900 A – Red optics – 40 A/mm

a) Arc exposure	1000 counts x 2 (45 seconds x 2 approx.)	
b) Star exposure	Spectral type	Counts
	M	3000
	K	4000
	G	8000
	A,F	12000
	O,B	16000
	(for 6600 to 5500 A: 30 seconds for a V =) star)	
c) Blue optics	Penalty – increase exposure x 2 for 6600 to 5500 A	
d) Sensitization	Decrease exposure x 2	

4.2.4 IIIaJ – 3200 to 5000 A – Red optics – 40 A/mm

a) Arc exposure	50 counts x 2 (2seconds x 2 approx.)	
b) Star exposure	Spectral type	Counts
	M	2500
	K	8000
	A	30000
	(18 minutes for star with 0 mag at 8000 A)	
c) Blue optics	Increase exposure x 4	
d) Sensitization	Not investigated	

4.3 IAU radial velocity standards

Measurements have also been conducted on spectra of IAU radial velocity standards. Most observations were conducted at dispersions of 40 and 80 A/mm. Arcturus was observed repeatedly but some hotter stars with sharp lines were also studied. The plates were scanned on the RGO PDS machine and the results show that the radial velocities measured are consistent with the IAU scale. In each case the standard deviation is quoted for the uncertainty.

1. At 40 A/mm for 18 observations of 5 IAU standards, the mean difference spectrograph - IAU = +0.2 +- 1.9 km/s

2. At 40 A/mm for 11 observations of Arcturus, the difference (standard deviation from IAU value) was 1.1 km/s

3. At 40 A/mm for 13 observations of 9 other stars, the mean difference spectrograph - IAU = -0.8 +- 3.9 km/s

4. At 40 A/mm for 5 observations of 5 stars (1 IAU standard), the mean difference spectrograph - IAU = -2.2 +- 7.6 km/s

5. At 40 A/mm for 6 observations of 4 stars (1 IAU standard), the mean difference spectrograph - IAU = -0.8 +- 4.8 km/s

The commissioning data were obtained by D.J. Stickland and R.P. Edwin.

5 Pre-slit filter data

Filters available:

Schott	RG	830	
Schott	RG	695	
Schott	RG	630	
Schott	GG	495	
Schott	GG	395	
Schott	GG	385	
Schott	BG	38	
Schott	BG	28	
Schott	UG	1	
		1.4	(neutal density, metal film)
		3.0	(neutal density, metal film)

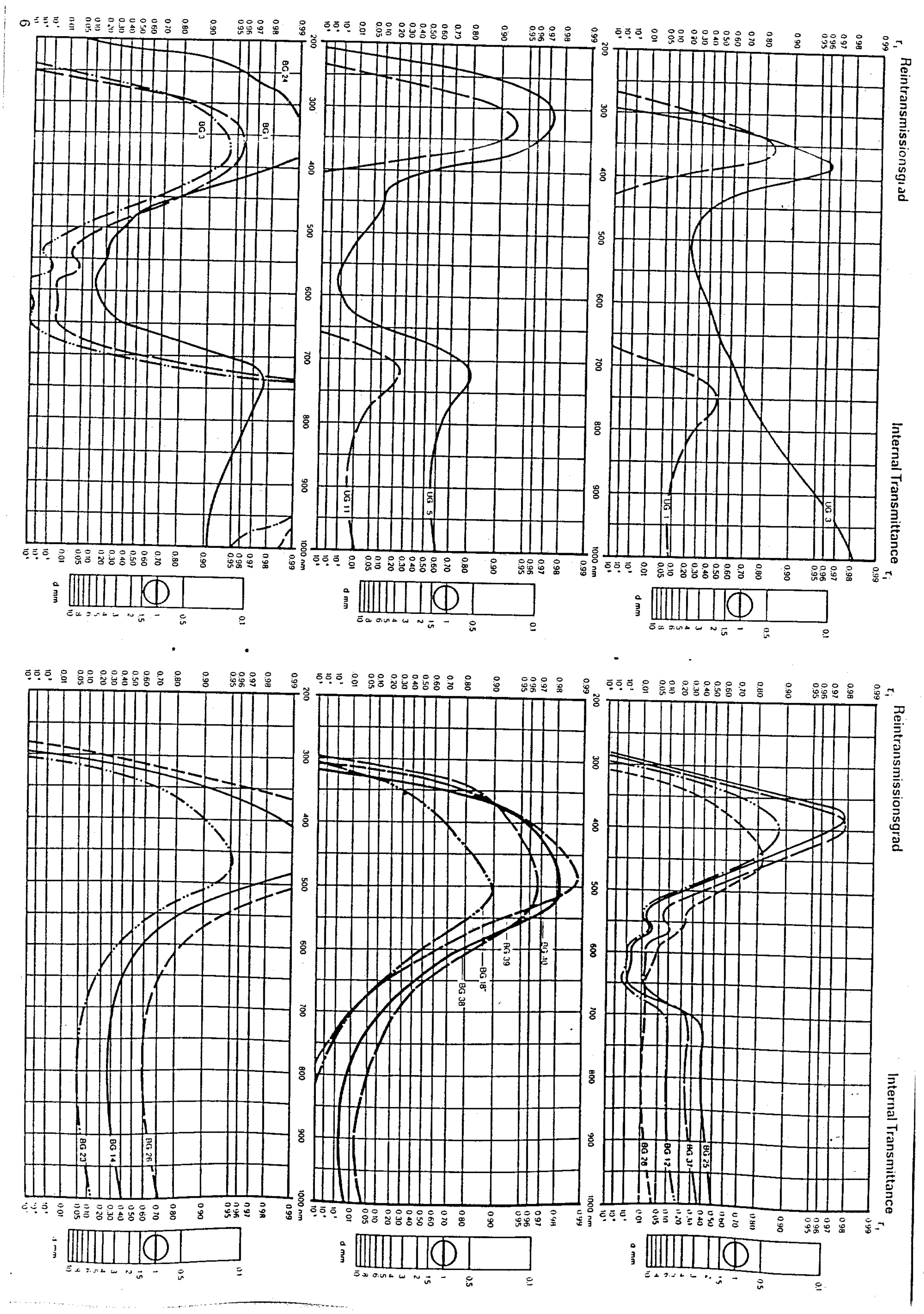

Figure 2: Transmission curves

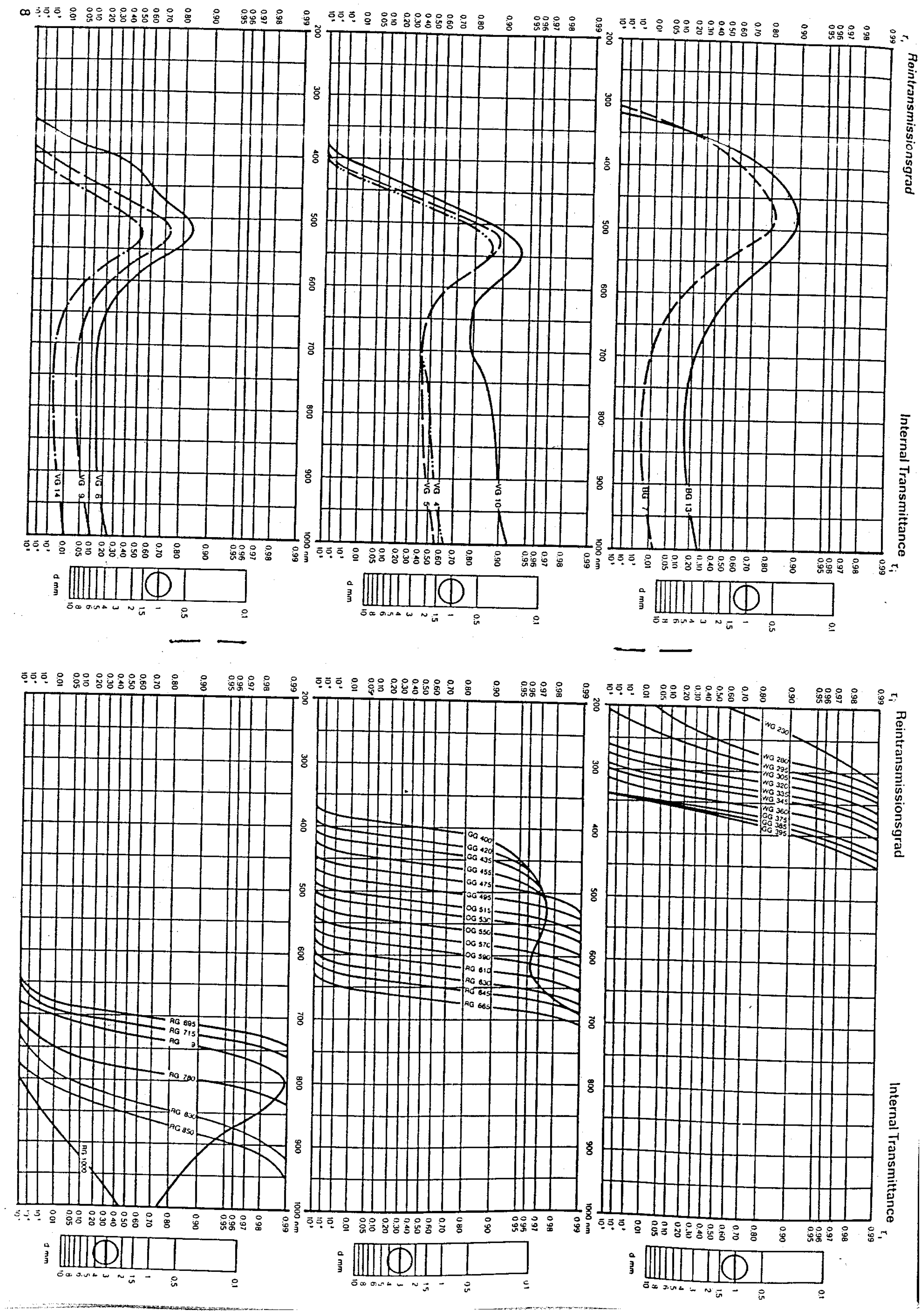

Figure 3: Transmission curves, continued

6 Supplement To The Technical And User Manuals For The St Andrews Richardson Brealey Spectrograph - Operation With A CCD Camera

R.P. Edwin
May 1988

6.1 Introduction

During 1987 components were manufactured and purchased by the University Observatory, St Andrews under SERC contract SO/792/86 to enable the Richardson Brealey Spectrograph to be used with a CCD camera. In photographic mode the instrument had proven inefficient when compared with other spectrographs equipped with electronic detectors. The modifications allow CCD cameras of the standard RGO design (with kinematic mounting interface) to be mounted onto the spectrograph.

In February 1988 the system was commissioned during a one week allocation of time on the JKT. The changes in the operation of the spectrograph in this mode are described in thisa supplement. Also some data on instrument stability and sensitivity are presented.

6.2 Optical modifications

The optical system has required minor changes to match the spectrum imaging plane to the CCD elements within the cryostat. In the original design, the focal plane was located 12.5 mm from outer surface of the main instrument casing. The CCD surface is located some 15.5 mm (RCA) or 14.5 mm (GEC) from the cryostat faceplate. In addition, the window on the cryostats is 4 mm thick which must be included in the optical design.

A new field flattener has been provided which images over a 30 mm field at the CCD plane. One surface of the field flattener is within a mm or so of the cryostat window, although fouling is mechanically impossible if everything is installed correctly. Relative to the 56 mm x 90 mm aperture in the main casing plate (through which the field flattener protrudes), the optical centre, for both the spectrograph and cryostat is located 20 mm from the edge nearest the camera and is in the 90 mm dimension. (The 20 mm dimension represents a 2 mm shift of the optical centre).

The field flattener has been coated with single layer MgF_2 anti-reflection coatings optimised for the CCD red response. The coatings were conducted by David Jackson at the RGO.

A new low dispersion grating has been added to the existing suite of three. The new grating has 300 l/mm and provides a dispersion of approximately 160 A/mm. (Grating is Milton Roy (ex Bausch and Lomb) type 35-53-06-180 with blaze of 6.5°for 7500 A). Details of wavelength ranges and dispersions for all gratings are given in Section 5. These tables assume that the detector format covers 15 mm of spectrum.

6.3 Mechanical modifications

The major mechanical modification has been the removal of the plateholder and replacement by an adapter ring to which the cryostat can be clamped. The ring incorporates the standard clamping and location arrangements common to RGO cameras. The ring is held onto the casing via 7 x M6 studs with nuts and washers. The ring is precisely located on the surface of the casing by three metal pads permanently bolted to the casing. No attempt should be made to disturb the pad locations.

The cryostat can be rotated about the optical centre in order to align the CCD pixels relative to the dispersion direction. The 7 x M6 nuts, securing the ring, should be loosened and fine control of rotation is achieved using a micrometer tangent screw included in the modification. The radius on which the tangent screw operates is 14l mm.

The shutter mounted within the casing adjacent the slit has been removed because it was not compatible with the CCD control system. Also the shutter limited grating rotation. A different shutter

(Compur model 141) has been mounted within the filter spacer "above" the slit. This location is not ideal because, when the shutter is "shut", the slit can not be viewed, but the physical size of the unit restricted mounting at any other location. The shutter is interfaced for control by the CCD software and operates from fully open to closed within 4 msecs. The shutter is not permanently allocated to the spectrograph but it is now necessary for normal operations.

6.4 Routine operational procedures

The CCD detector system has simplified spectrograph operation and observations require less physical contact with the instrument. Once the CCD cryostat is mounted on the telescope, there some alignment and focusing procedures to be conducted. The grating mounting rotation and choice of optics are as per the original manuals.

Since the spectrograph should be in approximate focus after previous use, the CCD rotational alignment is probably the first task. As mentioned previously the cryostat can be rotated by first releasing the 7 x M6 nuts holding the adapter ring. It is advised that this operation should be performed with the telescope pointing so that the cryostat is held in intimate contact with the casing by gravity. Integrations on arc spectra and resultant image displays will quickly reveal the pixel alignment relative to the spectrum axis and rotation adjustments should quickly converge to satisfactory alignment.

Fine focus is achieved using the Hartmann mask. The focus adjustment is still by means of a micrometer which defines the location of the camera mirror. The clamp mentioned in relation to photographic use has been removed because it fouled the adapter ring. The focus setting used during commissioning was close to 5 mm. Shift between Hartmann exposures was detected graphically on the ARGS display, there being no software routines available.

The slit dekker is normally used so that only the central portion of the slit is exposed (2 mm or 27" sky equivalent). For arc spectra and 22 μm pixels, the width of spectra were found to be correspondingly about 20 pixels wide (1 pixel = 1.1" geometrically). On the other hand, flat field exposures were made with a long slit. Because of fringing effects with the coated GEC chip it was found necessary to obtain flat fields at each grating/dispersion setting of the instrument. A temporary arrangement for a flat field source was used in which a tungsten halogen source was used to illuminate the slit through the A and G comparison arc unit. An out-of-focus diffusing screen was directly illuminated at this location. If the screen is in sharp focus at the slit then non-uniform illumination along the slit is possible from the "grain" of the screen. This results in a spectrum with streaks, as if the slit jaws are dirty.

The possibility of the spectrograph fouling the telescope at declination settings of greater than $+75°$still exists. An algorithm has been incorporated into the telescope control software certain telescope motions. The installation and successful operation of this software should be checked and particular care taken whenever declination settings greater than $+75°$are used.

The filters for photographic mode remain available for use with CCDS. Glass Schott filters with a blue cut-off are efficient for blocking blue orders in red spectra. However, a copper sulphate filter is the most efficient filter for blocking red scattered light in blue spectra. The red sensitive CCD could detect a relatively high background of red radiation without the filter. A suitable filter was borrowed from the People's Photometer.

OBSOLETEThe exposure meter was a useful indicator of integration progress and can be used as in photographic mode.

6.5 Wavelength and Dispersion Tables

The following tables summarise the possible wavelength ranges and dispersion with each of the four gratings, 300, 600, 1200 and 2400 l/mm. Data assumes first order operation and a CCD format of 15 mm along the dispersion direction.

Table 1: Wavelength ranges and dispersion 300 L/mm

ANGLE	EDGE		CENTRE		EDGE	
SETTING	A	A/MM	A	A/MM	A	A/MM
15.0	2839.0	157.8	3988.2	158.7	5143.0	159.4
15.5	3406.4	158.1	4557.1	158.9	5713.1	159.5
16.0	3973.4	158.3	5125.6	159.1	6282.7	159.6
16.5	4540.2	158.5	5693.7	159.2	6851.9	159.8
17.0	5106.6	158.7	6261.4	159.4	7420.5	159.9
17.5	5672.7	158.9	6828.7	159.5	7988.6	160.0
18.0	6238.3	159.1	7395.4	159.6	8556.0	160.0
18.5	6803.4	159.2	7961.5	159.8	9122.8	160.1
19.0	7368.0	159.4	8527.1	159.9	9689.0	160.2
19.5	7932.0	159.5	9091.9	160.0	10254.3	160.2
20.0	8495.5	159.6	9658.1	160.0	10818.9	160.2

Table 2: Wavelength ranges and dispersion 600 L/mm

ANGLE	EDGE		CENTRE		EDGE	
SETTING	A	A/MM	A	A/MM	A	A/MM
15.0	1419.5	78.9	1994.1	79.3	2571.5	79.7
15.5	1703.2	79.0	2278.5	79.4	2856.5	79.8
16.0	1986.7	79.1	2562.8	79.5	3141.4	79.8
16.5	2270.1	79.2	2846.9	79.6	3425.9	79.9
17.0	2553.3	79.3	3130.7	79.7	3710.3	79.9
17.5	2836.3	79.4	3414.3	79.8	3994.3	80.0
18.0	3119.1	79.5	3697.7	79.8	4278.0	80.0
l8.5	3401.7	79.6	3980.8	79.9	4561.4	80.1
19.0	3884.0	79.7	4263.5	79.9	4844.5	80.1
19.5	3966.0	79.8	4546.0	80.0	5127.2	80.1
20.0	4247.7	79.8	4828.1	80.0	5409.5	80.1
20.5	4529.1	79.9	5109.8	80.1	5691.3	80.1
21.0	4810.2	79.9	5391.1	80.1	5972.8	80.1
21.5	5090.9	80.0	5672.1	80.1	6253.3	80.1
22.0	5371.2	80.0	5952.6	80.1	6534.3	80.1
22.5	5651.1	80.1	6232.6	80.1	6814.3	80.1
23.0	5930.5	80.1	6512.2	80.1	7093.8	80.1
23.5	6209.5	80.1	6791.3	80.1	7372.8	80.1
24.0	6488.1	80.1	7069.8	80.1	7651.2	80.O
24.5	6766.1	80.1	7347.8	60.1	7929.0	80.0
25,0	7043.6	80.1	7625.3	80.1	8206.2	79.9
25.5	7320.6	80.1	7902.2	80.1	8482.8	79.9
26.0	7597.1	80.1	8178.5	80.0	8758.8	79.8
26.5	7872.9	80.1	8454.1	80.0	9034.1	79.8
27.0	8148.2	80.1	8729.1	79.9	9308.1	79.7
27.5	8422.8	80.1	9003.5	79.9	9582.5	79.6
28.0	8698.8	80.0	9277.1	79.8	9855.7	79.5
28.5	8970.1	80.0	9550.1	79.8	10128.1	79.4
29.0	9242.8	79.9	9822.3	79.7	10399.7	79.3
29.5	9514.7	79.9	10093.8	79.6	10870.5	79.2
30.0	9785.9	79.8	10364.5	79.5	10940.6	79.1

Table 3: Wavelength ranges and dispersion 1200 L/mm

ANGLE	EDGE		CENTRE		EDGE	
SETTING	A	A/MM	A	A/MM	A	A/MM
15.0	709.8	39.5	997.0	39.7	1285.8	39.8
16.0	993.4	39.6	1281.4	39.8	1570.7	39.9
17.0	1276.7	39.7	1565.4	39.8	1855.1	40.0
18.0	1559.6	39.8	1848.8	39.9	2139.0	40.0
19.0	1842.0	39.8	2131.8	40.0	2422.2	40.0
20.0	2123.9	39.9	2414.0	40.0	2704.7	40.1
21.0	2405.1	40.0	2695.6	40.0	2986.4	40.1
22.0	2685.6	40.0	2976.3	40.1	3267.2	40.1
23.0	2965.3	40.0	3256.1	40.1	3546.9	40.0
24.0	3244.0	40.1	3534.9	40.1	3825.6	40.0
25.0	3521.8	40.1	3812.6	40.0	4103.1	40.0
26.0	3798.5	40.1	4089.2	40.0	4379.4	39.9
27.0	4074.1	40.0	4364.6	40.0	4654.3	39.8
28.0	4348.4	40.0	4638.6	39.9	4927.8	39.8
29.0	4621.4	40.0	4911.2	39.8	5199.9	39.7
30.0	4893.0	39.9	5182.2	39.8	5470.3	39.6
31.0	5163.1	39.8	5451.8	39.7	5739.1	39.5
32.0	5431.6	39.8	5719.6	39.6	6006.1	39.3
33.0	5698.4	39.7	5985.7	39.5	6271.3	39.2
34.0	5963.6	39.6	6250.0	39.3	6534.5	39.0
35.0	6226.9	39.5	6512.4	39.2	6795.8	38.9
36.0	6488.3	39.3	6772.8	39.0	7055.0	38.7
37.0	6747.7	39.2	7031.1	38.9	7312.1	38.5
38.0	7005.1	39.0	7287.3	38.7	7566.9	38.3
39.0	7260.4	38.9	7541.3	38.5	7819.5	38.1
40.0	7513.4	38.7	7793.0	38.3	8069.6	37.9
41.0	7764.1	38.5	8042.3	38.1	8317.3	37.6
42.0	8012.5	38.3	8289.2	37.9	8562.5	37.4
43.0	8258.5	38.1	8533.5	37.6	8805.0	37.1
44.0	8501.9	37.9	8775.2	37.4	9044.9	36.9
45.0	8742.7	37.6	9014.3	37.1	9282.0	36.6
46.0	8980.9	37.4	9250.6	36.9	9516.3	36.3
47.0	9216.3	37.1	9484.1	36.6	9747.7	36.0
48.0	9449.0	36.9	9714.7	36.3	9976.1	35.7
49.0	9678.7	36.6	9942.3	36.0	10201.5	35.4
50.0	9905.5	36.3	10167.0	35.7	10423.8	35.0

Table 4: Wavelength ranges and dispersion 2400 L/mm

ANGLE	EDGE		CENTRE		EDGE	
SETTING	A	A/MM	A	A/MM	A	A/MM
25.0	1760.9	20.0	1906.3	20.0	2051.6	20.0
26.0	1899.3	20.0	2044.6	20.0	2189.7	20.0
27.0	2037.0	20.0	2182.3	20.0	2327.2	19.9
28.0	2174.2	20.0	2319.3	20.0	2463.9	19.9
29.0	2310.7	20.0	2455.6	19.9	2599.9	19.8
30.0	2446.5	20.0	2591.1	19.9	2735.1	19.8
31.0	2581.5	19.9	2725.9	19.8	2869.5	19.7
32.0	2715.8	19.9	2859.8	19.8	3003.0	19.7
33.0	2849.2	19.8	2992.9	19.7	3135.6	19.6
34.0	2981.8	19.8	3125.0	19.7	3267.3	19.5
35.0	3113.4	19.7	3256.2	19.6	3397.9	19.4
36.0	3244.1	19.7	3386.4	19.5	3527.5	19.3
37.0	3373.9	19.6	3515.6	19.4	3656.1	19.3
38.0	3502.6	19.5	3643.7	19.3	3783.5	19.2
39.0	3830.2	19.4	3770.7	19.3	3909.7	19.1
40.0	3756.7	19.3	3896.5	19.2	4034.8	18.9
41.0	3882.1	19.3	4021.1	19.1	4158.7	18.8
42.0	4006.3	19.2	4144.6	18.9	4281.2	18.7
43.0	4129.2	19.1	4266.7	18.8	4402.5	18.6
44.0	4250.9	18.9	4387.6	18.7	4522.5	18.4
45.0	4371.4	18.8	4507.1	18.6	4641.0	18.3
46.0	4490.4	18.7	4625.3	18.4	4758.2	18.2
47.0	4608.2	18.6	4742.0	18.3	4873.9	18.0
48.0	4724.5	18.4	4857.3	18.2	4988.1	17.8
49.0	4839.4	18.3	4971.2	18.0	5100.8	17.7
50.0	4952.8	18.2	5083.5	17.8	5211.9	17.5
51.0	5064.7	18.0	5194.2	17.7	5321.4	17.3
52.0	5175.0	17.8	5303.4	17.5	5429.4	17.2
53.0	5283.8	17.7	5411.0	17.3	5535.6	17.0
54.0	5390.9	17.5	5516.9	17.2	5840.2	16.8
55.0	5496.5	17.3	5621.1	17.0	5743.1	16.6
56.0	5600.3	17.2	5723.7	16.8	5844.2	16.4
57.0	5702.5	17.0	5824.4	16.6	5943.6	16.2
58.0	5802.9	16.8	5923.4	16.4	6041.1	16.0
59.0	5901.5	16.6	6020.6	16.2	6136.8	15.8
60.0	5998.3	16.4	6118.0	18.0	6230.6	15.6

6.6 Performance Data

Image resolution with a 1.5" slit and 22μm pixels estimated from arc spectra.

FWHM arc lines	$\sim$2 pixels
	$\sim$40μm
22 μm pixel = 1.1"	
Camera focus settings	4.45 mm red optics
	4.40 mm blue optics

Cryostat rotation adjustment for camera GEC3-B

micrometer reading	4.45

Cryostat tilt adjustment screws with above camera

A	3.87
B	3.74
C	3.35

Adjustments A, B and C produce a clearance of 0.3 mm between casing and end face of cryostat.

Field flattening lens, bi-convex, fused silica with surface radii 249 mm and thickness 1500 mm. See separate drawing for more details.

6.7 Signal vs Magnitudes

The data have been normalised for a star with m_v = 10 and for 100 sec integrations. In each case the signal, averaged over 2 mm of spectrum, is in ADUs integrated across a 22 μm (1 pixel) section of the spectrum. The conversion of ADUs for the camera in use was 1 ADU = 1 electron approximately. The electronic readout noise was 6 to 7 electrons per pixel per readout. The spectrum with normal seeing and and manual guiding was typically 5 pixels wide.

Table 5: Signal vs magnitudes

Spectral Type	Central Wavelength (A)	Signal (ADUs per 22 μm of spectrum
2400 l/mm grating		
B	3500	150
B	4000	400
K	4000	160
B	4200	1500
F	4200	1200
G	4200	100
K	4200	60
K	6500	380
1200 l/mm grating		
B	4100	520
G	4100	160
M	4100	50
G	5200	1200
G	6250	1400
B	6500	580
M	6500	2000
G	6770	1900
300 l/mm grating		
G	4800	5700
G	7050	24000
G	9100	3600
GD7l (White dwarf)	5125	6800

6.8 Flexure Data

Flexure was measured using cross correlation analysis of arc spectra. Spectra were recorded at telescope positions separated in H.A. by 1 hour and at declinations +70°, +30°and -10°. Spectral shifts are given in units of a pixel (22 μm) in the dispersion direction for the equivalent of 1 hour integrations. The shifts were found to be smooth and regular.

Table 6: Flexure data

Declination	H.A. start	H.A. end	Shift
+70°	-5	-4	-0.074
	-4	-3	-0.078
	-3	-2	-0.069
	-2	-1	-0.062
	-1	0	-0.043
	0	+1	-0.029
	+1	+2	-0.009
	+2	+3	0.010
	+3	+4	0.021
	+4	+5	0.066
+30°	-5	-4	-0.055
	-4	-3	-0.058
	-3	-2	-0.058
	-2	-1	-0.055
	-1	0	-0.037
	0	+1	-0.027
	+1	+2	-0.017
	+2	+3	0.002
	+3	+4	0.022
	+4	+5	0.039
-10°	-4	-3	-0.015
	-3	-2	-0.018
	-2	-1	-0.024
	-1	0	-0.026
	0	+1	-0.049
	+1	+2	-0.019
	+2	+3	-0.024
	+3	+4	-0.019