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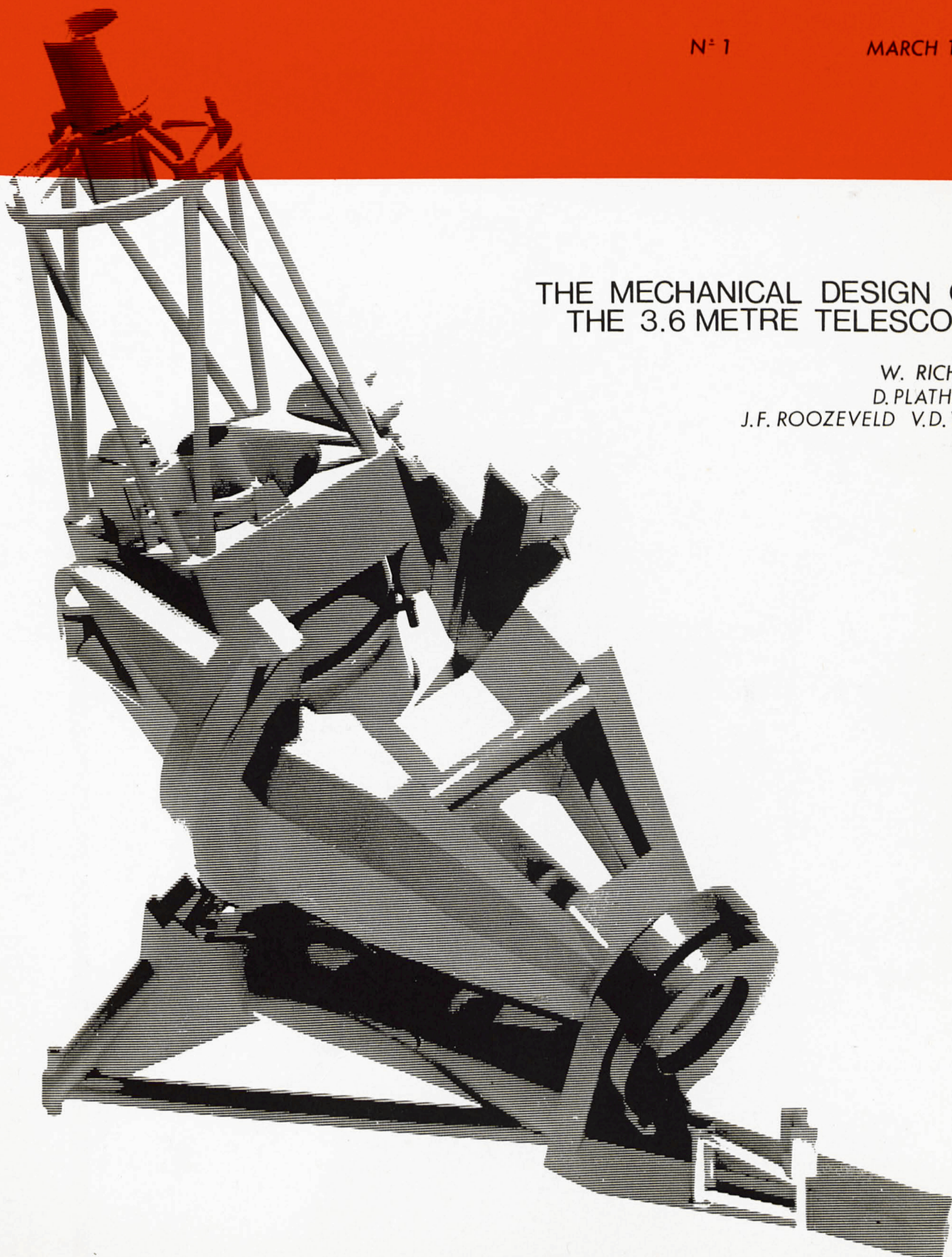
TECHNICAL REPORT

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THE MECHANICAL DESIGN OF THE 3.6 METRE TELESCOPE

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THE MECHANICAL DESIGN OF
THE 3.6 METRE TELESCOPE

W. RICHTER
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P R E F A C E

The European Southern Observatory (ESO) is the result of a scientific collaboration for astronomical research in the Southern Hemisphere between the six European member countries, Belgium, Denmark, Federal Republic of Germany, France, Netherlands and Sweden.

Situated 600 km north of Santiago de Chile, the observatory is located on a mountain named La Silla, 2400 m above sea level in the southern tip of the Atacama Desert.

According to the prescriptions of the ESO Convention, signed in 1962, the principal instrument of the observatory will be the 3.6 m telescope, currently being built and due to be commissioned in 1976. This instrument will be installed on the highest summit of La Silla.

Designed as a general-purpose instrument, it will be used for furthering a wide range of research programmes in the visible and infrared part of the spectrum. Research with the observatory's existing telescopes has underlined the need for such a large instrument.

The ESO Telescope Project Division, established on the CERN site in Geneva following an agreement on co-operation reached between the two organizations, is responsible for the design and construction of the observatory's newest and largest telescope. This Division has now begun to issue a series of Technical Reports treating the various design and construction aspects of the different parts of the telescope. The present report is the first of the series and will be followed in the near future by others.

S. Laustsen

Leader of TP Division, ESO

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1. INTRODUCTION

1.1 General features

The 3.6 m telescope is designed for observation in three different focus positions:

Prime focus with an aperture ratio of $f/3.04$

Cassegrain focus with $f/8.09$

Coudé focus with $f/31.79$.

For observation in prime focus, the instrumentation and observer are housed in a small cage on top of the telescope tube. This cage has an outer diameter of 1.5 m. Its shadow reduces the usable surface of the main mirror by $(1.5/3.6)^2 = 17\%$. The 24 cm plate covers a field of 1.1° with a scale of 19 arcsec per mm at this focus position.

For observation in Cassegrain focus, the observer has at his disposal for instrumentation and himself a cage of 4.6 m diameter and 2.2 m height. This will be the most important observation point of the telescope. At this focus, a 30 cm plate covers a field of 0.58° with a scale of 7 arcsec per mm.

For observation in coudé focus, a laboratory on each side of the telescope is provided. The light beam passes via 5 mirrors to the laboratory and has a focus which does not move as the instrument turns to follow the star. The focus is provided for 0.1° field (corresponding to 20 cm) with a scale of 1.8 arcsec per mm.

The main mirror of the instrument has a usable diameter of 3570 mm and a central hole of 700 mm diameter. It weighs 11 tons. The secondary mirrors for Cassegrain and coudé observation are of respectively 1200 mm and 1100 mm useful diameter and weigh 350 kg each. The additional three flat mirrors for the coudé light beam are of 1250 mm, 985 mm and 400 mm diameter.

The mechanical structure of the telescope consists of

pedestal 45 tons in weight
polar axis 130 tons in weight
telescope tube 70 tons in weight.

Mirrors and mirror cells are included in these weights.

The pedestal is the fixed part of the telescope structure with hydrostatic bearings and a spur gear drive for the polar axis.

The polar axis is the part of the telescope which turns about an axis parallel to the earth's axis, thus eliminating the effect of the earth's rotation.

The telescope tube supports the main and secondary mirrors and turns about the declination axis which is perpendicular to the polar axis.

Descriptions of the telescope have been presented in 1967 by A. Baranne ⁽²⁾, in 1968 together with

a comparison to other large telescopes by K. Bahner ⁽¹⁾, in 1971 after the first design study by the ESO-TP division by S. Laustsen ⁽⁸⁾ and Ch. Fehrenbach ⁽⁵⁾ and finally in form of short progress reports in the ESO annual reports ⁽¹¹⁾.

This report now describes those parts of the telescope which are definitively designed. Most of them are being currently executed. Other parts, where further design work is still necessary, as e.g. Cassegrain cage, integrated telescope equipment, coudé auxiliary telescope, etc. will be described in later reports.

1.2 History and time schedule

1953	First proposals for 3.6 m telescope
1962	ESO convention signed
1965	Blank for main mirror ordered
1968/1969	Pre-design of building, dome and telescope presented to Instrumentation Committee
September 1970	ESO starts collaboration with CERN
mid 1971	Review of design concept after telescope conference, incorporation of major changes to building, telescope and controls
mid 1972	Specifications for building, dome and main parts of telescope sent to firms. Controls computer delivered

Current status

end 1973	Contracts signed and execution of all items started. Mirrors ready. Computer control with model of telescope drive working
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Future schedule

end 1974	Building prepared for dome erection, dome ready for shipment to Chile, telescope parts and controls ready for pre-assembly in Europe
end 1975	Dome erected, 50% of sanitary, electrical and air conditioning installation finished, telescope working in Europe with computer control
end 1976	Building with telescope and controls ready for operation in Chile.

2. MIRRORS AND MIRROR CELLS

The optical system of the telescope has been described by H. Köhler ⁽⁶⁾ and R. Wilson ⁽¹⁰⁾. The distances between the mirrors and to the focal points are given in Table 2.1.

The mirrors are of fused silica and delivered by Corning Glass ⁽⁹⁾. Grinding and figuring was done by REOSC. The mirror dimensions are presented in Table 2.2.

Basic studies for the design of the mirror cells and the mirror supports are made by A. Bayle and Ch. Fehrenbach ⁽³⁾; further details see A. Couder ⁽⁴⁾.

2.1 Main mirror cell

The cell of the main mirror has a box structure which gives high rigidity and reduced weight. There are good facilities for fixing auxiliary equipment, e.g. Cassegrain spectrographs, to the rear side of the cell. The outer diameter of the cell is 4.50 m, its height 1.05 m.

There are 3 holes in the bottom of the cell to lift the mirror out of the cell with 3 steel bars.

Special attention has been paid to eliminate additional perturbing forces that may appear in the support system; all bearings in the back support, as well as in the side support, have been given a slight freedom of movement, in order to eliminate the effect of small unavoidable displacements

between mirror and support, which occur as a consequence of thermic expansions and elastic deformations.

The mechanical back support system has 3 fixed peripheral supports defining, in the direction of the optical axis, the exact position and collimation of the mirror. Each of these supports consists of a mirror pad, a ball and socket joint, and a micrometer screw arrangement for adjusting the pad.

The back supports carrying the weight of the mirror are 30 in number distributed around three concentric circles in a way defined by Couder. Each of these supports consists mainly of a mirror pad, a long shaft and a lever, carrying at one end an adjustable counterweight. All the various parts are carried by ball or roller bearings.

The pneumatic side support system has 3 defining supports, each consisting of a lead-covered mirror pad, a ball and socket joint, a device for compensating for thermic dilation, and a micrometer screw arrangement for adjusting the pad. Each of the defining supports is dimensioned to carry the total weight of the mirror when the pneumatic side support bags are not inflated and have been tested for a maximum load of 30 tons.

TABLE 2.1 DISTANCES BETWEEN MIRRORS AND FOCAL POINTS

Prime focus

main mirror vertex to prime focus 10 844 mm

Cassegrain focus

main mirror vertex to Cassegrain secondary 7 491 mm
 Cassegrain secondary to Cassegrain focus 8 931 mm

Coudé focus

Main mirror vertex to coudé secondary 7 664 mm
 coudé secondary to coudé mirror 3 6 425 mm
 coudé mirror 3 to coudé mirror 4 4 250 mm
 coudé mirror 4 to coudé mirror 5 15 590 mm
 coudé mirror 5 to coudé focus 7 000 mm

TABLE 2.2 MIRROR DIMENSIONS

	Diameter (in mm)		Thickness (in mm)		Curvature radius of (in m)	Weight (in kg)
	physical	useful	centre	edge		
Main mirror*	3654	3570	455	532	21.690	11.125
Cassegrain secondary	1240	1197	136.6	118.6	-10.684	339
coudé secondary	1150	1050	141	117.5	- 7.030	296
coudé mirror 3	1330	1250		151	-	462
coudé mirror 4	1040	985		129.5	-	242
coudé mirror 5	410	400		52	-	15

* hole diameter 700 mm

The pneumatic side support bags are 18 in number. Each consists of a square-shaped baseplate with rounded off corners. The plate has a foil of neoprene on the front forming a buoyant air bag. At the back, the baseplate has a ball and socket joint connected to a steel rod, which at its other end carries a shoe of hard steel. This shoe has the shape of a spherical cap with its centre of curvature in the centre of the ball and socket joint. The spherical cap supports against a flat steel surface, fixed to the inner wall of the mirror cell and so oriented that the perpendicular to the surface is exactly at right angles to the optical axis of the mirror. The steel rod is carried by a counterweight lever.

The pressure in a supporting air bag is a function of the angle of inclination of the optical axis of the mirror and of the angle between that radius of the mirror, which goes through the centre of the air bag considered, and the radius to the lowest point of the circumference of the mirror. The air pressure in the 18 different bags is automatically regulated by an air pressure control (a mechanical computer).

2.2 Other mirror cells

The cells for the secondary mirrors and for the flat mirrors 3 and 4 of the coudé beam are all designed according to the same principle. There are 3 fixed radial supports and 3 fixed axial supports on the outer edge of the mirror disc.

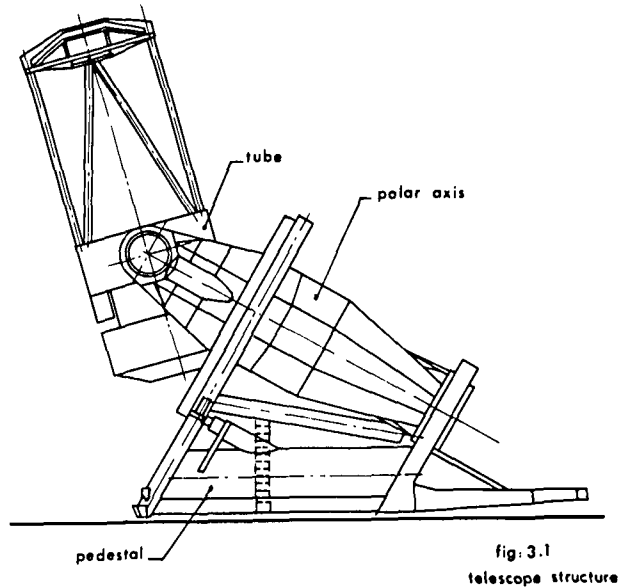
In addition, 6 counterweights act through lever arms onto the outer edge of the mirror to provide an additional axial support. A further 6 counterweights support through lever arms the central part of the mirror from the back.

The cells themselves are thin-wall box constructions and weigh about as much as the mirrors.

3. MAIN STRUCTURE

In this chapter, the steel construction is described. This main structure provides mountings for the mirrors according to optical requirements.

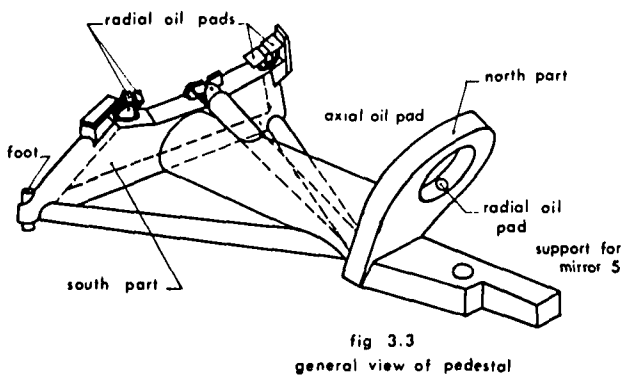
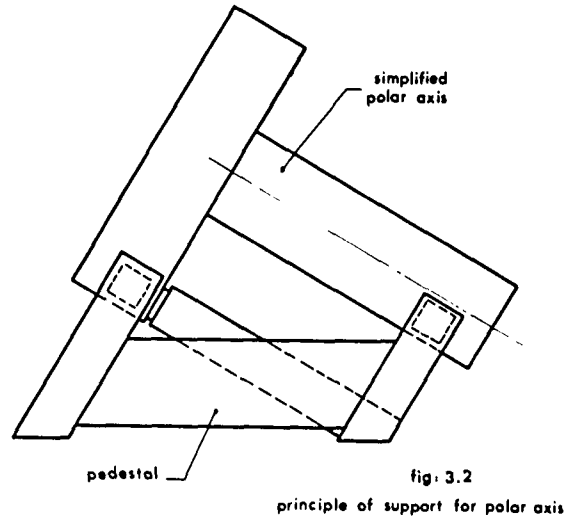
The 3.6 m telescope is designed as an equatorial mounting. The main structure consists of the pedestal as a static base frame; the polar axis, rotating with the hour angle; and the tube, pointing to the stars (fig. 3.1). The polar axis and parts of the tube are designed as closed box structures, whilst the pedestal represents a combination of closed box and single frame structure.



3.1 Pedestal

The pedestal comprises a number of boxes and bars strictly following the support requirements of the polar axis, which floats on a configuration of 8 oil pads.

The principle of this support for the polar axis is shown in fig. 3.2. Here, the polar axis is simplified to two cylinders. The oil pads support these two cylinders at four points radially (2 V-shaped supports) and at one point axially. The pedestal transmits the forces from the oil pads to three feet, two in the southern, and one in the northern part (fig. 3.3).



The design of the pedestal (fig. 3.3) clearly separates the two requirements for supporting the polar axis. The first system, composed of push-pull beams, takes the static loads from the axis. The second system is built of the northern and southern part box sections and the big central tube in between which provides the torsional stiffness of the pedestal to cope with the lateral vibrations of the telescope polar axis.

For aligning purposes of the whole telescope, all feet can be adjusted in the vertical direction. The two feet of the southern part (fig. 3.4) are not able to take horizontal loads. A device in the middle between these two feet blocks the horizontal forces and provides the possibility for a horizontal alignment of the southern part of the pedestal. The third foot on the northern part transmits vertical and horizontal forces.

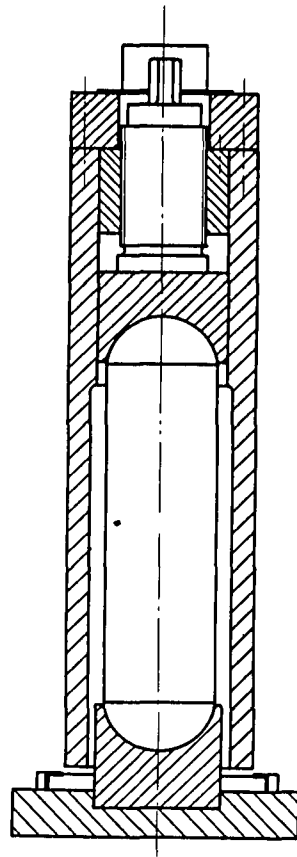


fig. 3.4
foot of south part

3.2 Polar axis

A combined fork-horseshoe configuration was chosen in order to avoid long fork prongs and very large horse-shoe diameter.

As can be seen from fig. 3.5, the whole polar axis is built of closed box sections which give high stiffness in bending and torsion at a reasonable load to weight ratio.

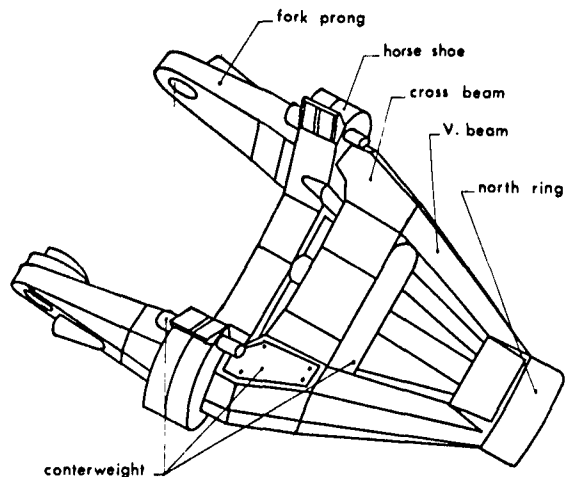


fig. 3.5
general view of polar axis

Special load problems had to be solved due to the hydrostatic bearing supports of the declination axis, which are described in detail in chapter 4.2. An axial preload of 80 tons between fork prongs and centre section of the tube was necessary requiring careful layout of the fork prong, horse shoe, crossbeam area, as shown in fig. 3.6.

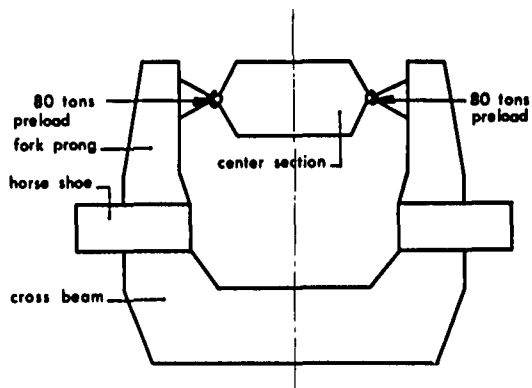


fig. 3.6
preload of declination bearings

The preload for the bearings gave an additional advantage viz. it reduced the deflection value of the fork prongs in the 6 o'clock position. Computations have shown that the displacement of the node of the telescope due to gravity will be of the same value within a tolerance of some 0.1 mm for all hour angles. The position of the polar axis can thus be very well defined.

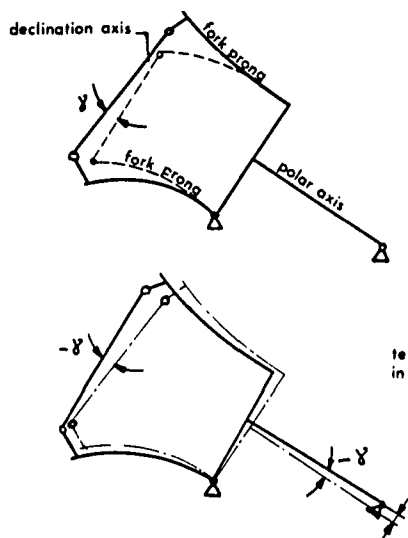


fig. 3.7
telescope deflection
in 6 o'clock position

On the other hand, in the 6 o'clock position, this bearing system causes a rotation of the tube about an axis perpendicular to the polar- and tube axis (fig. 3.7). This rotation γ is of the order of 25 arcsec. It can be corrected by lifting the north end of the telescope. The resulting error in the 12 o'clock position can be corrected by the δ -drive.

As part of the telescope balancing system, a big movable counterweight is screwed to the V-beam. It balances the polar axis and the tube in a direction parallel to the declination axis with a possible couple of ± 2500 kpm.

As the polar axis is rather unsymmetrical in the horseshoe area, two big static weights are screwed to the top ends of the horseshoe. In addition, plates can be fixed on the upper part of the crossbeam (fig. 3.5)

The polar axis can rotate 102° in both directions from the 12 o'clock position to the mechanical end-stops which are installed for emergency cases. These end-stops brake the kinetic energy of the telescope down to zero by plastic deformation of a steel plate. For safe operation, the max. rotation angle is reduced to a slightly lower value by means of limit switches.

3.3 Tube

The tube is composed of three different structural areas, each giving an optimal solution for the related requirements. As a consequence, only the upper part is built according to the Serrurier system, whilst the main mirror cell is fixed to the center section by six flexion bars. The center section is a stiff closed box structure combining the loads from the upper and lower part of the fork on the polar axis (fig. 3.8).

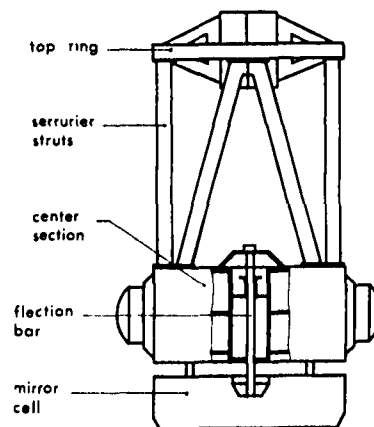


fig. 3.8
telescope tube

The Serrurier struts consist of eight tubes of equal length and cross-section to guarantee a proper functioning of the deflection system. The maximum displacement of the top unit configuration is calculated as 1.8 mm in the 6 o'clock position.

The top ring configuration is built of an outer ring fixed to the Serrurier struts by four motor driven screws (fig. 3.9). The outer ring is also equipped with four alignment and preload devices to position and preload the four spiders which are welded to the inner ring. This ring supports the top units which are described in chapter 6. The centre of gravity of the whole configuration including the top units with the secondary mirror passes through the fixation points of the outer ring on the Serrurier struts, when the tube is horizontal.

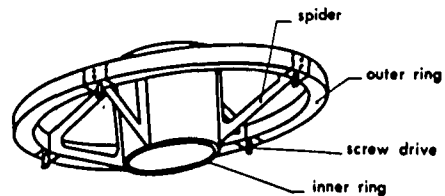


fig. 3.9 top ring

The design of one flexion bar is shown in fig. 3.10. The bar is clamped rigidly on one end and has a backlash-free ball joint as second support. This ball joint acts as a membrane which gives freedom in the axial direction to avoid stresses due to thermal elongation. The attachment of the cell is again built as a backlash-free ball joint, this time without freedom in the axial direction. This ball

joint also consists of a number of thin parallel steel plates acting as membranes fixed to the flexion bar at the inner ring edge and to the mirror cell on the outer edge. An additional short flexion bar takes the axial load but is flexible in all other directions.

The choice of such a complicated beam element was dictated on the one hand, by the demands for high flexibility, and on the other, for high strength in taking radial loads. The membrane joints are moreover free of backlash and friction.

The flexion bars are fixed to the main mirror cell out of the plane of the centre of gravity. Due to this fact, a rotation of the main mirror of 3 arcsec in the 6 o'clock position is expected.

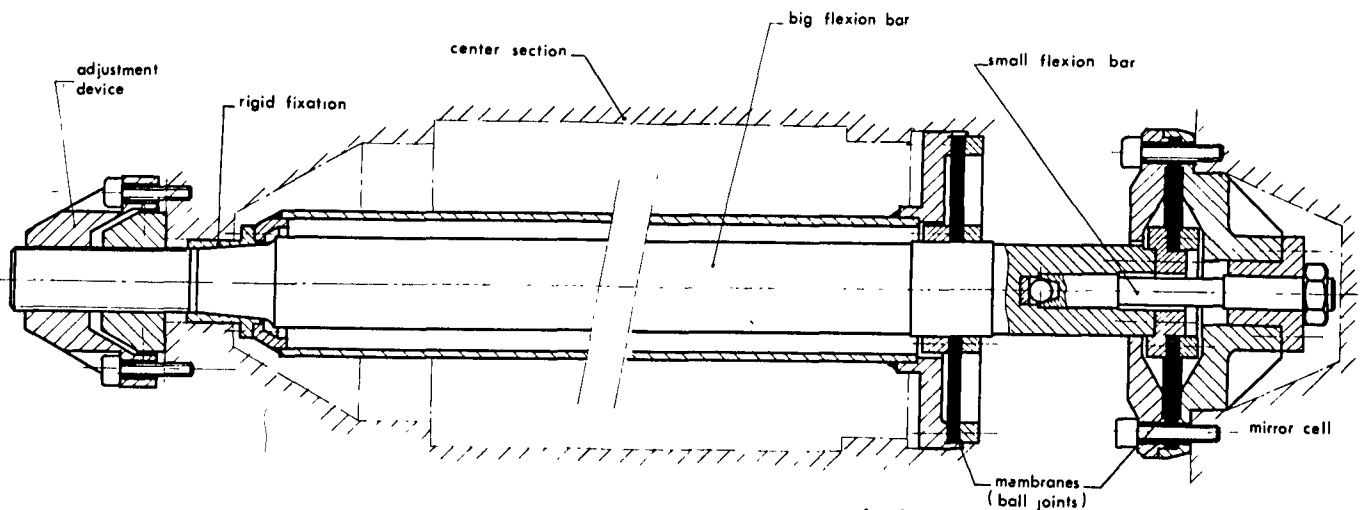
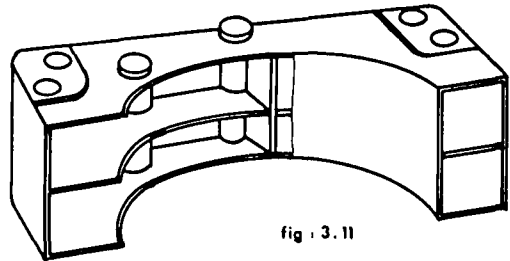


fig: 3.10
flexion bar

The centre section in which the six flexion bars are housed has a box structure as shown in fig. 3.11. This structure is penetrated by a number of small steel tubes (six of them are taken by the flexion bars) and four big tubes in the corners. These big tubes house the movable counterweights which balance the tube in the direction of the optical axis.



Another counterweight, operating perpendicularly to the declination and optical axes, is fixed sideways to the structure of the centre section underneath one of the bearing shafts of the declination axis.

Between the main mirror and the centre section, the mirror cover is installed. This is a special design derived from the iris shutter principle to fit into the limited space (see chapter 8.1).

3.4 Structural analysis of main structure

Deflections and stresses of the telescope tube and polar axis have been analysed using a computer programme which replaced the actual structure by beams. These beams have the same cross-sections and moments of inertia as the corresponding parts of the real structure. The joints of these beams transmit forces and moments for the stiff (welded or screwed) parts of the structure. They transmit only certain forces where the real parts are connected by bearings.

The tube was calculated in three orientations:

tube axis vertical
tube axis and declination axis horizontal
tube axis horizontal and declination axis
inclined at 45° .

The polar axis was calculated in

0 hour position
2 hour position
6 hour position.

The results of this computation have been used to improve the telescope, i.e. less total weight and higher stiffness.

The remaining deformations are:

- optical axis of tube in horizontal position passes 1.8 mm beneath declination axis;
- the 90° angle between declination and polar axis changes by 10 sec of arc when telescope arrives in 6 o'clock position;
- main mirror tilts by 3 sec of arc when tube is horizontal;
- mirror 4 (2nd flat of coudé beam) tilts by 100 sec of arc when polar axis is in 6 hour position. This will be compensated with the alignment drive of mirror 4.

4. HYDROSTATIC BEARINGS

The hydrostatic bearings for the polar axis are comparable to those used in telescopes of a similar size. Only for the bearings of the declination axis did a new design have to be made, because all existing large telescopes have ball bearings to support this axis. The additional requirements for the declination axis necessitated a new design also for the hydraulic plant.

4.1 Polar axis

So far, large telescopes have been built with a cylindrical bearing surface on the horseshoe. The second bearing ring has had either a spherical or a cylindrical and plane surface for the oil pads. For the bearings of the azimuth axis of big antennas hydrostatic bearings with spherical surfaces have been used.

The comparison of these different possibilities made it clear that nowadays, the production of precise spherical surfaces is simpler than the manufacture of precise cylindrical surfaces. In addition, a round oil pad on a spherical surface requires fewer precautions for the proper alignment than a square oil pad on a cylindrical surface. These points lead to the choice of a spherical bearing surface for the horseshoe and the north bearing ring (fig. 4.1) for the radial loads.

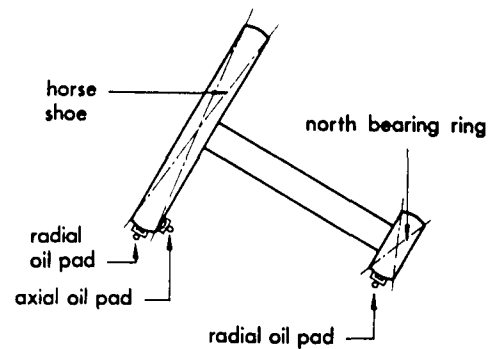


fig 4.1
oil pads of polar axis

The axial forces can be supported by oil pads acting either on a flat surface of the horseshoe or on a similar surface on the north bearing ring.

For this telescope, the support on the horseshoe was chosen because this allowed one to have a pedestal which transmits the forces more rigidly to the ground. It avoided moreover having the radial oil pads of the north bearing ring on top because the radial forces there would act in the opposite direction if the axial forces were taken at the north ring.

The radial pads and the axial pads on the horseshoe are designed in pairs sitting on a balancing arm (fig. 4.2). The radial oil pads on the north bearing ring take much less load and are therefore designed as single pads. Each one of the eight pads is sitting on a ball which allows the self alignment of the pad (7). The sizes of the different pads are chosen in such a way that the required oil pressure for the eight different pads is equal. The oil film thickness will be 0.1 mm.

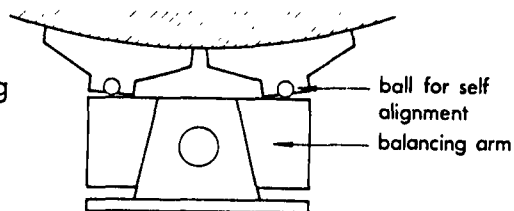


fig 4.2
radial oil pads on horseshoe

4.2 Declination axis

The oil pad configuration for the declination axis had to be chosen in such a way that these bearings can support the tube loads in every position of the polar axis. For this purpose, the oil pads act at 60° onto spherical surfaces (fig. 4.3) and the two bearings are preloaded against each other with a force slightly greater than the total weight of the telescope tube.

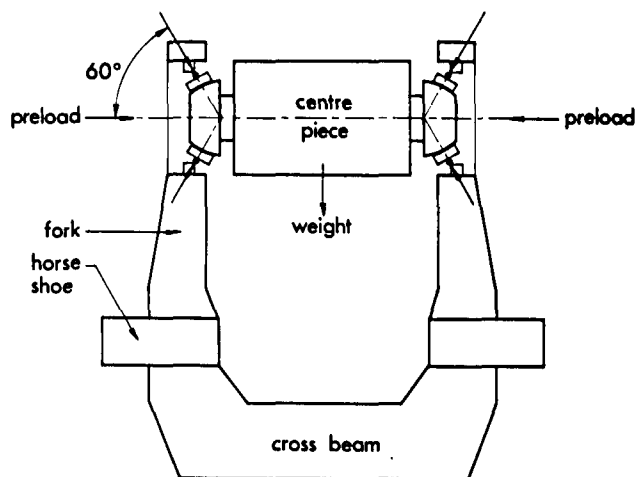
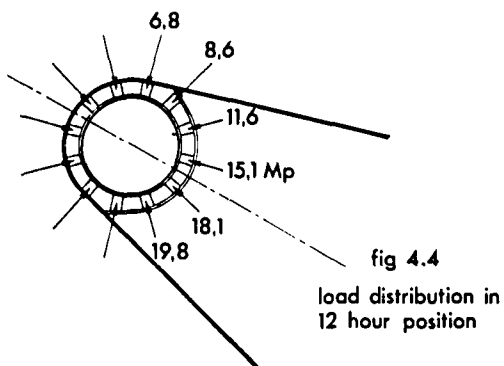


fig 4.3
oil pads of declination axis



There are 12 individual oil pads around each of the two declination bearing shafts. Fig. 4.4 shows the load distribution for these twelve pads when the declination axis is horizontal. This corresponds to the situation with the polar axis in the 12 o'clock position.

For the polar axis in the 6 o'clock position, the declination axis is inclined as shown in fig. 4.5. In this position, the total load on the lower bearing is higher than on the upper bearing. Due to the high preload, the load for all 24 oil pads remains positive.

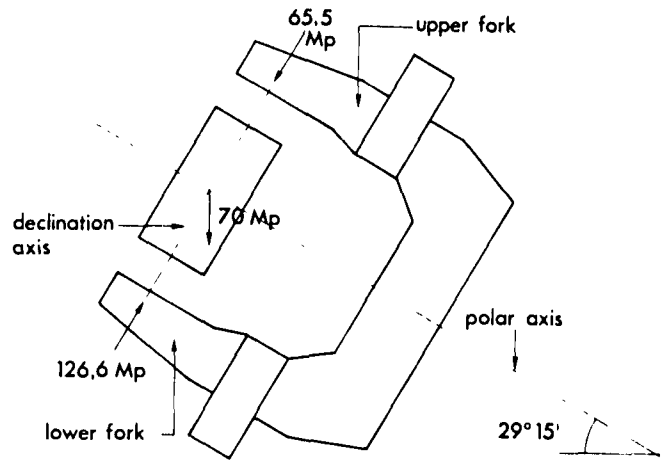


fig 4.5

inclination of declination axis in 6 hour position

The load distribution for this case is given in fig. 4.6. The influence of the elasticity of the forks has been taken into account.

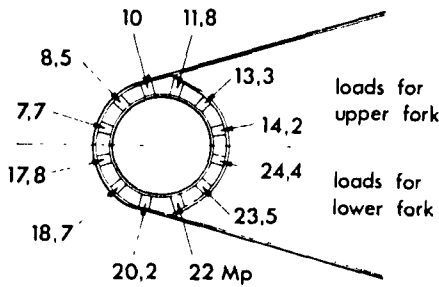


fig 4.6

load distribution in 6 hour position

The load for each individual oil pad changes between the values given in fig. 4.4 and 4.6 according to the position of the polar axis. This requires special care for the oil distribution (see next chapter).

4.3 Hydraulic plant

The hydraulic plant has two independent pumping stations. One of them supplies the oil pads of the declination bearings with a pressure of 95 bars, the other one supplies the oil pads of the polar axis with a pressure of 32 bars. Each of these pumping stations

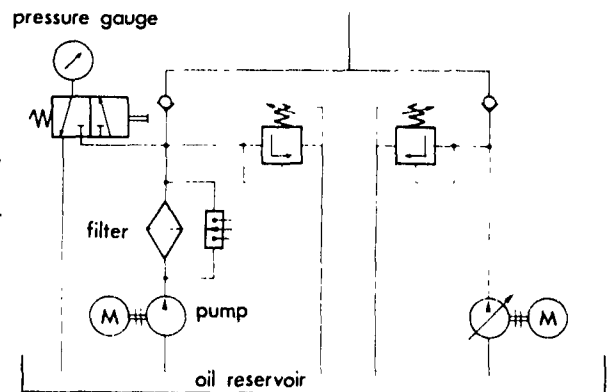


fig 4.7

pump group

consists of two pumps (one being a spare) with filters and pressure gauges according to fig. 4.7. The distribution to the oil pads is governed by flow regulators, which maintain a constant flow irrespective of pressure changes in the pad. Pressure and flow are controlled by two gauges to protect the system against rupture of the supply line or an excessive load of the oil pad which would stop the oil flow. This system is shown in fig. 4.8.

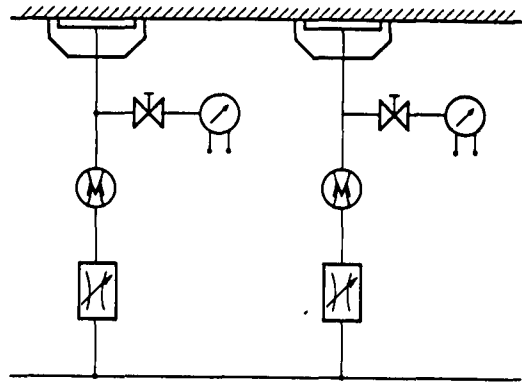


fig 4.8
oil distribution to oil pad

5. DRIVES AND POSITION CONTROL

The telescope can rotate about polar and declination axis with variable speeds. For setting a maximum speed of 1 degree/sec and for guiding a minimum speed of less than 0.5 arcsec/sec will be used. The tracking speed for the polar axis is 15 arcsec/sec, ± guiding speed.

Both axes have nearly identical gear drives and encoders to read the position of the telescope axes. Limit switches control the limits of motion about the two axes and a special damping device, which acts on the horse-shoe, is provided to stop possible vibrations of the telescope.

5.1 Drives and gears

A complete gear drive is shown in fig. 5.1.

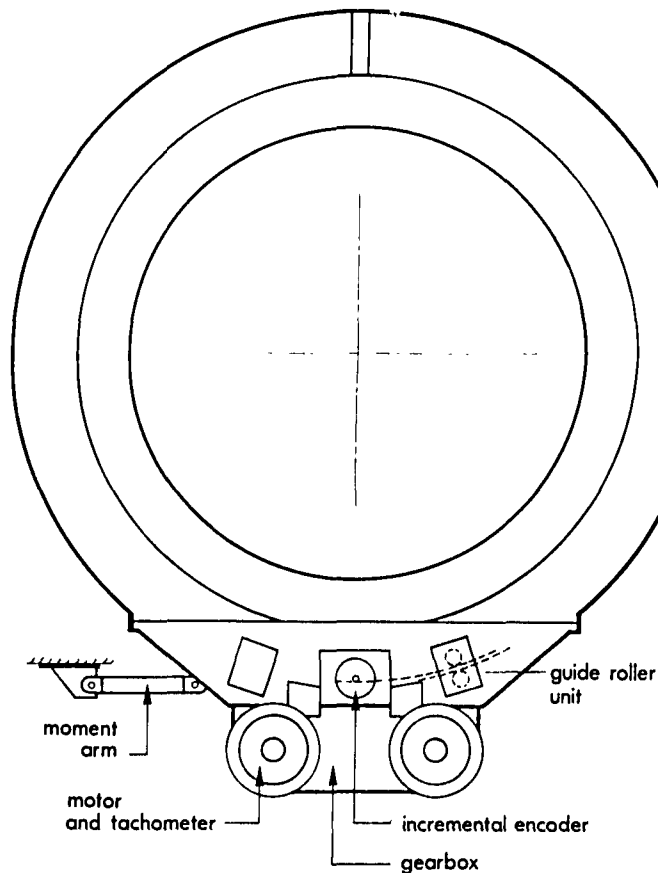


fig 5.1
main gear

It has two motor -tachometer units. Each of them drives the big gear wheel via three reduction stages (fig. 5.2). Using one of the two motors as brake and driving the system with the other motor, makes the whole gear drive free of backlash.

The forces on the gear wheels are normally very small due to the balanced system and to the hydrostatic bearings of both axes. Nevertheless, for security reasons, the gears are designed for a torque of 1000 kpm at the big gear wheel.

The Inland torque motors run at 40 rpm to set the telescope onto the next star and at a speed 1 : 10 000 slower to guide the telescope during observation.

The gear has a total reduction of $2 \times 6.8 \times 18 = 250$. The last stage has a pinion with 40 teeth and a gear wheel with 720 teeth. The helix angle is 12° , the pressure angle 17.5° and the centre distance of the shafts is 1.8 m.

As precision for the grinding of the teeth of the last stage, it is required to have the single pitch errors less than $5\mu\text{m}$ and the profile errors less than $7\mu\text{m}$ for the big gear wheel. The corresponding errors for all the other gear wheels are less than 3 to $4\mu\text{m}$.

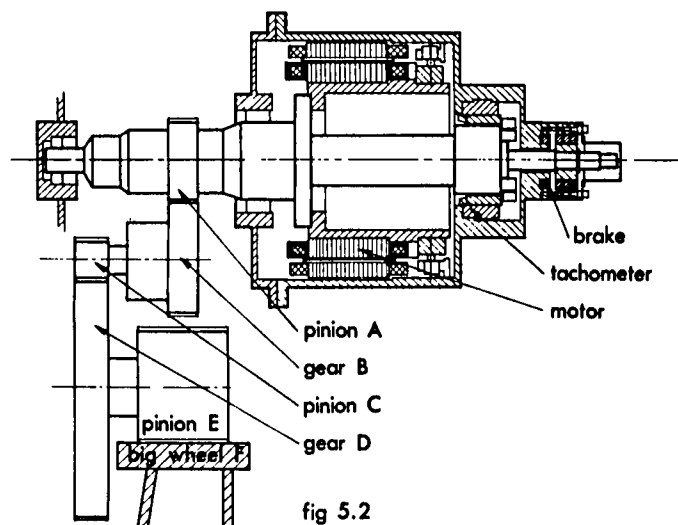
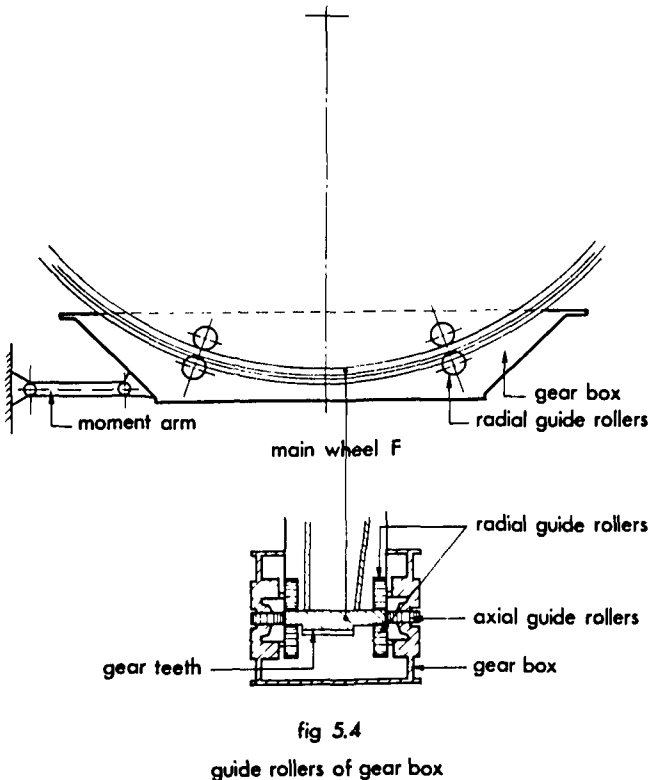
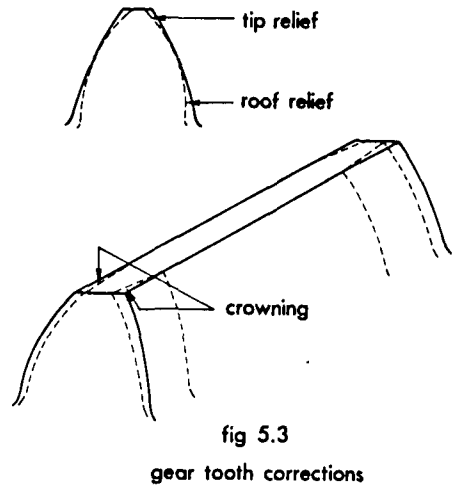


fig 5.2
motor-tachometer unit and gear train

In order to get smooth running of the gear wheels, corrections of the tooth profile, according to fig. 5.3, have been added. Tip and root relief let the teeth come smoothly into mesh and crowning avoids that teeth carry the whole load right on an edge.



A further condition to get a precise gear drive is to ensure that the tooth contact is always perfect and does not suffer from the elastic deformations of the telescope structure. This requirement was met by choosing a gear box which rides with guide rollers on the rim of the main gear wheel (fig. 5.4). This gear box is fixed to the structure only by an articulated moment arm.

5.2 Position encoders and limit switches

Both drives have two position encoders. One of them acts as an absolute encoder and is used to set the telescope with a precision of better than 10 arcsec to the required star. The other encoder reads increments of 0.2 arcsec to

make the required corrections of the telescope positioning during guiding.

The first encoder is absolute and reads the position optically from a band which is engraved and fixed to a drum on the shaft. The second encoder is driven via a friction wheel from the rim of the big gear wheel (fig. 5.5). The big reduction (1 : 100) of this friction drive gives very high resolution but due to micro-slip effects, the indication of this encoder is not absolute.

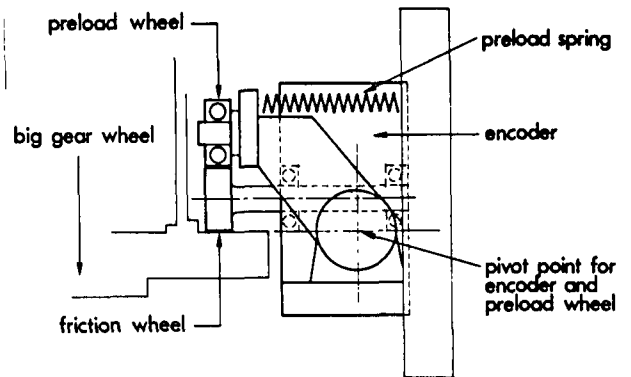


fig 5.5
incremental encoder

The polar axis has two limit switches to allow a rotation of $\pm 100^\circ$ from the 12 o'clock position. Another switch indicates whether the polar axis is in the eastern or the western range, and a micro switch locates the polar axis in 12 o'clock position .

Apart from the two limit switches for the range, the declination axis has two more limit switches to indicate vertical and horizontal position of the tube. Another two switches indicate on which side of the pole and on which side of the equator the tube is.

A further three limit switches, which work with a ball in a cone (fig. 5.6) indicate when the tube axis arrives at 11° , 7° or 6° above the horizon.

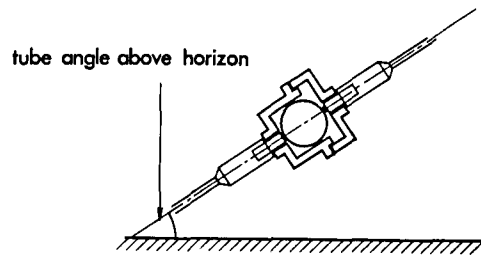


fig 5.6
horizon limit switch

All these limit switches are used in an interlock system which prevents the tube coming too far down towards the horizon. At 11° the fast drive is stopped, at 7° the slow drive stops, and at 6° the safety clamps start to fix the big mirror. Only in the 12 o'clock position of the polar axis can the tube go to the horizontal position to exchange the top units.

5.3 Damping device

An independent motor-tachometer unit acts on the horseshoe via a friction drive (fig. 5.7). This unit is provided to act as a damping device if wind forces create torsional vibrations in the polar axis.

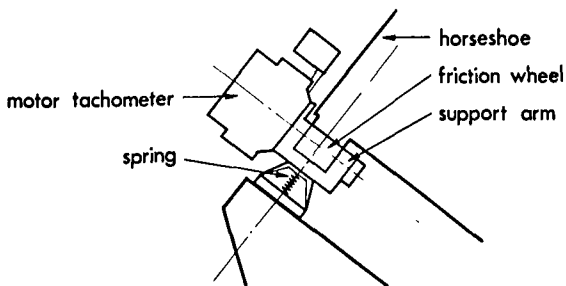


fig 5.7
vibration damper

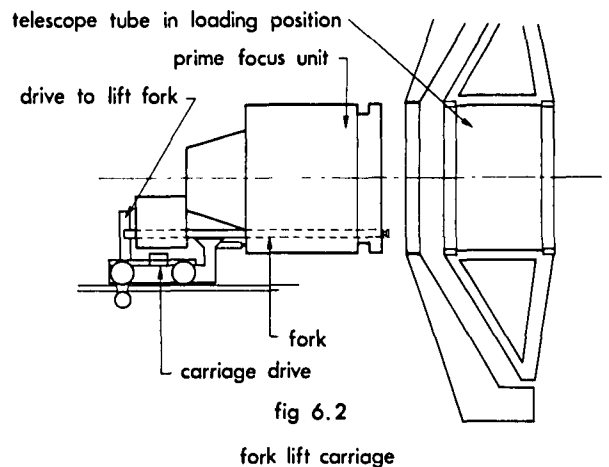
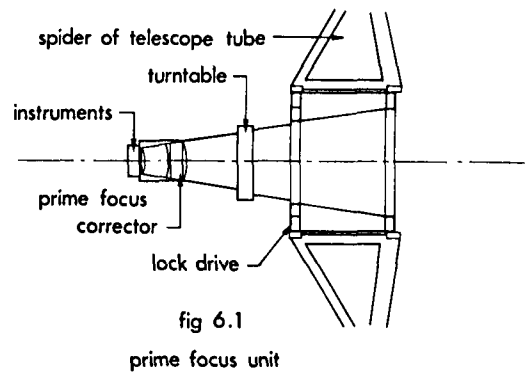
6. TOP UNITS

There are four different units which can be introduced into the upper end of the telescope tube. These units are the prime focus unit and the prime focus cage, the unit which supports the Cassegrain secondary mirror and the unit with the secondary mirror for coudé observation. When not in use, these units are stored on carriages on a platform above the observing floor and facilitate the exchange of the top units.

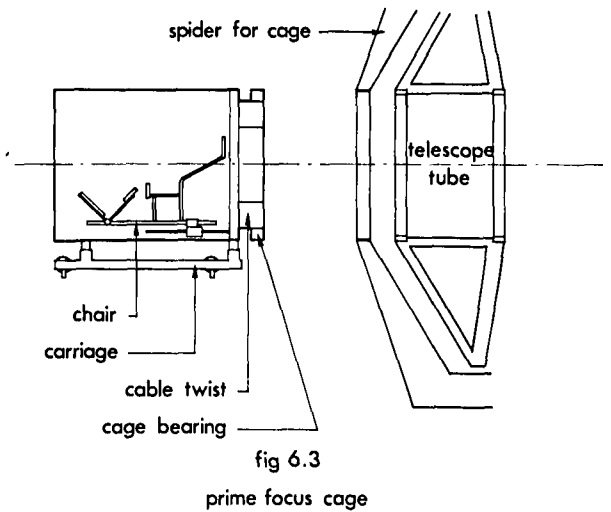
6.1 Prime focus

The prime focus unit (fig. 6.1) is the mechanical structure which supports the prime focus corrector and the instrumentation for prime focus observation. The whole unit, together with the instruments, can be brought into the telescope tube with the aid of its carriage, which is similar to a fork lift truck (fig. 6.2).

The unit has two motors which lock it to the telescope tube and a turn-table allows turning of the instruments about the optical axis of the tube. The instrumentation of this unit can be checked, replaced, and repaired, when the unit is on the carriage, where it is easily accessible.



The cage for the observer (fig. 6.3) is independent of the prime focus unit. This is to prevent the observer transmitting vibrations to the prime focus instrumentation. When sitting on the telescope tube, the cage has its own spider to the outer top ring. The space for the observer within this cage of 1.5 m outside diameter is very restricted.



It is therefore envisaged that the observer will enter this cage only to check his instrumentation at the beginning of the observation, and for the rest of the time, information is transmitted by a TV camera to the control room on the floor. Nevertheless, a chair is provided which allows the observer to adjust the head, arm and foot rests as far as it is possible within the limited space. The motor drives are also incorporated; one to turn the cage around, the other one to lift the seat up and down. Entry into the cage is from the platform, when the tube and cage are in the horizontal position.

6.2 Secondary mirrors

Two identical top units (fig. 6.4) with their carriages are provided for the two secondary mirrors viz one for the secondary mirror for Cassegrain observation, the other for the coudé secondary mirror. These units have two motor-controlled drives (collimation drives, fig. 6.5) to align the optical axis of the secondary mirror to the optical axis of the main mirror and one further motor-controlled drive, to adjust the focal point of the system

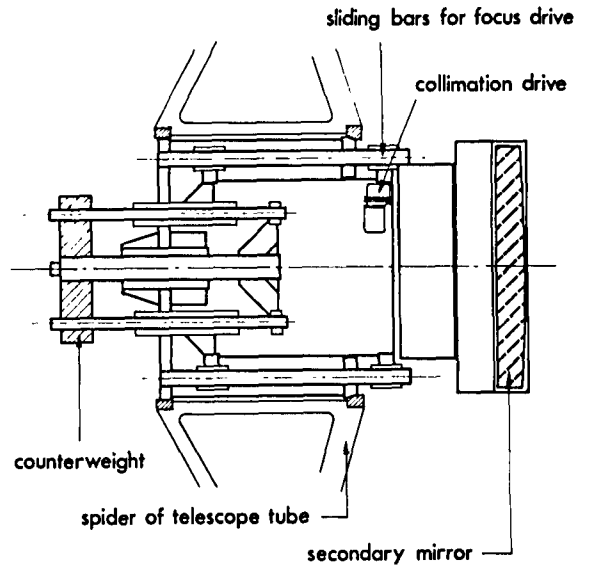


fig 6.4
secondary mirror unit

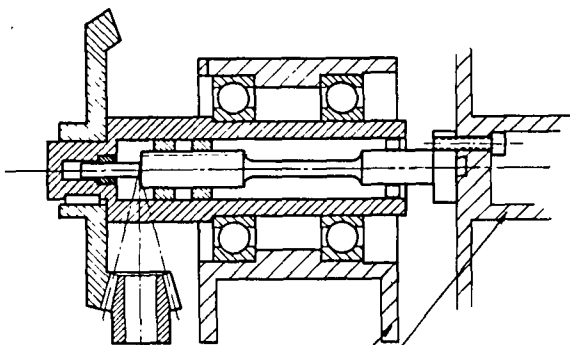


fig 6.5
collimation drive

to the position which is required for the instrumentation at the focus. This last drive has two speeds to allow a fast scan and a fine adjustment. While the mirror is displaced along the optical axis of the tube, a counterweight (half as heavy as the mirror) runs twice as fast in the opposite direction. This arrangement keeps the centre of gravity unchanged.

7. FLAT MIRRORS

The telescope is equipped with three flat mirrors to bring the coudé light beam through the structure of the polar axis into the coudé laboratories (fig. 7.1).

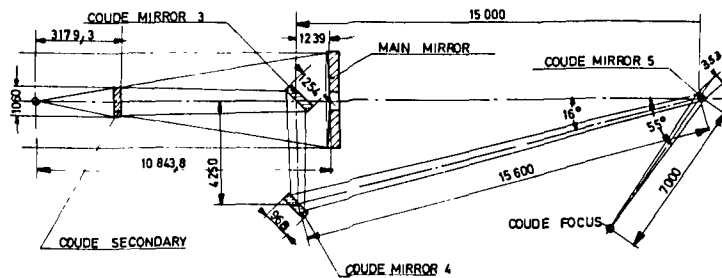


fig: 7.1 coudé light path

The mirrors can all pivot about two perpendicular axes by motor-driven devices. Their position on the structure of the telescope and their operation required different solutions for their fixation.

7.1 Mirror 3

The first flat mirror which the incoming light beam encounters is known as mirror 3. It is located in the node of the telescope and deflects the beam from the optical axis of the tube in the direction of the declination axis, hence its surface is inclined 45° to those two axes.

The mirror cell is fixed to a support structure. During coudé observation, this support structure is clamped to an extension of the central shaft of the main mirror cell (fig. 7.2). The clamping device is motor-driven.

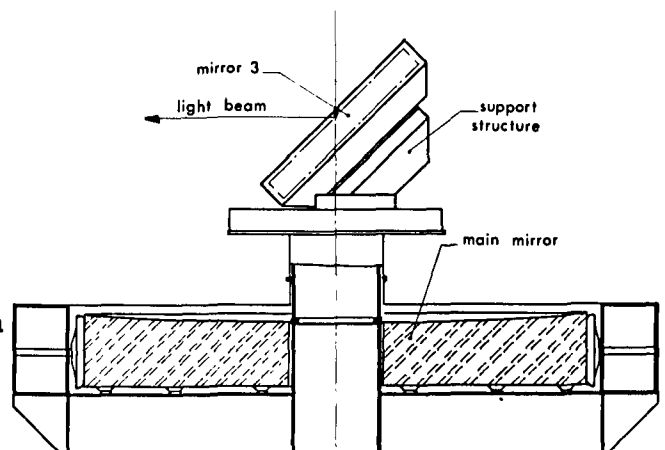


fig. 7.2 mirror 3 in operating position

7.2 Mirror 4

This mirror deflects the light beam from the direction of the declination axis into the light path through the polar axis as shown in fig. 7.1. Its support structure is screwed to the west fork prong of the polar axis. The mirror-cell unit is fixed to the support structure by means of three motor-driven screws, as is the case for the mirror 3 cell.

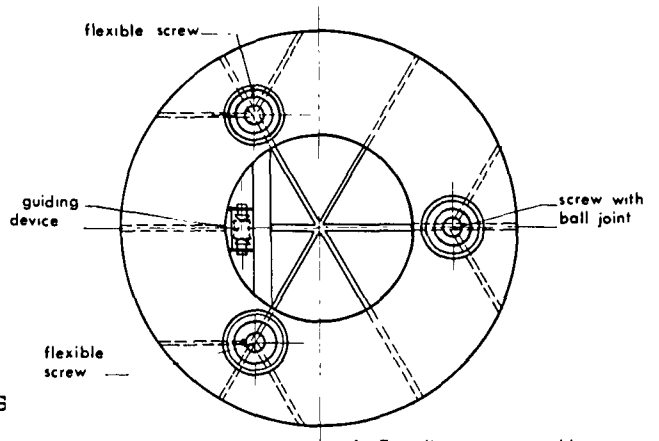


fig 7.4 alignment screw drives

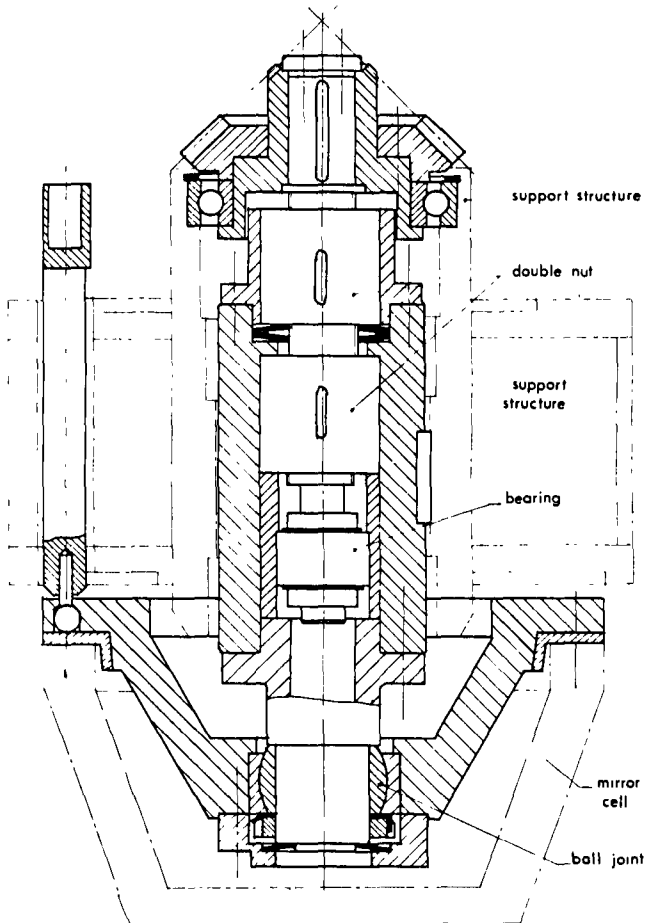


fig 7.5 screw with ball joint

The screw drives are arranged as shown in fig. 7.4, so that a tilt of the mirror about two axes is possible by axial motion of the screws. To compensate the variation of the distances between the three screws, only one screw has a backlash-free ball joint to the mirror cell (fig. 7.5).

An arm, fixed to the top of the centre section, brings mirror 3 into the stored position when it is not needed for coudé observation (fig. 7.3). The arm takes the mirror block by motor-operated pins, the clamping device is opened, and the arm can swing the

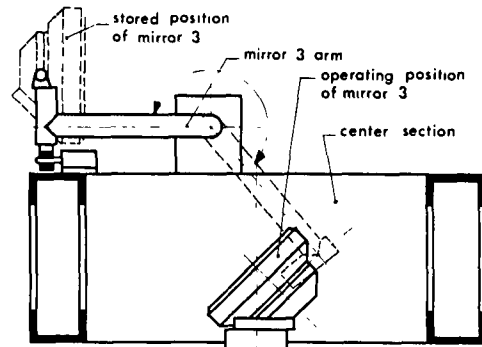


fig. 7.3 mirror 3 installation

mirror into its stored position on the outer edge of the top area of the centre section. The whole process is computer-controlled and a mechanical interlock system prevents one step until the preceding one has been completed, so that wrong operations are impossible.

A back-up of the computer control system using mechanical devices seemed to be necessary in this situation, because of the danger of the main mirror being damaged by faulty operation of mirror 3. This is another reason why the exchange procedure is carried out with the tube horizontal; the main mirror is thus in a vertical position and out of the exchange area.

The total time needed to bring mirror 3 into position or back again is two to three minutes. The operation can be effected when the top units have to be exchanged. Both operations are necessary at the same time with the tube horizontal.

The swinging arm solution offers the possibility of using a circular mirror 3, because space problems are not so acute as with a mirror stored in the centre of the main mirror, beside the Cassegrain beam.

The other two (fig. 7.6) are flexible and can only transfer axial displacements. To keep the cell free from rotation about the axis of the rigid screw, a spring-loaded guiding device (fig. 7.7) has been installed between the two flexible support screws. The screws have preloaded double nuts to eliminate the backlash. Each one is connected to an absolute encoder which permits alignment by the computer. It is possible to tilt the mirror through angles of up to 1 degree. The full course of the screws is limited by electrical end-stops which disconnect the on-off motors.

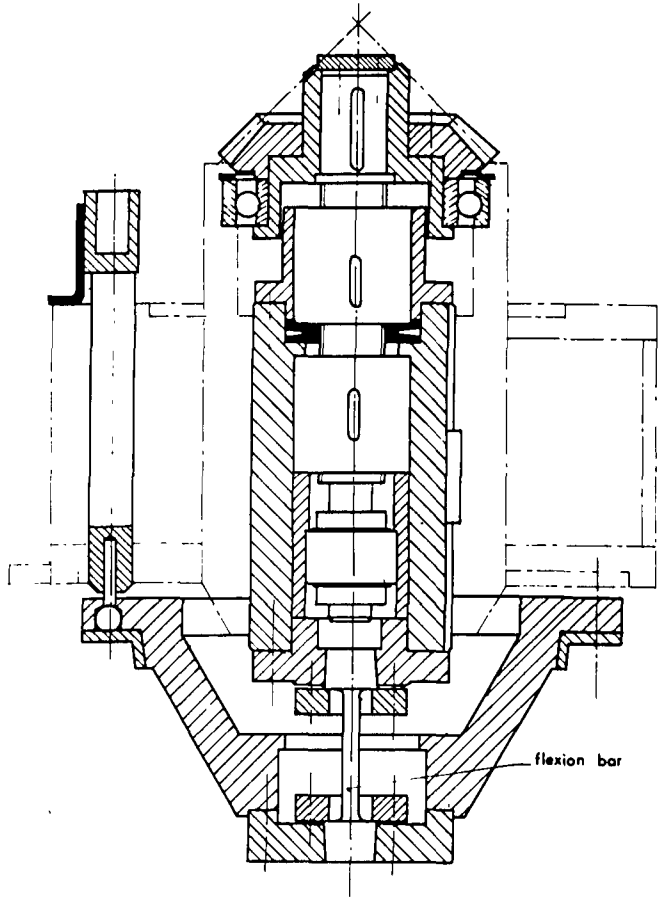


fig. 7.6 flexible screw

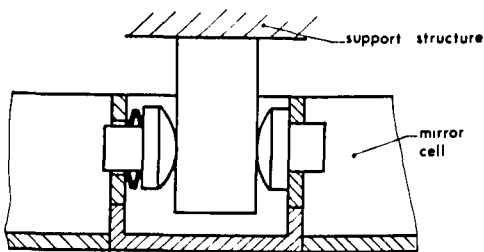


fig. 7.7 guiding device

The full course of the screws is limited by electrical end-stops which disconnect the on-off motors.

7.3 Mirrors 5 (fig. 7.8)

Mirrors 3 and 4 are part of the rotating telescope structure and thus follow the light beam automatically. The mirror 5 is fixed to the pedestal and therefore has to operate through greater rotation angles to reflect the beam coming from the polar axis light path into the coudé laboratory (fig. 7.1).

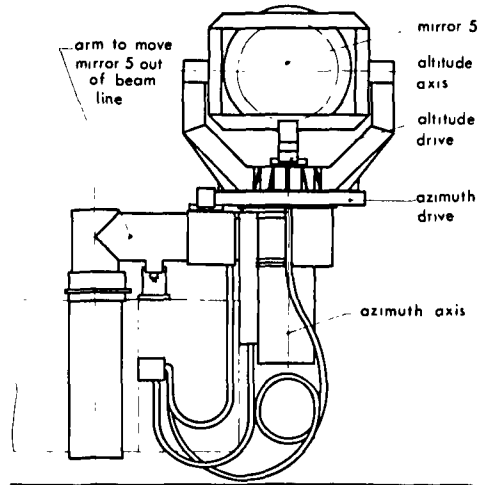


fig 7 8 mirror 5 assembly

As the direction of the selected coudé laboratory can again vary between $27,5^{\circ}$ and 55° , both east and west of north, the facilities of mirror 5 have to be rather highly developed, hence an alt-azimuth mounting with restricted operation angles. The altitude axis works from 0° to $+ 22^{\circ}$, whilst the azimuth axis can rotate from 102° west to 20° east (fig. 7.8).

Both axes are supported by hydrostatic oil pads to obtain a smooth and vibration-free motion. The oil supply is pressure- and flow-controlled so that variations of more than 10% for the oil film thickness are excluded. Maximum rotations of about 1 arcsec of the declination axis about the azimuth axis are caused by this permitted variation of the oil film thickness.

To simplify the design of the bearing bracket area, the declination axis is set back by 67 mm from the mirror surface and azimuth axis. This is especially important for large reflecting angles. The combined displacement error of this solution is minimised by optimal positioning of the declination axis in height.

The axes are driven by high precision worm gears and the backlash of the drive system is compensated by counterweights. The motors are of the Inland type and are controlled by a closed servo loop with a tacho-generator and an incremental encoder with 10.000 pulses per revolution. Worm, motor, tacho-generator and encoder form one coaxial unit as shown in fig. 7.9. Identical units are used for both axes. Due to the great facilities on the electronic control system in connection with the Inland motor, a simple one step worm gear with a ratio of 1 : 800 was sufficient. The pitch is 1 mm so that the wheel has a pitch diameter of 800 mm. Bearings and the cutting of the gears have to be of very high precision, so that the mirror can follow the beam coming from the telescope and reflect it into the various coudé channels.

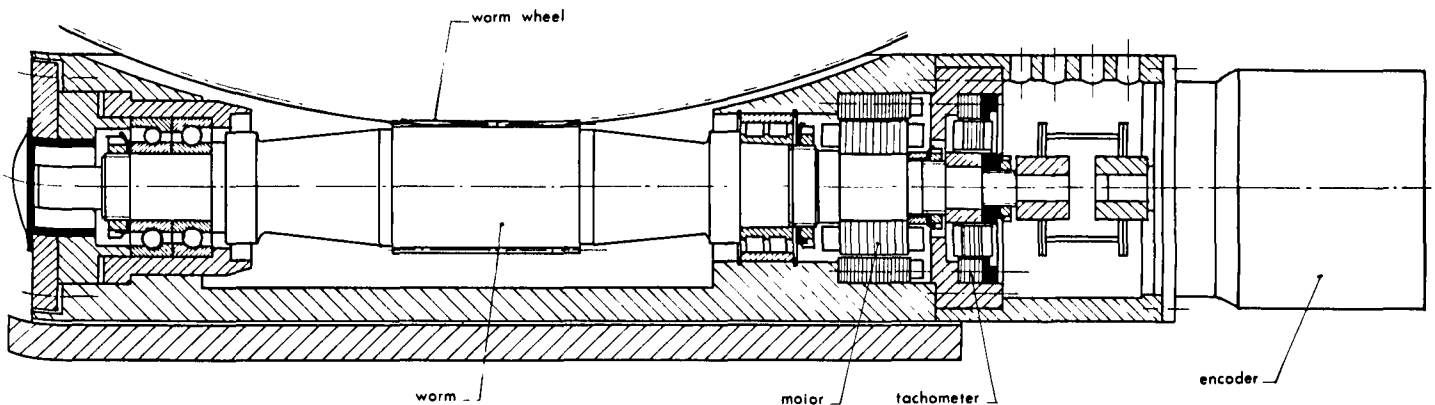


fig 7.9 drive unit

Another facility was required for the mirror 5 operation. The light beam from the coudé auxiliary telescope must be brought into the main building at an angle of 27.5° east to the south-north line, without reflection by mirror 5. For this reason, the whole mirror 5 configuration is fixed to an arm which can swing the mirror out of the

light path. The swinging arm is fixed to the pedestal and is operated by an on-off motor. Adjustable end-stops guarantee a reproducible operating position. The whole unit is equipped with several alignment possibilities so that the reflecting point of the mirror can easily be adjusted according to the real position of the polar axis.

8. MIRROR COVERS AND BAFFLES

Mirror covers are already highly developed and normally present no problem.

The ESO 3.6 m telescope, however, ended up with special mirror covers because space restrictions and beam limitations did not permit standard solutions. The same is true for the sky baffle. There, too, a special system had to be found to fulfill the requirements for both the Cassegrain and coudé beams without obstruction to either.

While all the elements of the telescope described in the foregoing chapters are of steel, all mirror covers and baffles consist of aluminium structures as far as mechanical requirements did not require other materials. The type of aluminium used is corrosion-resistant with rather good mechanical properties being strong enough to protect the mirrors from damage by smaller mechanical shocks. On the other hand, the weight is reduced to about one third of that of steel, which is important in this case, as mirror covers always sit on top of the mirror and thus induce a relatively high couple in the fixations of the mirror cell.

8.1 Main mirror cover

This cover is installed in the space between the centre section and the main mirror cell. It is fixed to the centre section for two reasons: firstly, the main mirror cell is already loaded with additional equipment unconnected with its real function of supporting the main mirror, and secondly, it would not be convenient to disconnect the cover from the cell for mirror-aluminizing procedures.

Because of the restricted space available for the cover, the basic idea was to use a large iris shutter, but even this turned out to be enormous, so a simpler, less space-consuming system, was developed (fig. 8.1 and 8.2). In the closed position, the cover is made up of a configuration of trapezoidal segments, the long sides of which are curved, following more or

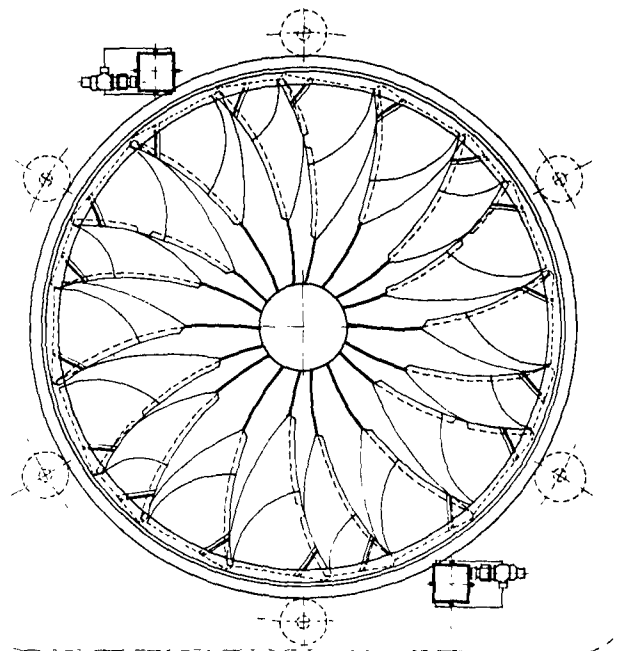


fig 8.1
main mirror cover closed

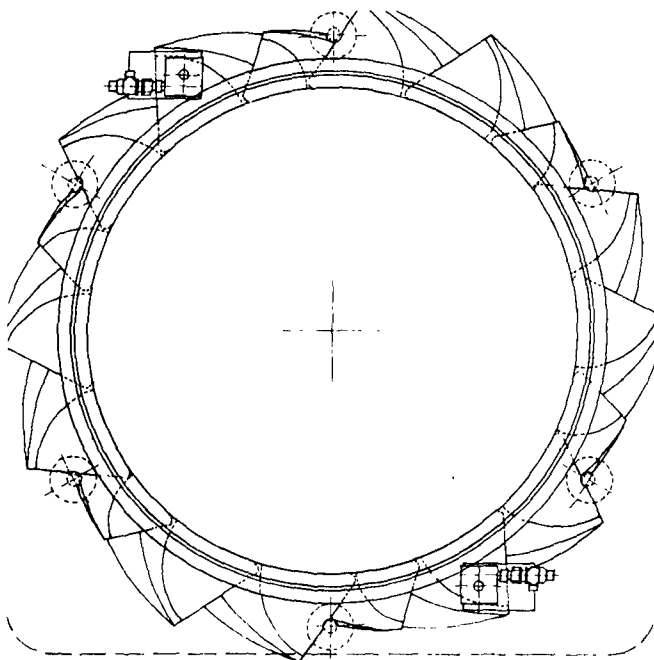


fig 8.2
main mirror cover open

less the useful diameter of the main mirror. These segments are supported in one corner by a shaft-bearing combination allowing the segments to rotate in their plane (fig. 8.1). The drive can bring them into the open position of fig. 8.2 so that the cover gives the free space for the light beam. The overlapping of the segments is either possible by an inclined positioning or - as it is done here - by arranging each

segment in three different levels. A careful study of the form of the elements avoids interference during motion.

The segments are built as closed box structures and are stiff enough to support a man. For emergency cases,

their tips are supported by the central shaft of the main mirror cell when the cover is closed.

The system is designed to fulfill the requirements of a mirror cover in the two end positions (open or closed). Unlike a true iris cover, it does not fully cover the unused part of the mirror for intermediate apertures.

8.2 Other covers

The secondary mirrors (Cassegrain, coudé) are equipped with marguerite-type covers.

The cover for mirror 3 has to open in an area in between three light beams so that it is difficult to find a solution which does not obstruct the light. Finally, a system was adopted which consists of two wings opening parallel to the major axis of the used elliptical area of the mirror. The corners of the rectangular wings are automatically folded inwards during the opening motion and vice versa when the cover is closed (fig. 8.3).

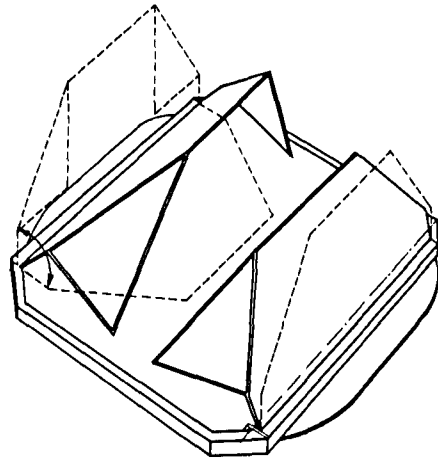


fig 8.3
mirror 3 cover

More or less the same cover system is used for mirror 4. It is somewhat simpler because only two corners have to be folded.

The simplest cover is used for mirror 5. A stiffened plate is pivoted onto the mirror surface as shown in fig. 8.4.

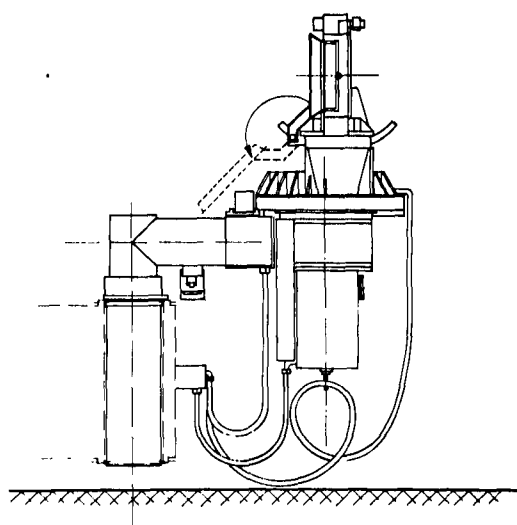


fig 8.4
cover of mirror 5

8.3 Baffles

The baffles, in general, do not require any special design, as long as they can be installed in a fixed position. This is valid for more or less all baffles which are shown in the optical layout sketch for the coude beam in fig. 8.5. Details of their optical function are given in a report on the optics.

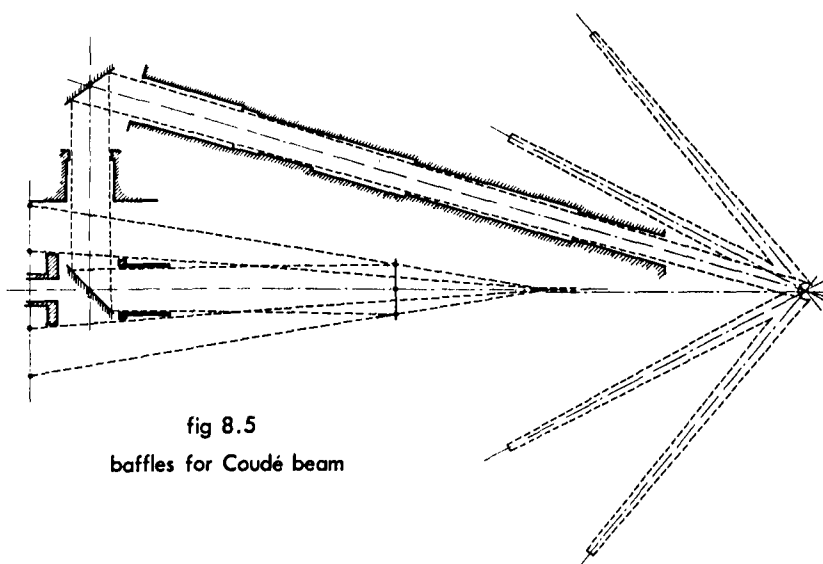


fig 8.5
baffles for Coudé beam

Only the baffle on the central shaft of the main mirror cell could not be executed as one static structure, although the beam for coudé and Cassegrain focus would provide that possibility (fig. 8.6). The baffle would then, however, have been too high up to permit the free operation of the mirror 3 arm. Therefore, a sort of a marguerite with very short blades was installed which limits the diameter for the Cassegrain beam in the closed position and lets the coudé beam pass in the open position. The motion of the blades is effected by a remote controlled motor.

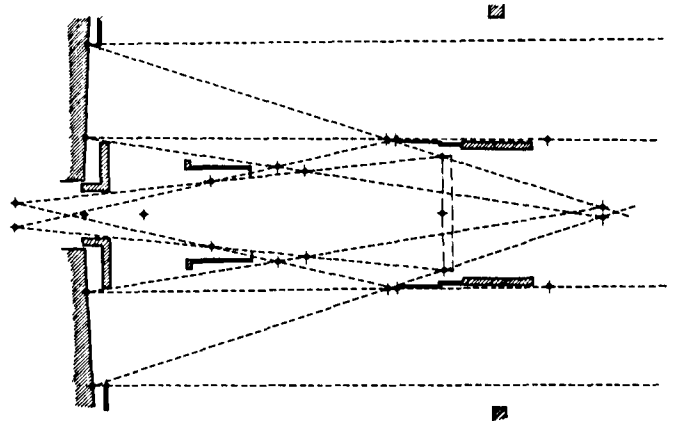


fig 8.6
baffles for Cassegrain beam

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