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OPERATION AND MAINTENANCE MANUAL

M A I N T E N A N C E M A N U A L

F o r

THE OOTY RADIO TELESCOPE

By

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MAINTENANCE MANUAL

FOR

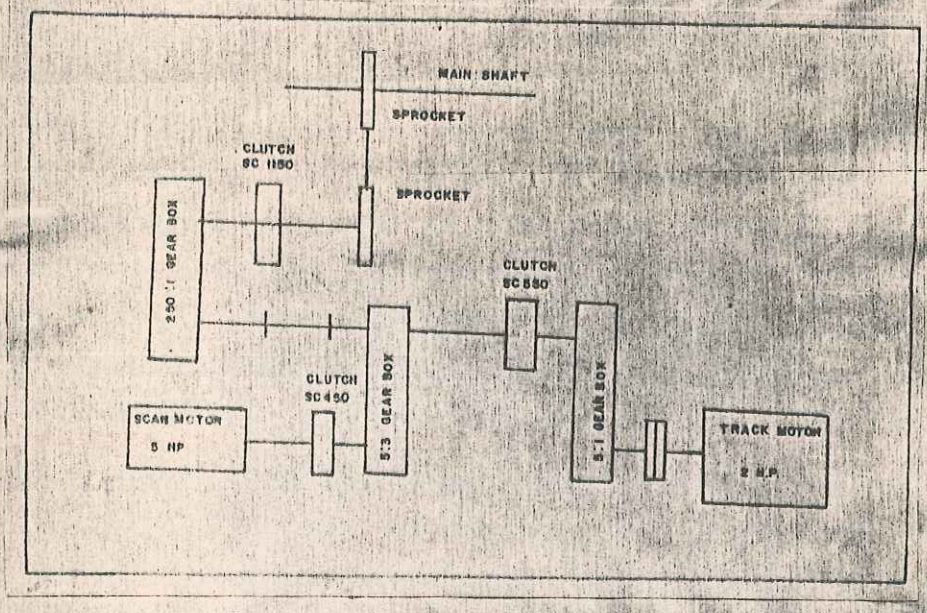
OOTY RADIO TELESCOPE

BRIEF SUMMARY

The Ooty Radio Telescope consists of 24 nos. Parabolic frames each mounted on 24 supports called Bent Supports. There are two bearings on which each frame-axis is situated, called Pivot Axis and Pivot Shaft Bearings respectively. There are 3 speeds for the telescope called Slew, Scan and Track. The Slew mode can be operated on both East and West and the speed at which the antenna rotates is 6.25 degrees per minute or 25 mts of Hourangle in a minute with the drive shaft rotating at 75 RPM. The scan mode also is operated both ways with the shaft speed being 9 RPM or the antenna moves 3 minutes in hour angle per minute. The track mode is operated only from East to West with the antenna moving 15 minutes of arc in a minute with the shaft speed at 3 rpm. Further the track motor is operated through a servo control which adjusts the speed, while tracking sources. The slew mode is operated by 4 motors of 12.5 HP each situated at Frames N_{10}, N_4, S_4 and S_{10} (Frames are numbered towards north and south starting from servo structure), called drive platform. The slew drive system consists of the motor driving a gear box of ratio 9.6:1 and the output of gearbox has a sprocket of 1" pitch and it is connected to another matching sprocket on the drive shaft with twice the no. of teeth making the speed reduction in the ratio of 1:2.

The track and scan drives are situated in the centre of the whole antenna frames called 'The Servo Structure'. The Scan motor is a 5 HP motor which drives a 5.3 gear box which is connected through the output of 5:1 gearbox and is coupled to a gearbox of ratio 250:1. The track motor is a 2 HP motor which has a braking generator and is driven through servo to suit the speed of earth, and is connected to the output of 5:1 gearbox (see Fig. below). To disengage track motor when scan motor is

working and vice-versa, two magnetic clutches are introduced (see Fig. below). The output of 250:1 gearbox is connected through a heavy duty magnetic clutch to a shaft which drives through a duplex chain and sprockets of reduction 1:2, the main shaft. The heavy clutch is to eliminate the heavy back-speeds in the gear boxes when slew mode is in operation.



Servo Platform Drives

Each frame is driven as follows: From the shaft through a duplex chain and sprockets of 1:3 reduction to the input of a gearbox whose ratio is 36:1. The output shaft of this gearbox has a pinion and this drives the drive sector of the frame made up of a channel into which pins are fitted, the ratio being 40:1.

The drive shaft extends from end to end for 24 frames (each frame of 23 metres centre) for a length of 529 metres. The shaft is a hollow pipe of 4" O.D. This is not a continuous shaft and in each frame there is a small drive shaft (solid) situated on two bearings on either side on which the brakes, sprockets are mounted. This shaft has two flexible couplings

on either side. The northern and southern shafts (considering one particular frame) have matching flexible couplings and are coupled. But the northern and southern ends of these two shafts have two rigid couplings, supported by 2 bearings. On the northern side, the other half of the rigid coupling carries a shaft which passes through a bearing and has a welded square shaft on to which the body of a universal joint, called 'Type C Coupling', is mounted. The southern shaft from rigid coupling is same but the southern end of the shaft is welded with a square bush through which the square shaft coming from the Type 'C' body passes in and is free to move, axially. Though this is the general arrangement the drive platform (N_{10}, N_4, S_4 and S_{10}) differ a little in that on these frames the brake is shifted to south to suit the sprocket of slew drive and having 2 type 'D' joints (they are similar to type 'C' but unlike type 'C' both square shafts are welded) and one flexible coupling.

The Pivot axis has 2 bearings called Pivot Shaft bearings and there are 48 nos. in the system. The pivot shaft bearings of end frames are designed for more heavier duty than the other 22 frames called intermediate frames.

The reflecting surface of the parabolic cylinder is made up of 1100 wires of 28 SWG stretching from end to end and passing through holes in the bakelite strips attached to the parabolic frame. The focus of the antenna is made up of trusses from end to end and these trusses are supported by 24 towers which are hinged to parabolic frame. The tower is movable up and down through hinge by turn buckles and guy rods to get the correct heights and also in north-south direction by 14 mm guy ropes and turn buckles. The truss between two frames is fixed as follows. On to the northern tower it is rigidly fixed and to the southern tower it is movable axially through two pipes and bearings called end connection. This is to allow for any misalignment movement of pivot axis of each frame. There are 24 nos. of 10" brakes (Electromagnetic) in the antenna, one for each frame to hold it in any position when motors are not working.

The whole antenna could be rotated for about 143 .egrees of arc from east to west.

SAFETY DEVICES

There are following safety devices in the antenna:

) Overspeed and Non-operative (undervoltage) tachos:- here are 3 tachos for slew, 2 at the ends of shaft and 1 at the ervo. For scan and track there is one tacho in servo. In case he common clutch slips while tracking, there is another tacho n servo. All these will stop the antenna if there is any mal-unctioning of speeds or the speed of shaft increases beyond 85 PM.

i) Misalignment Synchros:- The two ends of the drive shaft re connected with a gearbox of 16:1 and to this are fixed two ynchros which will detect any misalignment, breakage etc. of ne shaft and will stop the antenna.

ii) Misalignment loop:- If the frames get misaligned there re two loop systems;one at east and one at west, which have lternatively ring and insulator through which a wire passes hich is energised. When frames get misaligned the wire touches he ring and it operates a trip device and antenna stops.

r) When the antenna comes to east and west ends there are two Ms at N_1 and S_1 which will operate switches and antenna stops.

In case the antenna overshoots the limit switches there e Crush-type limit switches which will stop the antenna.

MAINTENANCE PROCEDURES

To avoid any undue damages and to check the healthiness of the system and its safety the following maintenance schedule is adopted.

Daily :

i) Helpers and mechanics check 6 frames a day, while running, the brakes, any noise, chains and sprockets etc.

ii) Helpers in shift keep log book for 24 hrs and note down any abnormalities and the working of the antenna.

iii) Daily clearance of antenna - both mechanical and electrical - to be given to observers.

Weekly :

i) Every week the antenna is brought to stow-lock position and the foll, measurements are taken. Q-point height, N-S and E-W plumbs, stow lock gaps, X, Y and P readings, Type 'C' gaps and flexible coupling gaps. Any deviation in the measurements ($\pm$2mm in all cases except Q-point which is $\pm$10mm) should be viewed seriously and the cause checked before clearing the antenna for observations. Also a table of comparison of these has to be maintained for a quick check by senior officers.

ii) Senior persons in Engineering Department should check 4-6 frames in full rotation, for any sounds, chains, sprockets and frame behaviour and should note down X,Y and P readings, brakes etc.

Monthly :

i) Checking of brakes, cleaning the coils of dust etc. to be done.

ii) Check clutches and air gaps, servo drive.

Quarterly :

i) Check motor connections, safety circuits, devices etc.

ii) Check 36 mm turnbuckles for cracks etc.

Half yearly/ Yearly

i) Take radial gaps of frames. R_{max} 6mm R_{min} 1mm

ii) Check gear boxes and gears.

iii) Check drive shaft weldings (Dye penetrant).

iv) Check drive shaft and pivot shaft bearings.

Half yearly/Yearly v) Check structure weldings and Drive contd.. sector joints, counterweight joint, pivot shaft Sq. to round, shaft joint, pivot bearing seat, tower point at parabolic frames and bent supports splices.

vi) Check motors etc.

For all the above, relevant files have to be maintained under RAC/183 series.

vii) Apart from the above, the vertificality of bent supports and its level to be checked once a year to note down any deviations.

REPAIR AND SERVICE INSTRUCTIONS

CHANICAL

Whenever any repair as also changing of any parts etc. to be done, it is necessary to follow certain precautions so to avoidany misalignment and any damages during repairs. The llowing pages give the necessary instructions:

) Whenever any work is to be done on the drive shaft like pe C flexible coupling, rigid coupling bearings, 36:1 gearbox, and 57-teeth sprockets and chain, drive pinion etc. (in short y work on the drive system of the frames) it is necessary first bring the antenna to WEST END LIMIT (stowlock) position. Then erever the work is taken up,say in a particular frame or in tween, the two adjoining frameson either sides should be locked stow lock bolts and packers. Further it is necessary to take asurements like stowlock gaps, Q-point measurements, X,Y and P c. before and after repairs to check that nothing has deviated. so, note the diff. synchro voltage - this will give you if the aft has rotated while repair was going on.

B) Now the broader instruction for each work is given elow:

1) Changing coupling bushes in flexible couplings - emove one bolt at a time, change bushes and fix back. Then otate to next bolt and do the same until all 8 bolts, bushes e changed. Rotate by track to get the positions. Never emove All Bolts.

2) Checking Drive Shaft Bearings - Drive shaft earings at centre columns, north and south brackets can be ecked thus: Open the covers and check sleeve nuts and also pacer rings. Check bearings. If you have any suspision of foreign terials in grease, change grease. But when you check bear-ngs on platforms - the bearings on either side of the brakes d sprocket - first put the stowlock bolts and proceed as ove.

3) Changing Flexible Couplings, Rigid Couplings - ing the antenna to stow lock and do as per instruction at). Then mark the 2 halves of couplings (Match Mark) and sconnect. The one half can be changed and, while fixing, it is solutely necessary to fix the Match Marks.

In case you are changing both halves of the coupling t match marks as also match marks on the other ends and see at these match markscoincide.

Further, while fixing coupling on the shaft, it is cessary to ensure the following:

i) The key's taper is progressive from end of the shaft.

ii) No undue hammering on the coupling to force it in.

iii) Neither it should be slide-fit.

iv) To put back Thimble screws from coupling to key.

v) That the shaft is flush with the face of coupling.

4) Changing Coupling's Stub Shaft - Proceed first as er instructions (A), then put match mark on couplings and remove haft. Now Remove coupling and key. Put centre marks of keyway o the main shaft-line. Measure the exact distance within ±1mm he length of shaft. Gouge out the welding and then remove stub haft. Fix new shaft. Measure the length with same tape and eep the length. Also align the keyway centre line to the centre ne on the shaft. Spot weld. Put the whole shaft on two paralled r' Blocks. Put a dial gauge on the newly fixed shaft. Take eadings of out. By tapping adjust within ±2 thousands eccentricity otweld on 4 sides. Recheck dial readings. Recheck the length d centre line. If everything is in order Weld 1" on 4 sides d continue welding 2 runs. After cooling check welding by Dye- netrant test. Fix back the shaft and align match marks and nnect.

5) Changing Type 'C' bodies, shaft and square bushes -

) Type 'C' Square Shaft: Follow instruction (A). Then move Square Shaft. Check Bushes. The Vernier measurement ould be 1-75"± 0-001" only. Take a new Square shaft which ould also be within the tolerance. Then slide through square sh. Fix type 'C' body and put cotterpin after greasing. Put e bottom split pin.

) Type 'C' Body Changing: Follow instructions (A). Then nove the pins on both sides. Remove the body. Fix another ly. This should go in slide fit. Check the measurement of pe 'C' gap. It should be within 10mm+30mm. Put back the cotter- ns and split pins.

Changing Square Bush: Follow instructions (A). Then k the centre line of the square faceon one side and get this e right through the shaft to the other side of the rigid pling and on to the coupling. This is a must since the square es turn by 90° and rigid coupling turns by 60° (6 bolts), to matching. Further take the length over ends within ±2mm and e 'C' gaps. Then Gouge out the welding and remove the square

bush. Get a new square bush, mark the centre of one side square and match it to the line on the shaft. Measure the length and keep it to original as far as possible within ±2mm. Put dial gauge and set the eccentricity on the square bush to ±2 thousands of an inch. Check all the measurements like length and match line and weld with Eutectic 670 or 680 rods. Check the welding with dye penetrant.

6) Changing or Setting Drive Sprockets: - First check the pitch of the sprockets to be fitted and put the chain and see that the chain sits properly and rotate the chain around the sprockets to ensure that matching is O.K. Then follow instruction (A) and remove the sprockets. Put the new sprockets and align the straightness within ±1mm. Then put the chain.

7) Chain Changing, Re-rivetting - Follow instructions (A). Then remove one of the rivets and chain. For rivetting, check the rivet link first that the one side is properly rivetted and put it. Put the cover plate and with the tool, rivet the outer side while placing a flat plate against the other side. Mark this and check while running. It is advisable always that rivetting is done with chain on the sprocket teeth.

8) 36:1 Gearbox repairs, overhaul - Whenever this gearbox is taken up for work it is very important that the frame is firmly locked and the load released from the pinion on the drive sector. Follow instruction (A). Then whenever any bearing or shaft is to be taken out it is highly important to use pullers (suitably) to remove rather than hammering. (If gearbox is removed from its position mark the 4 corners along edges, note down the packings under and list. This has to be returned). Please note that these gears are shrunk fit and they cannot be removed from shaft. Do Not Hammer Trying To Remove Gears.

9) To Adjust Clutch-Air Gap and Alignment of Clutches- In servo structure there are 3 nos. Fawick Magnetic Clutches. It is necessary to adjust the air gap after checking it regularly,

say once in a month. The recommended air gaps are:

SC 1150	24 thou of an inch
SC 450	14 thou of an inch
SC 550	14 thou of an inch

For detailed adjustments see **Fawick** Service Instructions in file No.RAC/101-14. Roughly:engage the clutch and between the two halves check the gaps by feeler gauge. If the gap is not concentric adjust by bolts (there are 8/6 bolts by which the gap as well as concentricity can be adjusted) we need to adjust the gaps once in 3 or 4 months only, and the gaps can be adjusted 3 times. After 3 times by removing the above bolts the friction discs have to be removed through and new discs fitted.

If the spline is loose there will be sound and this has to be set right. If the bore is loose we have to give shim inside but not in pieces but in one piece covering 300° to get no eccentricity.

10) Shimming the Drive Sector for Reduction of Radial gap - For shimming any part of the sector of the drive sector first bring the drive sector to be shimmed to the west side and ensure that the next sector (in east rotation) should be on the pinion and preferably in the middle. Then loosen the nuts and bolts and hang the sector by long bolts (in intervals). Then put the shims. The shims should be so cut that it passes through one bolt. The shims are to be given for alternate bolts so that all gaps between bolts are covered. At the ends stop with preceding bolts since some of the bolts will pass through the joint of the sector. In case shimming is not uniform say at one end 6 mm and at the other end 3 mm, the reduction must be gradual. Tighten the bolts.

In the last sector (184-208 pins) you cannot bring the sector to west. In this case keep the sector in east.

In the concrete portions some of the bolts may slip. These things have to be cut off. Now, to put fresh bolts,proceed

as follows: Once you have removed the old bolt, place a jig plate to get the centre of bolt. The jig plate will have two sides of the bolt holes open. Place the bolt through the hole in the channel (The hole has been made bigger) and weld the bolt. Check the centres. Remove the jig plate and try sector to pass through the bolt. Ensure centres are O.K. Then full weld the bolt carefully so as to avoid any weld material projecting from the surface.

11) Adjusting Pinion, Slotting the Sector - For X and Y Correction - When X or Y becomes less than 1 mm then study the X, Y readings as follows. Min X plus Min Y. Suppose this is 6 mm and Min X is 0 and Max Y is 6 you can safely push the pinion north by 3 mm. For this break the pinion locks and take the P = pinion distance measurement (initial). Now Push the pinion north or south as the case may be and check pinion distance again to ensure that the required amount is pushed. Note down the correction in Readings (weekly) Reweld Locks. Check X and Y in full rotation.

Sometimes both X and Y will be low. In such cases we cannot push pinion. Then the sectors have to be moved. In such cases study the readings carefully; If both X and Y low readings do not appear in concrete portion, and only one side is reading low, draw a tabular column. Proceed as follows. A typical example is givem below:

The concrete portion is between 61 pin - 157 pin. Now X readings are low at say 74th pin being 0 mm. You can push the pinion by 2 mm. In that case study what will be the readings at 1 - 61 pins and 158 - 208 pins. Here you can slot the sector as there is no concrete. Check the table and preferably get somebody to recheck it before taking a decision.

In case the free portion is to be slotted proceed as follows: (1) loosen all bolts. Put longer bolts at 5 places and hang down the sector. Now cut slots to the required distance towards the direction in which the sector has to be moved in the

channel. NEVER CUT SLOTS IN SECTORS. Refit sector. Now place 5 or 6 stoppers on either side of the sector between the channel and sector and weld them. The stoppers should not project out of channel web, and should not be welded to any drive pins.

Sometimes both X and Y will be 0 in the concrete portion. In such cases decide to take one sector only and the other readings can be adjusted by moving pinion. In this case remove the sector and remove the bolts by cutting. Now whichever way the sector has to be moved cut slots in channel (when you put continuous cutting the concrete will get heated up and brake out and will not allow metal to be cut. Do it in short spells. Weld the bolts as in the case of shimming. Then refill the slotted area. Fix back sector and put stoppers.

12) Changing a Brake or Shoes etc. - The usual problems in brakes are as follows: (1) Coil burnt (2) brake shoe lining worn out (3) if the coil is burnt the brake will not work and the antenna will stop with brake failure annunciation. Check the coil for continuity and if burnt remove the coil. Fit the spare coil from Magneto Electricals, with Class 'F' insulation and check that the gaps with plunger inside is equal. This is essential since the brake is mounted on 11° slope. Keep the plunger gap to 16 to 18 mm.

If the brake shoe is to be changed remove the shoes by taking out the Dowel pin and take off the rivets. Fit new liners and mark rivet holes. Drill andcountersink the holes. Then put the countersink rivets from liner side so that the head of rivet is well inside the liner and rivet on outer side. Fix shoes and keep 0.5 mm (20th) gap on all sides between liner and drum by pressing the plunger.

Adjusting the brake torque: If the brake torque is to be adjusted this can be done by adjusting the spring. There are two nuts on the washer of springs between bars. Loosen check nut and if more torque is needed tighten the inner nut or vice versa. Check the length of spring before and after (6" length gives about 70 - 80 lb ft. of static torque). Now the plunger gap will be varying.

Adjust these gaps by adjusting outer nuts on shoe bar to 16mm to 18mm and check the released shoe gap (0.5 mm).

Whenever new brakes are to be fitted it is essential to check the coil for 1000 operations with circuit available. Also a micro switch has to be fitted on plunger and bar so that when the plunger is pressed the microswitch operates and when released it goes off.

13) Adjusting 'Q' Heights - 'Q' heights have to be adjusted by 36 mm guy rods turnbuckles. Supposing the 'Q' height is to be say 1600 mm and it is 1580 mm only then it has to go up by 20 mm. Now arrest the stow lock and put packers. Loosen the bottom guy rod by turnbuckle till the guyrod is loose. The turnbuckle is to be loosened by putting arod between the body and NOT BY HAMMERING. Now take the height. Let it be say 1591 mm. Now put a jack under the tower and lift the tower to the height of 1620 mm. To tighten top guyrod put two wooden poles through the Par. angles and tie them taking care to insert the poles through S.S. wires. Now with a rod through turnbuckle tighten. If it is too tight hammer at the end of the rod and NOT the BODY OF TURNBUCKLE. CLEAN THREADS IF NECESSARY.

Now, after tightening the turnbuckle loosen the jack. The tower will get lower, and stay at a height. This height is to be kept +8mm, than required. If this height is not achieved again readjust as above till you get the value. Once the height required height +8mm) is got remove jacks etc. and tighten lower guy rod turn buckle to get the required height (+ 8mm adjusted by lower guy rod gives about 1 T tension in lower guy rod). Any other measurement will make the tension lower or higher as the case may be).

14) To Adjust north-south of 'Q' point - These can be done 14 mm guy ropes on either side of the tower and their turnbuckles. Suppose one tower is to be adjusted north first take S plumb readings of 2 adjacent towers' 'Q' points. Then by tightening the north or south rope and loosening the other rope

djust the plumb. Sometimes the end connections may be jammed. n such cases loosen slightly both side ropes and by a wooden ole between tower and truss ease up the end connections. If ecessary do the same for adjacent towers and then adjust for lumb. Take again readings of the 5 towers for plumb, with ower adjusted being the middle one.

15) To Repair or servicing anchor tower bearings - Under circumstances Anchor Tower Bearing covers are to be opened less the following precautions are taken:

i) Dr. G. Swarup and Shri M.K. Bhaskaran must be informed.

ii) Shri M.K. Bhaskaran to certify and check that the tension plate, to which the ropes are attached, is properly anchored and tension released from Thrust bearing.

iii) A 36 mm bent rod to be welded to protect the shaft from lifting up.

iv) To anchor the plate, weld a plate and fix bolts from the tension plate and release the thrust from the bearing.

Now the bearing covers can be opened and any repairs may be ne, as in the case of pivot shaft bearings.

17) Structural - To ensure proper checking of structural mbers and to keep a watch on the deviations, it is necessary to the following checks.

Bent supports verticality:

The bent supports may deviate both in north-south and east- t directions. Hence two centre line marks are put on the bent pports (Vertical legs) on either side. Survey is being done rly for verticality and also the deviations. The deviations noted by putting a theodolite to the bottom mark and vertica- shifting the collinator to point at the top mark of legs, on h north-south face and east-west face. The deviations are ed.

Straightness of feed towers and trusses:

To know whether any deviations or local kinks haave taken ce in the trusses and tower it is necessary to note down the

readings. For this, in the feed tower on the 4 main angle sides a flat has been welded at two ends. These flats have grooves at 100 mm distance from the side face of the angle. The 28 SWG S.S. wire is stretched between the flats with one end carrying 4 kg weight through the grooves. There are markings (Centre punch) on the angles at equal distance. Starting from east or west the distance between the angle face and the wire is taken at markings and noted down. This is being done yearly or so, so as to ensure any deviations areshown comparatively with previous measurement.

In the same proceedure the truss straightness is taken on the 3 angles.

3) Checking of Turnbuckles:

Turnbuckles (top or bottom) of 36 mm guy rods, 14mm and 19mm guy ropes have to be tested visually for any cracks and loosening of threads etc. yearly.

Whenever a turnbuckle is to be adjusted please proceed as follows:

The 14 mm and 19mm turnbuckles can be adjusted easily as well as bottom 36mm guyrod turnbuckle. First put a bar in the yelet towards the rope or rod as the case may be and put another ong cross bar through the turnbuckle body and turn the screw body. n case it is tight first see whether the arresting scres are oosened fully and also clean the threads. If necessary hammer the row bar from the body of the turnbuckle. Never hammer the body of he turnbuckle direct. After adjusting, tighten the arresting crews and also the threads to be greased. Further fix back the ross wire (GI) and seal.

The 36mm turnbuckle (top) can be adjusted in the same way it care must be taken not to cut wires (S.S. reflector) when itting wooden poles. Further remove tension in the guy rod by ifting the feed tower by putting a jack under it at nose portion. ver hammer the turnbuckle body. If the load and tension is moved from guy rod it will be easier to rotate the body of the rnbuckle.

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D) Yearly checking of bent supports welding at splices and pivot bearings base:

It is necessary to check the welding of the above points in order to ensure that there is no cracks or so. It is desirable that even when the observations are going on bent supports splices and pivot shaft bearing bases can be checked, at the rate of one frame a week. First, do visual inspection for any apparent cracks and in case of any doubt, clean the surface and do a dye-penetrant test.

Also it is necessary to check the welding at square shaft to round shaft at pivot axis for any cracks.

Further please do not forget to paint the portions cleaned for checking.

16) General Service and Repair Instructions: -

A) Whenever any welding is to be done on a shaft situated on bearing please ensure that a separate good earthing is given from the shaft by'passing the bearings. On NO occasion the bearing should become a part of earth connection.

B) Under NO Circumstances, a brake is to be by'passed.

C) Under No circumstances, any work is to be done on the Drive system in the telescope unless the antenna is stowlocked and fuses for motors or MCC is put out.

D) WHENEVER ANY SAFETY DEVICE FAILURES OCCUR STOP THE ANTENNA AND INVESTIGATE. DO NOT TAKE ARBITRARY DECISION AND BYPASS THAT CIRCUIT. IN CASE IT IS TO BE BYPASSED BECAUSE OF SOME FALSE FAILURE ALSO, PLEASE GET CLEARANCE FROM ANY THREE OF THE FOLLOWING:

Dr. G. Swarup
Dr. M.N.Joshi
Dr. V.R.Venugopal
Mr M.K.Bhaskaran

E) NEVER HAMMER A TURNBUCKLE ON ITS BODY.

F) NEVER OVERHEAT, EITHER BY CONTINUOUS WELDING IN SAME SPOT OR BY GAS WELDING, ANY STRUCTURAL MEMBERS UNDER LOAD. ESPECIALLY BENT SUPPORTS.

G) NEVER GIVE SHIMS ON THE SHAFT ON ONE PORTION. IT SHOULD COVER UNIFORMLY FOR ATLEAST 300° OF ARC.

H) ONCE, A REPAIR, INSPECTION OR CHECK IS DONE DO NOT FORGET TO PUT BACK SAFETY COVERS, RAIN COVERS ETC.

I) CHECK HIGH SPEED GEAR BOXES OIL LEVEL REGULARLY.

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Shri. N.V. Nagarathnam

O O T Y R A D I O T E L E S C O P E

INSTRUCTION MANUAL

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SECTION I

IMPORTANT INSTRUCTIONS FOR OBSERVERS

ENEVER YOU START OBSERVATION FIRST CHECK THE FOLLOWING:

Check in Control Room Book and Board for rotation clearance. there is no clearance DO NOT START.

Check all lamps are burning especially (i) DS ON, (ii) MA1 , (iii) MA2 ON, (iv) TACHO ON.

Check clutch by pressing the clutch test buttons. The licator above should move. If the indicator Does Not move NOT START.

WHENEVER THE TELESCOPE IS STARTED, before starting, check ALIGNMENT LOOPS 1 and 2 separately by pressing Test Buttons the annunciations should come. If not, do not Start. Inform ntenance.

WHILE THE TELESCOPE IS IN OPERATION IF ANY ANUNCIATION ES IT SHOULD BE INVESTIGATED. DO NOT TRY OVER AND OVER TO RUN. MISALIGNMENT LOOP COMES CHECK WIND SPEED. ALLOWED SPEED ARE: CK - 35 Knots p.h. and SLEW - 40 Knots p.h. If the wind speed ow and still M.A. window glows DO NOT START AT ALL. THERE IS AJOR TROUBLE. INFORM AT ONCE. SAME APPLIES TO M.A. SYNCHRO, OVERSPEED. WHEN THESE THREE FAULTS ARE ANNOUNCED YOU SHOULD NOT T ON ANY ACCOUNT

The helper on duty should be asked to go around the scope area and check for any unusual sound, vibration etc; y two hours the observer should get the report. If he reports discrepancy the telescope should be stopped immediately and enance section informed.

During operation, watch the antenna position indicator ially seconds Synchro. Check with time. During slew, very minute the second synchro will rotate 25 times to 26 . If it is more than this, stop the telescope similarly rack one rotation per minute and for scan 3 rotations per e. This is very important.

ML/mm:270773 MAINTENANCE SUPERVISOR | MAINTENANCE ENGINEER

SECTION II

GENERAL OPERATING INSTRUCTIONS

. The power for the ORT control system is obtained through he 200A TPN switches located in the switch gear room.

(a) Keep the handle of 200A TPN switch (MCC) of the .V. Panel in the "IN" Position.

(b) Switch on the 200AMAIN SWITCH IN THE MCC RACK

(c) Push the sticks on the two instantaneous undervoltage elays upwards and the red stripes on the undervoltage relays is ept covered by the white card even if you take out your hands ff the sticks. In red box, if white card does not hold, do ot proceed further and call for assistance.

(d) If (C) is OK switch on (i) Control Supply,
(ii) Servo Rack Supply
(iii) Tacho supply
(iv) SLM Heaters
(v) Brakes
(vi) Scanning Motor
(vii) Tracking Motor
(viii) Slewing Motors (Four Green Start Switches of the slewing motors marked N10, N4, S4, S10).

After (d)(i) is done the control supply lamp will glow. .COME UP TO ACP in Control Room.

On the control panel check out for the glowing of the lowing lamps:

(i) Undervoltage
(ii) Clutch Power
(iii) MA-1 lamp
(iv) MA-2 lamp
(v) DS lamp
(vi) Tacho lamp.

A. If lamp (ii) does not glow check the clutch power supply situated at the bottom of the left side of ACP whether theswitch is in "ON" or "OFF" position and restore it to the "ON" position. The power supply meter should read around 135V D.C. Check the fuses, if the lamp does not come after the switch is put to "ON". Call for assistance if replacing fuse does not help. Fuse should have a 2 Amp. rating for D.C. and 1 Amp. rating for A.C.

B. Lamp (iii) and (iv) indicate the healthiness of Misalignment Loop System. They should normally glow. If they do not glow corresponding annunciation will come. If you do not get any annunciation but the lamp does not glow, change the bulb and see. Check the power supply which is above the clutch power supply. Note down the readings of MA Loop Voltmeter. If it does not read any value change the fuse of (AC)/DC and watch out for the lamps to glow. Incase of annunciation and lamp not glowing adopt the following test procedure:

I Press MA-1 Test push button and see whether the lamp glows. If it does not glow then it means that the +ve wire or -ve wire is cut. +ve wire means the stainless steel wire through the centre of the loop. -ve wire is a PVC wire running along the truss or frame connecting the loops.

II Now press $\frac{\text{PB - Test}}{\text{MA}}$ and $\frac{\text{PB - Test}}{\text{+ve wire}}$ simultaneously and see whether lamp glows. If it glows, it means +ve wire is OK. If it does not glow +ve wire is cut. To see whether +ve wire is cut, check physically the wire by walking along the telescope.

III Now press $\frac{\text{PB - Test}}{\text{MA}}$ and $\frac{\text{PB-Test}}{\text{-ve wire}}$ simultaneously and see whether lamp glows. If it glows -ve wire is OK. If it does not glow -ve wire is cut.

On performing these tests, one should be able to find out what is wrong with the misalignment system. Call for assistance.

C. Lamp (v)

(i) Check the reading of the DS Meter. The reading should not be beyond the red mark.

(ii) Check the fuse in the Misalignment detector box kept on the Servo Rack # 2 in Servo Room. If it is OK and still the lamp is not coming CALL FOR ASSISTANCE AND DO NOT PROCEED WITH THE ROTATION

D. Tacho Lamp:

If tacho lamp does not come check out for the corresponding HRC fuse in MCC. If that is OK and you do not get the lamp indication CALL FOR ASSISTANCE.

If all the six lamp indications are OK you are through to switch on CONTROL SUPPLY.

2. Also make sure whether Master cut out is in the "ON" position.

3. Energise Control Supply by operating PB-CS ON .

The Control Supply lamp will come "ON" and the system is ready for operation.

Brake Meters will be indicating position 1 or 12 in A or B. If the pointers are not moving check the power supply which is located in the M.A.loop chasis below. Check the fuses.

4.A. FOR SLEW MODE, Press START EAST/WEST - till the EAST/WEST lamp comes "ON". The SLEW lamp also will come "ON".

(i) Check if the brake meters register the value O.K.

(ii) Watch out for the variations in the Differential synchro error meter. They should not exceed 1.5 volts.

(iii) Check the Antenna Position Indicator for smooth running.

4.B. SCAN MODE: Before pressing Scan start push button the following tests are to be performed.

1. Checking the scan clutch by pressing the Scan Clutch Push Button and watching out for the indication of Scan lamp and meter reading upto the value marked scan.

2. Checking the common clutch by pressing the COMMON CLUTCH PUSH BUTTON and noting the common clutch indi cation lamp, the meter reading upto the value marked common.

If the above test performances are OK then proceed with the rotation.

NOW PRESS THE SCAN START EAST/WEST Push button till you get the EAST/WEST lamps glowing. The SCAN lamp also will come "ON".

The scan and common clutch lamps will be "ON" and the meter reading should be above the "red mark".

In case it goes below red mark immediately inform maintenance personnel and one of the senior scientists. Performance of brake meter, diff. synchro error meter andA.P.I should be watche d as in slew mode.

4,C. TRACK MAINS The following tests are to be done before starting the telescope:

1. Testing of track and common clutches should be done by pressing the respective push buttons, and lamp indication, meter reading must be checked.

Now you press Start Track WEST push button till you get the west lamp and track lamp comes"ON".

The clutch lamps will also come "ON" and the meter reading should be above the red mark.

The same observations of brakes meter, misalignment synchro reading, and API to be made as in Slew Mode.

5. What to do when you get following annunciations during the above operations:

a. BRAKE FAILURE - If it is not possible to rotate the telescope and you get the annunciation brake failure, try the rotation again and watch out the brake meter reading in both A and B posi tions of North and South brake meters.The value at which the pointer stops gives the brake which has altered. If you get different values at A and B position both the brakes have failed. Whenever the brake fails and telescope stops press Wait a Min.Button. Sometimes it may be

momentary fault and after 2 or 3 operations if you cannot get ing with the telescope call for assistance.

b. CLUTCH CURRENT FAILURE - If you get this annuncia- on, watch out for the clutch power supply fuses. If the fuse found OK call for assistance.

c. MISALIGNMENT LOOP - This is the third important nunciator in the system, the other two being Misalignment nchro and overspeed in order of importance. If this annuncia- on comes one should become very alert immediately. Before setting note wind speed. If wind speed is low (i.e. <20 Kn) i the annunciation has come, something is seriously wrong. NOT PROCEED FURTHER. If the wind speed is around25-30 Knots d the annunci ation has come, try to reset it. The fault in is case is likely to be because of high wind. If wind exceeds knots bring the telescope to west position. Inform one of e senior scientists immediately at whatever time of the day or ght.

Also watch out for the indicating lamps; if they do not ow (i) Check the power supply fuses

(ii) Perform the tests described in 2 B.

But if you observed that wind speed is low, the +ve and e wire indication lamp and power supply are OK but still you t the annunciation and cannot energise control supply, CALL FOR SISTANCE AND DO NOT START ANY OPERATION TILL YOU GET CLEARANCE DO SO FROM CONCERNED PERSONS IN WRITING.

d. When you get Antenna End position annunciation, e telescope will be stopped automatically.

e. WAIT A MINUTE - Whenever you stop the telescope is annunciation will come and it will go off after a minute. ring the flashing of the window you will not be able to start e system.

f. OVER SPEED - When you get this annunciation during an/Track or Slew operation, you MUST CALL FOR ASSISTANCE AND LESCOPE SHOULD NOT BE STARTED unless it is cleared in writing.

g. MOTOR TRIP - If you get this try to reset it; if it is not getting reset and the annunciation remains permanent call for assistance.

. Differential Synchro annunciation is the most important of all annunciations and should never come during the normal operation of the telescope. If it comes, first inform the Scientist-in-Charge immediately and record in log book. Then check the fuse of the misalignment detector box located in the servo room. If that is OK, CALL FOR ASSISTANCE AND DO NOT ROTATE.

6 Bypasses in the Control Panel

(a) Misalignment bypass - By using this rotary selector switch on the control panel one can bypass EAST or WEST misalignment incase of emergency.

(b) Slewing Motor bypass - This selectorswitch allows one to run the telescope on three motors alone in case of failure of any one of the four motors. The selector switch has to be placed in the position of the motor to be bypassed and the corresponding motor has to be switched off at M.C.C.

Both operations (a) and (b) may be performed only after written approval is obtained from the senior scientist present at the time of emergency.

(c) East Limit Switch, West Limit Switch by Passes - these can be done in case of need without approval. A record of such bypasses should be maintained in the log book as well as a separate file in the control room by the observers.

7. 1. ANY RED STOP BUTTON IN THE OPERATING PANEL WILL STOP THE TELESCOPE.

2. CS-OFF ALSO WILL STOP THE TELESCOPE.

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SECTION III

INSTRUCTION MANUAL - CONTROL SYSTEM

CONTENTS

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INSTRUCTION MANUAL - CONTROL SYSTEM

1. Introduction:

The Ooty Radio Telescope is a parabolic cylinder 530 metres long in North South and 30 metres wide in East-West. The telescope consists of 24 parabolic frames each pivoted on a rectangular pivot shaft at the top of two supports. The entire telescope is driven in the East-West direction by a drive shaft through AC induction motors with suitable gear reduction. Twentyeight electromagnetic brakes of fail-safe design are used to hold the telescope in any desired position. The basic design of the telescope requires that

(i) the motors and brakes be interlocked

(ii) all the 24 frames be driven in unison.

All the safety features in the control system are because of these design requirements.

2. Basic Operation:

Depending upon the speed requirements the Radio Telescope can be driven in the East-West direction using the following three modes.

	Mode	Speed of drive shaft	Coverage angle of antenna in sky.
1.	Slewing	75 rpm	375°/hr.
2.	Scanning	9 rpm	45°/hr.
3.	Tracking (a) mains	3 rpm	15°/hr.
	(b) servo	(around 3 rpm)	14°/hr to 15°/hr.

(See Figures 1,2,3 for Block diagram of Electrical/Mechanical Systems.)

In the slewing mode four induction motors of 12.5 HP are used.. These motors are located on N_{10}, N_4, S_4 and S_{10} platforms. These motors, through suitable gear reductions, rotate the drive shaft at 75 rpm.

The scanning mode consists of a 5 HP induction motor located at the servo structure which is between N1 & S1 towers. The scanning motor is also supplied through the motor control centre. This motor drives the drive shaft at 9 rpm through scan and common clutches and suitable gear reductions.

In the track mode a 2 HP AC reluctance motor is used. This track mode can be done only from East to West. Further, in this mode, the telescope can be driven controlled either by mains frequency in which the speed is constant, or a servo sytem, in which the speed is variable - for tracking sun, star and moon. The tracking motor is placed at the servo structure of the telescope. For details of the servo system please refer to Fig. 4(a) & (b). The drive shaft is rotated at 3 rpm by this motor using track and common clutches and required gear reduction.

3. Principle of operation:

The major electrical components of the drive system are the motors, brakes and clutches. Electrical power to these flow through contactors located at the Motor Control Centre (M.C.C.) in the switchgear room. Only control wires required for operating the contactors are brought to the Antenna Control Panel (A.C.P.) in the control room.

The design requirements of the telescope demands that

(i) motors be energised first

(ii) brakes be released next

(iii) motors and brakes be interlocked.

Therefore the control logic has been designed as such. That is, brakes are released only after electrical energization of motor. To test whether brakes have been released or not micro-switches have been installed on each brake and these together interlock the motor. Thus any failure in either motor energization or brake release stops further operation and gives alarms or indications.

In case of scanning and tracking motors, in addition to the above, two clutches have to be engaged. These are (i) common clutch (ii) scan/or track clutches for corresponding modes: These clutches are energised along with the motor and are suitably interlocked.

Summary of the control system logic is given in Fig. 5(a) and (b). For stopping the moving telescope for whatever reason any one of the red push buttons located at the control panel or M.C.C. or at the base of N4, S4, N10, S10 and servo towers can be pressed. There is one at the top of Servo Structure also.

4. Interlocked operating devices:

The motor, brake, clutch system is tested for fail-safe operation mainly by three interlocking devices:

(i) Undercurrent relays: These test whether a minimum current is passing into each phase of each motor (roughly 4 Amps). If not, they produce an alarm and stop further operations.

(ii) Brake microswitches: There are 28 brake microswitches each sensing one brake release. These microswitches are connected in series and actuate a relay which allows the continuous energisation of motor.

(iii) Clutch current relay: This senses the current passing through the clutch coil. In case of failure it cuts off the motor/brake operation.

For initial energization of the system a gate pulse is given by a pneumatic time delay relay for a period of 500 - 700 msec. At the end of this period, if the system is healthy continuous rotation by any one of three modes is automatically achieved. If the system is not healthy a fualt condition is indicated and the whole cycle comes to a stop.

Note:- The nomenclature used for the important contactors and relays are as follows:

42 SLM/SCM/TKM	- Main contactor which supplies power to slew, scan, track motors.
42 BR	- Main contactor which supplies power to brakes.
R/CL	- Clutch current sensing relay.
CAG	- Undercurrent relays sensing motor current.
X/BR	- Contactor actuated by brake microswitches.
2/BR	- Pneumatic time delay relay.

5. Overall Safety Devices:

The following devices are installed in the telescope for safety and are used in the control system with various other interlocks.

5.a. Limit Switches:

The limit switches are fixed at both east and west ends of the telescope and are used to stop the telescope automatically at the extreme positions. These limit switches are of snap action type and are actuated by cams fixed on the drive sector. The east limit switch will stop the telescope at - 4^h05^m and west limit switch ~~xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx~~ at $+5^h27^m$. If it is desired to go further, the east and west limit switches can be bypassed and go up to east end and west end limit switches. Their positions are respectively - 4^h07^m and $+5^h28^m58^s$ respectively. There are also crushing type emergency limit switches after end limit switches to stop the telescope ~~xxxxx~~ in case of failure or any damage to the above limit switches.

The east, west and end limit switches are fixed at N1 and S1 towers (S1 only east, west) and emergency limit swithhes are at N4, S4, N10 and S10 towers.

Normally the telescope will be rotated only upto the east and west limit switches.

5.b. Over Speed Tachos:

The over speed tachos are installed in the telescope to monitor the drive shaft speed.

These tachos at N12, S12 and servo structure are used in the slew mode and one tacho at servo structure for scan/track mode. The slew tachos are coupled to the drive shaft through suitable gears and a chain and rotate at 150 rpm and the scan/track tacho also rotates at 150 rpm and is coupled to the scan/track motors through 250:1 gear-box and a chain.

The output of the speed tachos are used to actuate relays through electronic circuits. Under normal speed the relays will operate. In case of over speed the output of the

tachos will be more which will trip the relays, and the entire system willcome to a stop. There is also provision in the electronic circuit to trip the relay in case of no voltage from tachos.

In scan/track mode over speed will occur if one of the clutches fail to engage due to mechanical damage. In this case the telescope will be falling freely as the brakes are released and the motors are not transmitting this torque. Then the scan/track tacho will be driven to overspeed and the electronic circuit will trip the entire system arresting the rotation of the telescope.

5.c. Differential Synchro:

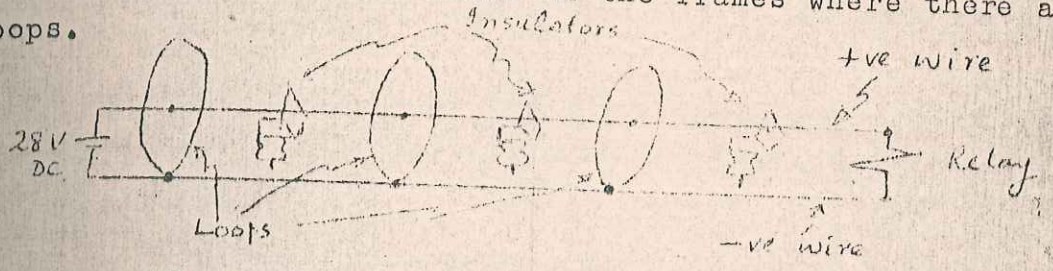
This system is used for detecting misalignment in the main drive shaft of the telescope. The synchro control transformer and the transmitter are fixed at both ends of the drive shaft of the telescope and are coupled to it through 16:1 gear reduction. The differential error voltage from transmitter at N12 is fed to an electronic circuit which operates a relay. The relay contacts are used in the control system to trip the system in case of a misalignment. The misalignment detector circuit made by BARC is kept on the servo rack # 2 in the servo room The relay is set to trip if the drive shaft misaligns more than 150° in either east or west directions. Misalignment will occur if the shaft or the shaft interconnecting coupling breakes. So this is one of the very important safety systems of the telescope and the telescope should be stopped immediately if the misalignment detector trips the control system.

5.d. Misalignment loops:

This consists of two systems (i) East misalignment loop (ii) West misalignment loop.

This is a very simple system used in the telescope to detect the misalignment of frames. The system consists of stainless steel loops of $20\frac{1}{2}$" diameter fixed on alternate frames

in both east and west side. A central wire (18 gauge) made of stainless steel runs through the centre of the loop and is supported by insulators fixed in the frames where there are no loops.



The basic function of this system can be understood from the above diagram. A dc supply of 28 V is fed at one end and a relay is connected across the central wire and the loop at the other end. The 28 V supply and the relay are situated at the back of control panel. Under normal conditions, the circuit will be through and when a frame misaligns the central wire, touches the loop thereby shorting out the relay which trips the control system.

Test facilities are provided in the control panel to check the healthiness of this detection system.

6.a. Monitoring Indicators:

The antenna position indicator directly gives the position of the telescope in terms of hours, minutes and seconds on graduated dials. The system consists of three master synchros are installed at N1 structure and are coupled mechanically to the telescope. The slave synchros are in the antenna position indicator fixed at the control panel. The master and slave synchros are connected electrically through wires. The mechanical rotation of the master synchros is transmitted electrically to the slave synchros which in turn rotate the pointers on the dial through suitable gears.

In slew mode the seconds needle makes approximately 25 revolutions in one minute of time and in track one revolution per minute.

There are indicating lamps for undervoltage, clutch supply, control supply, East loop (MA1), West loop (MA2), differential synchro (DS), overspeed tacho, east, west and end limit switches, east, west rotation, slew, scan, track servo, track mains, start servo, servo ready, scan, track and common clutches.

There are five meters for monitoring clutch current, north brakes and south brakes, differential synchro error voltage and servo error voltage. All of them are important and must be periodically seen by the observers.

6.b. Fault Indicators:

The fault indicator or the annunciator is fixed at the top of the control panel and has ten windows with the following inscriptions.

1. Brake Failure
2. Clutch current failure
3. Misalignment loop
4. Misalignment synchro (Differential Synchro)
5. Wait a minute
6. Over Speed
7. Antenna End Position
8. Motor Trip
9. Spare
10. Mech. Maintenance.

The working prieniple of the Annunciator is as follows. When a fault occurs the particular window starts flashing and simultaenously a hooter comes on. The hooter is silenced by pressing the hooter silence button and window glows now steadily. The reset button is pressed and if the window still glows the fault is a permanent one. If the fault is temporary the reset button will make the window light go off.

There is provision for testing the lamps to see whether annunciation system is ok. If the lamp test button is pressed all windows should glow. The reset button should make th go off.

Causes for fault indications:

1) Brake failure:

The brake failure indication will come during starting if one of the brakes or all the brakes fail to release. The indication will also come during operation if one of the brakes fails. The indication will also come when the power to brakes and brake control power supply fails.

2) Clutch current failure:

This indication will come when the clutch coil opens and clutch current sensing relay drops out. The indication will also come when power is not fed to the clutches through the circuits or the clutch power supply fuse blows out.

3) Misalignment loop:

This indication will come when there is misalignment between frames or when the central stainless steel wire or the wire connecting the loops breaks or when the central wire touches the loop due to very high wind or the failure of power from power supply.

4) Misalignment synchro: (Differential Synchro).

This indication will come only when there is actual misalignment in the drive shaft.

5) Wait a minute:

This indication will come whenever the telescope is stopped and the window flashes for a minute and goes off automatically. This is not a fault but restricts the operator from starting the telescope immediately before the mechanical vibrations die down. The operator will not be able to start unless the flashing of this window stops.

6) Over Speed:

The over speed annunciation comes whenever there is actual over speed in the mechanical drive system.

7) Antenna end position:

This window flashes whenever the telescope reaches the east or west limits. This is not a fault but indicates that the telescope has reached the extreme position. The window will glow permanently as long as the telescope is in this position and the control supply is on.

8) Motor trip:

This annunciation will come whenever the motor fuse blows out or when the under current relay trips or when the thermal over load relay trips.

9) Mech. Maintenance:

This window flashes along with the caution cabinet when the master cut out is put off. The control system can not be switched on till this window goes off, and this enables the maintenance staff to make sure that the system will not be energised under any circumstances.

Important Note on fault indicators:

As may be seen from the description above, some of the fault indicators are more important than the others. Thus misalignment synchro, overspeed and misalignment loop are the most important of the fault indicators in that order. None of them should normally come on. Whenever they do, extreme precautions must be taken by the observer/scientist in handling the telescope. The other fault indicators are only displayed for helping the observers/maintenance staff to locate the fault quickly.

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SLEWING MOTOR DRIVE PLATFORMS (N_{10}, N_4, S_4, S_{10})

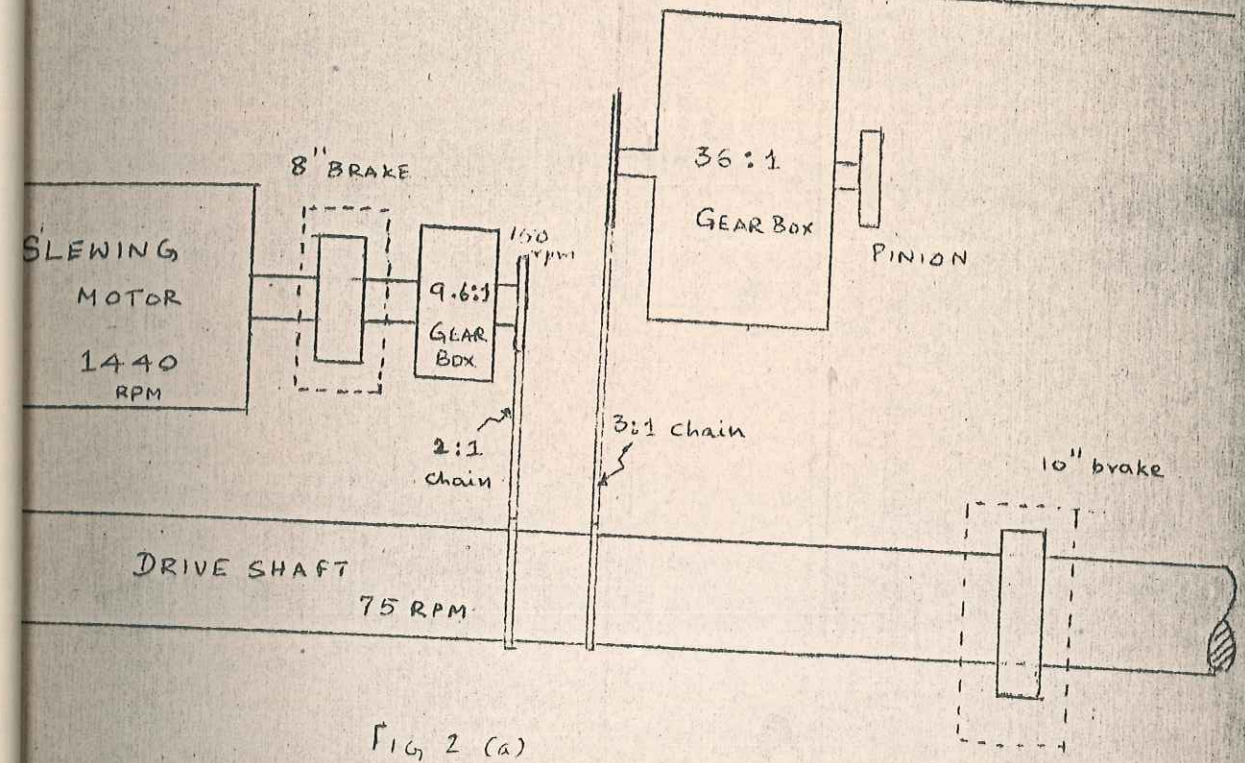


FIG 2 (a)

SERVO STRUCTURE PLATFORM

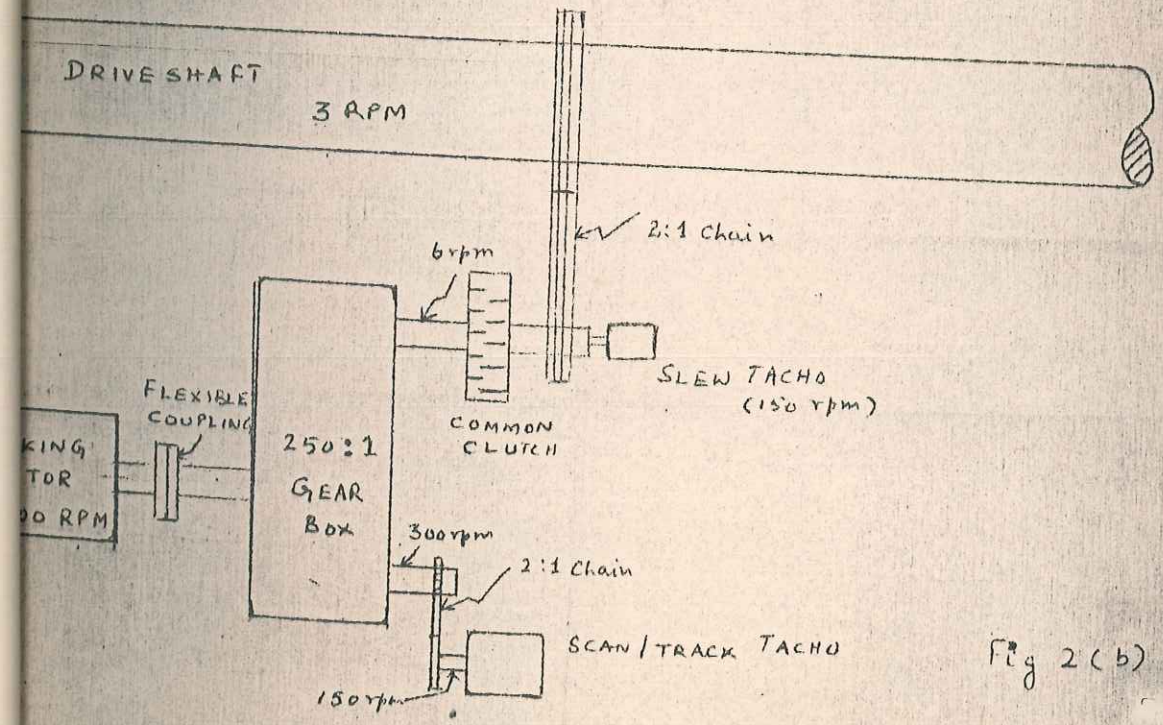


Fig 2 (b)

N_{12} & S_{12} Tachos & Diff Synchros

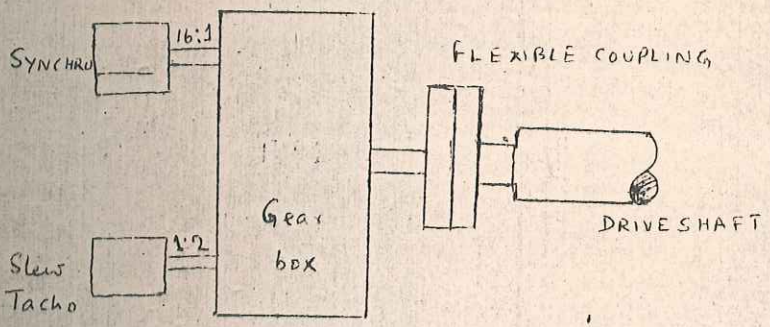


Fig 2 (c)

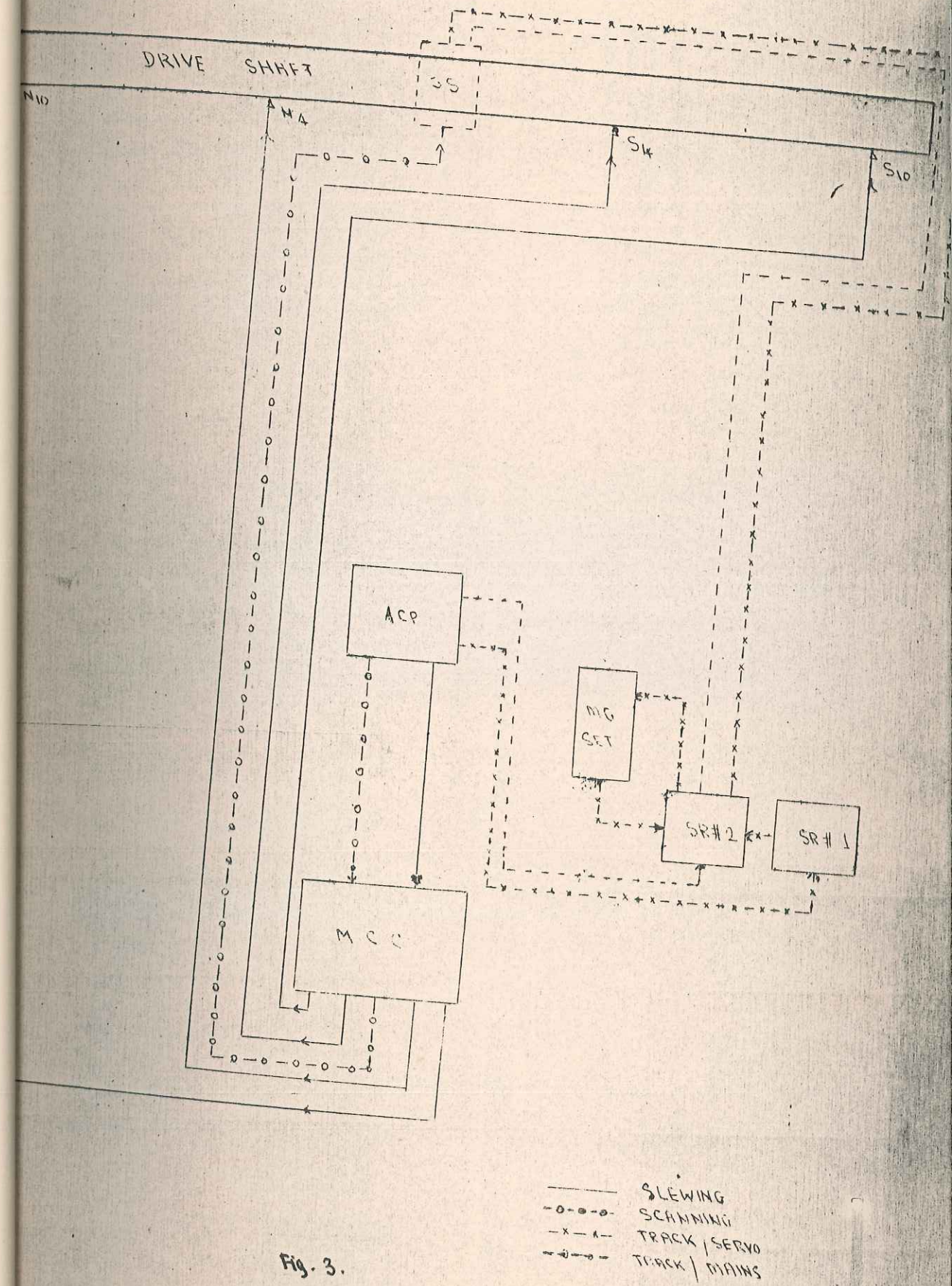
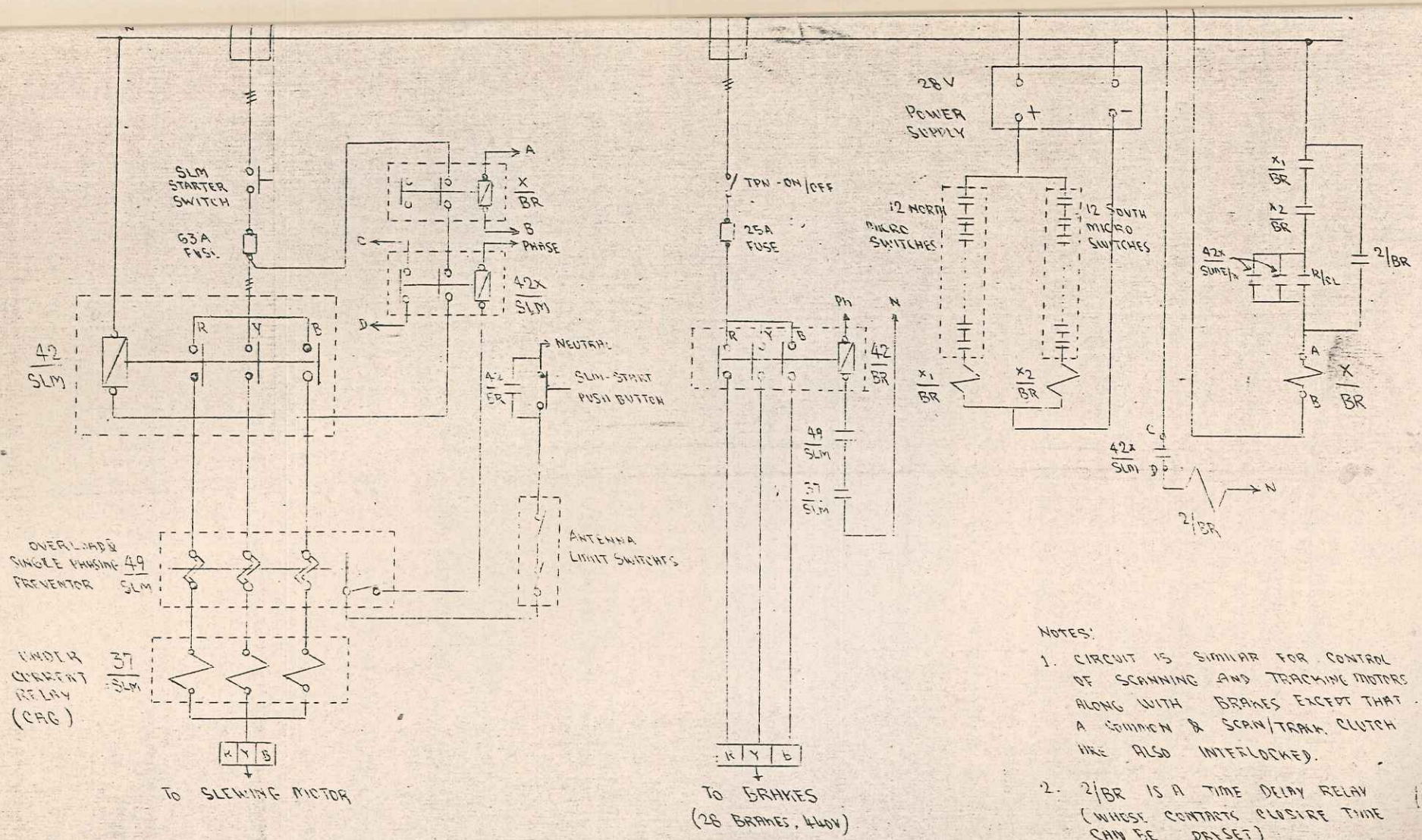

DRIVE SHAFT
N10
W4
S5
S4
S10
ACP
MG SET
SR#2
SR#1
MCC
SLEWING
SCANNING
TRACK / SERVO
TRACK / MAINS

Fig. 3.



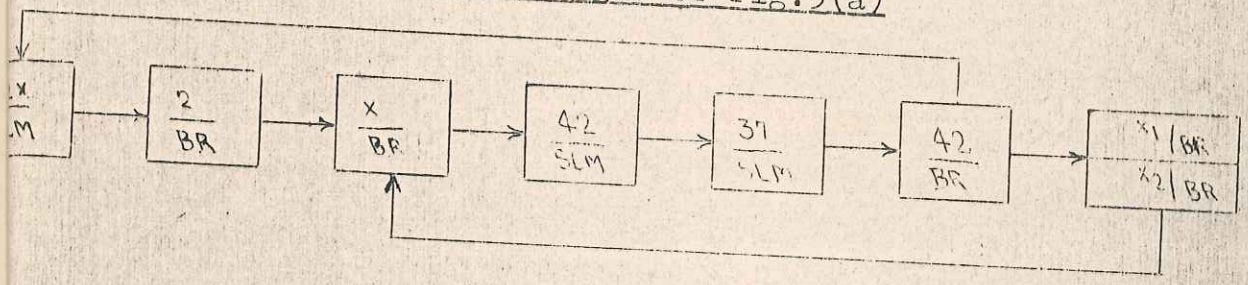
NOTES:

1. CIRCUIT IS SIMILAR FOR CONTROL OF SCANNING AND TRACKING MOTORS ALONG WITH BRAKES EXCEPT THAT A COMMON 8 SCAN/TRAK. CLUTCH ARE ALSO INTERLOCKED.
2. 2/BR IS A TIME DELAY RELAY (WHOSE CONTACTS CLOSURE TIME CAN BE PRESET) THE PRESET DELAY TIME IS OF THE ORDER OF 500 to 700 mSec.

FIG 5(a)

ABBREVIATED ELECTRICAL CIRCUIT FOR CONTROLLING BRAKES & SLEWING MOTORS OF OOTY RADIO TELESCOPE.

FIG. 5(b) - Condensed Logic of Fig.5(a)



Explanatory notes for Figures 5(a) and 5(b):-

1. When a green start button (E/W) is pressed the auxiliary contactor 42X/ SLM is energized.
2. 42X/SLM anergizes the pneumatic time delay relay 2/BR for ~700 m Sec.
3. 2/BR energizes X/BR (Auxiliary contactor for Motor/Brake combination).
4. X/BR energizes 42/SLM (Main Contactors of Motors).
5. 37/SLM Senses whether current is being fed to motors.
6. If 5 OK, 37/SLM energizes 42/BR (Main contactor for Brakes).
7. Release of brakes is sensed by brake microswitches and they energise $\frac{X1}{BR}$ & $\frac{X2}{BR}$. These two together provide hold on for X/BR.
8. 42/BR also provides hold on for 42X/SLM.
9. Thus the cycle is closed and continues to operate the motor/brake system.
10. For stopping the telescope a red stop push button breaks this cycle.