AUSTRALIA TELESCOPE NATIONAL FACILITY

PARKES RADIOTELESCOPE

REPORT ON TELESCOPE BEHAVIOUR & OPERATION UNDER WIND LOADING CONDITIONS

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APRIL 1993

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1.0 EXECUTIVE SUMMARY

1.1 Aim

The aim of this study is to make recommendations on the operation of the Parkes Radiotelescope to the extent that operation is affected by wind storms, including:

- Stability at Stow (Zenith);
- Stability at operating angles;
- Structural strength.

1.2 Electrical Operation

The operation of the telescope should be investigated to reduce the frequency of breakdowns due to blowing of fuses in the control system and to permit stowing of the telescope with emergency or UPS power. A study of controlled emergency elevation stowing by electrical regenerative braking is recommended.

1.3 Stowing

The telescope should be turned into the wind and stowed to zenith when the anemometer indicates that the wind exceeds 30km/hr.

1.4 Jacking

Jacking off the azimuth rail should follow stowing and may commence once the telescope is within a few degrees of zenith.

1.5 Truss Strengthening

Three tubular steel sections in the backup structure truss are recommended to be strengthened.

1.6 Personnel Safety

Personnel should not stay in the close vicinity of the telescope if the wind exceeds 100km/hr (when the telescope is stowed) or 90km/hr (when the telescope could not be stowed for some reason).

1.7 Future Inspections and Maintenance Procedures

Physical inspection to minimise the chance of metal fatigue should be carried out every five years.

All present knowledge of operating and maintenance procedures should be collated and kept in central locations.

1.8 Training

Staff at Parkes should be trained in the procedures that are to be followed in the event of high winds. These procedures could be in the form of a notice that is posted in relevant places in the facility.

2.0 INTRODUCTION

2.1 Scope

The purpose of this study was to carry out checks on the structure and mechanical systems of the Parkes 64 metre Radiotelescope and to recommend operating procedures in wind storms. The telescope has been in operation for 30 years and some operational problems had occurred in 1992 which prompted a review of the safety of the telescope in windy conditions.

This study is confined to evaluating the telescope above the azimuth rail. Stresses in members and equipment, as well as overall stability at a range of elevation angles and wind conditions were investigated.

2.2 Past Modifications

The telescope has had a number of additions and modifications since its original construction, including the following.

Resurfacing

The reflecting surface of the telescope has been upgraded by the replacement of some 40% of the steel wire mesh panels by perforated aluminium surface panels. An area of the reflector from 8.3 metres radius to 22 metre radius (approximately) was resurfaced. The central steel plated area out to 8.3 metres was covered by an aluminium sheeted paneling.

Drive Systems

New motors and servo control equipment have been installed.

Prime Focus Area

Additional cladding has been added to the aerial cabin at the top of the tripod, to enclose the receiver platform at prime focus. A hoist has been added to the top of the aerial cabin.

2.3 Visit to Parkes

On 18 February 1993, an inspection visit was made to Parkes by John Brooks and Brian Wilcockson of CSIRO, and Dick Mesley, Peter Moore and Jeff Schafer of Connell Wagner. A report on this visit is included as an Appendix to this report.

2.4 Previous Investigations

In order to bring together all material found and considered, and to collate known information, past reports from Macdonald Wagner on the following are included as appendices to this report:

- 1989 Report on Visit to Parkes by Charles Needham, Branko Gorenc and Leigh Walker

- 1984 Report on visit to Parkes by Les Parker.

2.5 Tornadoes

The Australian Wind Loading Code AS1170.2 excludes the effect of tornadoes. A previous edition of the Code (1973) states that "the occurrence of a tornado or tornadic squall is possible in virtually any part of Australia. The number of these which have been recorded has, however, been so small that it is impossible to assign any frequency". Although a tornado would have disastrous effects, Holmes et al (Ref 10) state that the probability of a particular structure being hit by a tornado is considered to be significantly less than the level of risk associated in AS1170.2 with the strength limit state.

2.6 Nomenclature

Telescope Axes

The Freeman Fox documents refer to "zenith angles", "altitude bearings" and "altitude axis drives".

For conformity with current practice, in this report we refer to "elevation angles" instead of "zenith angles" (zenith angle being the complement of elevation angle), "elevation bearings" and "elevation drives".

Turret

In current practice it would be normal to refer to the supporting structure between the azimuth wheels and the elevation axis as an "alidade". In this report we have chosen to call it the "turret", the nomenclature on the MAN and Freeman Fox drawings.

Moments and Torques

"Moment" and "Torque" are terms for moment of a force (kNm in SI units). Although Freeman Fox refer to "wind torque" on the telescope, "torque" implies torsion (of shafts, motors, etc) and so for this report, the turning effect of wind and/or dead load about the telescope axes is referred to as "Moment". The consequent effect at the wheel/gearbox or motor is referred to as "Torque".

Wind Speeds

The wind speeds nominated by the Wind Code, AS1170.2, are given in metres per second (m/s). Wind speeds are registered at the telescope control room in km/hr. Where comparisons are made between speeds at various heights, this report uses m/s and where these are related to the anemometer at the site, km/hr is used.

2.7 Operation in Wind - Past Practice

This section describes telescope operating procedures as presently understood by Connell Wagner.

Over the 30 years of operation of the Parkes Telescope, procedures of operation have been developed to include stowing procedures when winds of certain velocities are attained. Under computer control, the decision to stow is made depending on wind speed, the angle of elevation of the dish and the angle of approach of the wind relative to the azimuth look angle of the telescope. Experience has shown that this method can maximise the observing times of the telescope with a minimum of risk of damage to the telescope.

It is reported (Yabsley Ref 9) that motor currents in the drive motors have been monitored and give a measure of the wind torque registered at the drives. It is likely that this method gives a direct measure of the turning moment that the wind applies to the telescope.

The drive currents in Ref 9 are from the original drive systems prior to their replacement by GE motors and SWEO control system in the 1980's.

Care should be taken in extrapolation of motor current data from performance in low speed winds to the prediction of the capacity to drive the telescope in higher winds where the size of the gust may coincide more with the size of the telescope.

The effect of size of structure related to the wind gust is discussed in Section 3.5 "Wind Forces and Moments for Mechanical Equipment Loading and for Stability".

3.0 WIND LOADS AND MOMENTS - DESCRIPTION

3.1 Freeman Fox Values

The designers of the telescope, Freeman Fox & Partners, compiled graphs of wind forces and moments for their design of the telescope and its constituent parts.

Wind Speed

The following selection was made in the design study (Freeman Fox 1957): "maximum horizontal gust velocity of 100mph at the standard height of 10 metres above ground level, applied over the whole structure" (Ref 1, p a2). On p a4, reference is made to operational requirements for accuracies at 10 and 20 mph (16km/hr and 32km/hr, respectively).

A table of direct conversion between metres per second (m/s), km/hr and mph is shown on Figure 3.1.

Drag Force Calculation

Reference is also made to the main structure (i.e. backup structure trusswork) creating a large percentage of the total drag (Ref 1, p a5). There are a number of contributions; mesh reflector surface, spirals, "ribs" (radial trusses) and the hub.

Wind Velocity Distribution

A distribution of velocity with height to a power law is described.

Design Loads

A comparison with present calculations is described below.

3.2 Present Calculations

Wind Speed

AS1170.2 (Ref 2) gives wind velocities and distribution of velocity with height for various "Terrain Categories". An open area such as Parkes is considered to be between Terrain Category 2 ("isolated trees, uncut grass and airfields") and Terrain Category 3 ("level wooded country") with Category 2 being more stringent (i.e. higher speed). An intermediate category of 2½ ("few trees, long grass") is also used. Except where stated otherwise, Terrain Category 2½ has been adopted for this study.

AS1170.2 gives 41m/s as the Basic Wind Speed for inland Australia for permissible stresses and 50m/s for the ultimate limit state. These values are then factored by multipliers for terrain category and structure importance.

A structure importance multiplier of 1.10 has been adopted for this study. The effect of this is to increase the permissible stress wind speed at 25 metre height in Terrain Category 2 from 45.1m/s to 49.6m/s (i.e. nominally 50m/s). This also reduces the probability of the survival (ultimate) wind speed being exceeded. A further consideration of probabilities is given in Section 6.6.

Drag Force Calculation

The data from the Australia Telescope design and relevant sections of the New York Academy of Science booklet have been used for design of antennas by Connell Wagner (Ref 3 & 4). The Parkes telescope is different to the antennas designed by Connell Wagner in that the porosity of the steel mesh perimeter is much greater than aluminium surfaced antennas. The application of the data for other antennas to Parkes is considered to be conservative.

3.3 Comparison with Freeman Fox Calculations (Wind Speed)

The wind speed profile used by Freeman Fox at 10m height approximates to Terrain Category 2 for permissible stress and at 50m height it approximates to Terrain Category 1. As the Parkes site is Terrain Category 2 (or even 2½), the Freeman Fox speeds are conservative. The wind speed at a height of 25 metres (approximately the vertex of the reflector) for the two cases is as follows: AS1170.2 50m/s and Freeman Fox 51.5m/s.

A graphical representative of the wind velocity profile is given in figure 3.3.

The change in forces that arise from this difference is only 6% which is insignificant in view of the uncertainty in drag coefficients.

3.4 Wind Forces for Backup Structure Analysis

To obtain forces on the reflector panels for backup structure analysis, the pressure distributions in Ref 3 were used and a correction factor applied for the porosities of the areas considered. These porosities were calculated as follows:

Radius	Item	Porosity
0.0 - 8.3	Central Solid Plate	0.0
8.3 - 22.0	Aluminium perforated panels	0.50
22.0 - 32.0	Steel mesh panels	0.72

3.5 Wind Forces and Moments for Mechanical Equipment Loading and for Stability

The drag forces and moments for the telescope with aluminium panels are greater than the original telescope with steel mesh panels. The overall design forces and moments in the present study are not significantly greater than Freeman Fox values for the following reasons:

- revised design wind speeds
- newer drag moment coefficient data
- different approach to overall and partial loading.

Overall Forces and Moments - Freeman Fox Approach

Freeman Fox data includes calculation of wind moments for "whole dish" and "part dish" loaded conditions. This is considered to be conservative in light of modern design code requirements. For example, the consideration of part dish assumes that the wind gust only affects part of the telescope and the worst case for wind moments (also called torques) is for one half to be affected. This is unlikely as a wind of 50 metres per second will travel 100 metres or more during the normal response time of the structure. (Wind design is based on 2-3 second gusts). It may be more relevant to assume part loading at operational wind speeds of 10-15 metres per second (35-55km/hr), but even at these speeds, a 3 second gust will envelop most of the reflector.

Overall Forces and Moments - AS1170.2

The question of "part loading" as expressed by Freeman Fox is addressed in AS1170.2 as "an approximate reduction for the lack of spatial correlation of fluctuating pressures", and is based on wind tunnel tests of model buildings. Tubemakers (Ref 5) states that the method of reduction that they describe (based on the previous version of AS1170.2), is more relevant to latticed structures than to buildings.

The static analysis provisions of the wind loading code AS1170.2 (Ref 2) permits a reduction in wind pressure on structures larger than 100 square metres by adopting a multiplier of 0.8. An alternative calculation using the dynamic analysis provisions of the same code gives a multiplier of 0.82 on the overturning moment. A similar approach adopted in Ref 5 gives a multiplier of 0.84.

If a new telescope of the size of Parkes was being designed, it is likely that a wind tunnel test or other expert opinion would be sought to determine whether a reduction factor would be adopted. We have concluded that a "reduction multiplier" of 0.84 is reasonable and this has been applied to the calculated forces and moments on the telescope. This approach suggests that the wind moments acting on the present telescope structure are only 10% more than for the original design with steel mesh panels. This would tend to be confirmed by indications that drive torques as measured by motor current did not increase significantly after the aluminium panels were fitted (Ref 9).

Overall Forces and Moments - Referenced Data

The compilation of moments for design checking was based on published information in New York Academy of Science 1964 (Ref 4) and JPL (Ref 8) and data from Australia Telescope studies (Ref 3 and 7). JPL data is an upper bound because it is a wind tunnel test on a model of a 64 metre antenna which is less porous than the Parkes telescope.

3.6 Details of Force and Moment Calculations

Zenith Drag Force

At zenith, calculation of the total area of the dish projected in the plane perpendicular to the wind gives an increase of 24% between the original telescope and the telescope refitted with aluminium panels. This translates to an increase in drag force (in a 50m/s wind) from 1,000kN (Freeman Fox figures) to a design drag force of 1,200kN (corrected for wind speed). This was then multiplied by 0.84 to obtain a value of 1,010kN (refer Section 3.5).

Drag at Operational Angles

The frontal solid area of the reflector is calculated to be 27% more for the telescope with aluminium panels compared to the original steel mesh panels. Incorporation of more recent data results in a 5% increase in calculated drag force (Freeman Fox 2,750kN, Present 2,870kN). The multiplier of 0.84 has not been applied for operational wind speeds to ensure adequate factor of safety in our final recommendations. The area exposed to the wind when the telescope is side on to the wind is the same as at zenith. There is however, a different effect on moments about the telescope axes.

A comparison of drag force is shown graphically in Figure 3.6(a).

Moments

The turning moments caused by wind on the telescope have been calculated for the original panels and the new aluminium panels.

(a) Zenith

The calculated design moment for the telescope stowed at zenith is 17,500kNm (including multiplier of 0.84). This is 10% greater than the Freeman Fox value of approximately 16,000kNm.

(b) Operation Angles

The maximum moment for rear wind at an elevation angle of 60° has been calculated as 42,500kNm. The corresponding moment for frontal wind has been adopted as 25% more than the Freeman Fox value (20,000kNm compared to Freeman Fox value of 16,000kNm). These are only comparative values since they are for a wind speed of 50m/s and must be factored down for operational wind when the telescope is not stowed.

Spreadsheet Calculations

The maximum design forces and moments described above have been input to a spreadsheet to calculate azimuth wheel loads at various operational angles and for different wind directions. Intermediate values have been calculated to give a value for a range of elevation and azimuth angles. A copy of the spreadsheet information is included in Figure 3.6(b) (wind speed in m/s).

A summary in similar format is also given for SPACEGASS results of stability which includes a calculation for varying wind speeds (m/s) when one wheel lifts off the rail (Figure 3.6(c)).

Figure 3.6(d) is a diagram showing the wheel number locations.

As the stability of the telescope is dependent on its weight, two calculations have been carried out:

(a) a conservative approach with masses of the telescope taken from the drawings (i.e. Dish 715 tonnes and Turret 135 tonnes)

(b) an analysis based on the figure given in a present Parkes manual being a total mass of 1,000 tonnes.

The result of these calculations is summarised in Section 6.4 "Wind Speeds for Stability".

4.0 COMPUTER MODELLING AND ANALYSIS

The parts of the telescope were modelled for analysis by the program SPACEGASS, a PC-based package which analyses 3-dimensional frameworks of members. Members may be rigidly connected together or pin-jointed. The latest version (6.1) was used with enhanced speed and capability over previous versions.

4.1 Backup Structure (BUS), Hub and Counterweight

The backup structure was modelled including all radial and circumferential trusses. The stiff hub was modelled only approximately because a full finite element analysis program would be required if stresses in the hub were to be evaluated. The stiff counterweight structure was also approximately modelled to obtain relevant reaction output at the elevation bearings and the elevation gear racks.

Both "half dish" and "full dish" analyses were run, the most efficient as regards time of program execution being a half dish with as many pin ended members as possible. The spiral purlins were modelled adequately by "lumping" to model the 180 spirals by 60 spirals connecting the BUS nodes. The weights of the radial purlins and the surface panels (aluminium plate and steel mesh) were calculated and input to the model.

The weights of the hub and counterweight were also taken off the construction drawings and input to the model as noted above. It was not practical to accurately model these structures and the approximate structural modelling was input with zero mass density. (The weight of the structure is automatically calculated for all members based on their cross sectional area, length, mass density and gravitational acceleration. If a stiff structure is included with large cross sectional area, any erroneous effect on dead weight is nullified if the members are given a very small density).

4.2 Tripod

A full model of the tripod has been prepared and run for two dead load cases (telescope at zenith and horizon). Although the Parkes telescope has a minimum Elevation Angle of 30°(60° Zenith Angle), the horizon case is run (Elevation Angle = 0°) and any load case intermediate between zenith and horizon can be calculated.

4.3 Turret

The main A-frame members of the turret and its base frame were modelled on SPACEGASS. The steel rooms that form part of the structure on either side were approximately modelled. These room members provide restraint to the elevation bearing for loads parallel to the elevation axis. The modelling assumes that all bolted splices in the structure are fully effective in transferring bending moments, axial forces, shears and torsion.

5.0 RESULTS OF COMPUTER ANALYSIS

5.1 Backup Structure (BUS)

The SPACEGASS analysis of the BUS (half dish) calculates member forces for 2,475 members for each of four load cases. Some of these are "convenience" members to model the hub and counterweight, but the majority required a check of member capacity under various loading conditions. To expedite handling of the large volume of output, two computer programmes were written ("SGOPB4" and "JSMZ").

The first of these (SGOPB4) condenses the output from SPACEGASS to one line per member per load case. Each line in the output file gives the member number, its connected node numbers, section property identifier, length and axial force. It also calculates the stress in the member and its "slenderness ratio".

The second program compresses the data even more by grouping the members of equal length symmetrically around the structure and combining the worst loaded members from each group from a dead load case with the worst loaded member from the same group in a wind load case. It also calculates the ultimate limit state axial force in the member and its theoretical capacity from AS4100, Steel Structure Code and "flags" any member whose capacity is exceeded. In this way the SPACEGASS output is condensed to files containing only a total of 225 lines of data.

There are 75 lines in each file comprising the output data for 75 groups of members and the following load cases:

- Dead Load Zenith plus Wind Load Zenith at 50m/s
- Dead Load Horizon plus Wind Load from in Front at 15m/s
- Dead Head Horizon plus Wind Load from the Side at 15m/s

These load cases "bracket" the worst loading conditions from wind load. By taking the worst loaded members in each group the dead load in each member is combined with the worst direction of wind loading. This gives a calculation for all wind directions at zenith that could not be carried out quickly with load combinations in the SPACEGASS program.

When the group loadings had been calculated it became a simple matter to carry out more detailed checks to confirm whether the load combinations considered by the program were valid and whether the slenderness ratio was greater or lesser than the program had assumed. This detailed check cleared all but a handful of members.

MEMBERS REQUIRING DETAILED CHECKS

Group No	Description	Results of Analysis	Action
37	Truss vertical under tripod support	Little capacity for wind load	Strengthening recommended
54	Circumferential truss, bottom chord second ring out from hub	Adequate	None
57	Circumferential truss, bottom chord, third ring out from hub	Permissible stress exceeded but ultimate capacity not exceeded. Only one member each side effected. Other load paths exist. OK with telescope stowed at 10m/s	None
60	Circumferential truss, bottom chord, fourth ring out from hub	Review of slenderness ratio shows adequate capacity	None

Group 37 BUS Truss Vertical

The tripod is supported on three points on the BUS. Each point is on the top chord of a radial truss. The truss member that carries the tripod load is a 60.3mm outside diameter tube with 4.9mm wall thickness and a total length of 2.8 metres. Its capacity can be increased most effectively by placing a steel sleeve around the member (possibly by welding two halves of a 76.1.mm OD tube of suitable wall thickness). The past satisfactory performance and lack of any problem in service over 30 years points to three factors:

(a) Wind on Tripod

The wind tunnel test carried out for the Australia Telescope predicts that the tripod is in a sheltered area, shielded from the wind at most angles. The circular sections used for the tripod structure are most suitable for minimising wind loading.

(b) Wind Angle

The wind load in the member is dependent on wind direction. For the worst effect, the wind direction has to be in the same vertical plane as the tripod leg (dish at zenith) and blowing towards that leg. When the telescope is front-on to the wind, the lowest tripod leg would take wind load to the lowest BUS radial truss, but shielding by the BUS is likely to be effective in this orientation.

(c) Dead Load

The stress in the BUS member due to dead load with the telescope stowed to zenith is not as great as when it is near horizon. The wind loading may be greater when stowed, but the combination of loads has not exceeded the member capacity in 30 years of operation.

5.2 Tripod

The tripod was modelled and analysed for dead load to calculate its dead weight for input to the BUS analysis. Detailed analysis of member stresses has not been carried out.

5.3 Turret

The turret has been modelled and analysed for dead load and wind load from the elevation axis, and an analysis has been done to determine the effect on wheel loads due to non-flatness of the azimuth track or out-of-round of azimuth rollers.

A detailed structural check of members in the turret has not been made.

Should the azimuth track be out of plane, the effect of one wheel being raised by 5mm is to redistribute the wheel loads such that the raised wheel takes about 5% more than it would under a normal flat rail situation. An out of plane of this magnitude is very unlikely.

Jeffery (p 67 Ref 4) states that the central portion of the turret between the two A-frames is deliberately designed to be relatively weak in torsion "to ensure that all four azimuth rollers are equally loaded under the dead weight of the structure". This is not clearly shown by the analysis, although the use of bolted splices in the turret structure may give some additional flexibility. This flexibility has not been modelled, but the 5% difference shown in the model adopted resulting from an extreme movement of 5mm is not a significant effect.

5.4 Turret Splices

Past Welding

The only known problems with the turret structure are the noises investigated during the Macdonald Wagner visit in 1989. The fact that site welding had been carried out in the past indicates that some aspect of performance of the telescope was perceived to be affected by movement occurring in the base of the turret. This welding appears to have been ineffective in that at least one of the welds has subsequently cracked.

Causes of Stresses

Horizontal forces parallel to the elevation axis produce bending stresses in the front and rear cross beams of the turret. These are the members with the bolted splices noted in the above paragraph. The analysis carried out as part of this study gives results indicating torsional stresses at these splices, as well as bending stresses. Differential temperature and azimuth wheel misalignment can also result in stresses at these splices.

Effects of Welding

The partial welding of the splice joints results in an immediate stiffening of the joint, but also results in the loading of the weld rather than the bolted connection. As appears in this case, overstress on the weld or the effect of shrinkage in the weld metal has cracked at least one of the welds. If the welding has cracked right through, the loads would still be taken by the bolted splice as originally designed.

Other Bolted Splices

The splices discussed above are not the only bolted splices in important structural members of the turret. The A-frame legs that support the elevation axis are spliced at top and bottom.

Possible Corrosion Effects

One problem that can occur with bolted splices is that water can penetrate between the faces of the spliced joint. Depending on the quality of protective treatment of the mating surfaces, this may not be a problem in a dry inland environment. No evidence of staining from corrosion was noted during the site visit.

6.0 TELESCOPE STABILITY AGAINST OVERTURNING AND COLLAPSE

6.1 Loading Conditions

The stability of the telescope during wind storms needs to be considered in two configurations:

(a) At Zenith
At zenith (elevation angle = 90°), the telescope is in the stowed position with approximately equal wind effects with wind from any angle. The effect on the elevation drives varies with the angle of the wind and the actual wheel loads will vary with the angle of the wind, but the drag force on the dish and the overturning moment effect of the wind will be independent of the wind direction. If the stow lock is engaged, there is no load applied to the elevation drives.

(a) At Operational Positions
With the telescope at elevation angles less than 90° and down to the operational limit of EL = 30°, the drag force and turning moment effects on the dish are generally greater than at zenith. The worst position for telescope survival is for the reflector to be exposed to high winds when the dish is at a low elevation angle. It is necessary to stow the telescope to zenith before extreme winds occur.

6.2 Overturning

The distribution of load to the wheels changes with increasing wind speed. As the overturning moment increases, the wheel load(s) on the downwind side increase and those on the upwind side decrease. (The central pintle bearing on the azimuth axis does not contribute to the vertical forces because of the flexibility of the plate that connects it to the base of the turret).

Rigid Body Stability

It may be considered that the effect of the overturning moment is to increase the eccentricity of the vertical load (predominantly dead weight) in the downwind direction. When this eccentric force reaches the downwind wheel or wheels, a position of neutral stability is reached. If the horizontal load increases further, a position of instability would be reached and the telescope as a rigid body would fall over.

Structural Failure of the Turret

Whether this rigid body rotation would occur depends on the strength of the members that carry the load to the wheels. If the structural strength of the members carrying the load to the wheel(s) was exceeded, yielding or buckling would occur resulting in progressive collapse of the telescope.

6.3 Concrete Tower Failure

Although analysis of the concrete tower is not part of this study, the tower is an important element in the support of the telescope. Two modes of failure may be considered. They are (a) structural collapse due to excessive wheel load and (b) overturning due to failure of the foundation material. Overturning of the tower and structural collapse of part of the concrete structure are both excluded by keeping the line of action of the resultant vertical force well within the azimuth rail track. This is achieved by stowing the telescope to zenith during wind storms.

6.4 Wind Speeds for Stability

SPACEGASS analysis and a spreadsheet calculation of static equilibrium have given figures for stability of the telescope and various wind speeds and elevation angles.

For the more conservative approach (minimum calculated telescope weight), these are summarised in the following table.

OVERALL STABILITY CALCULATIONS

Elevation Angle	Wind Speed at Wheel Lift m/s (km/hr)	Wind Speed at Instability m/s (km/hr)
30	41 (148)	-
60	37 (133)	-
90	45 (162)	>50 (180)

These calculations predict that for the telescope stowed at zenith, the first wheel lifts when the wind is diagonally from the side, and that there is a margin of safety after the wheel lifts off the rail. Instability first occurs when the wind is directly from the side and the two windward wheels lift off. The safe wind speed at zenith is therefore at least that stated by Freeman Fox (115mph = 51m/s; Ref 1, p91).

Freeman Fox also nominate (p 93) a safe wind speed for overturning at EL = 30° of 70mph (= 31m/s). This compares with 41m/s in the above table. This is a large discrepancy, although the difference between the design study and the final telescope design is considerable. For example, the design study refers to "azimuth tie downs" which were not finally adopted, possibly because the final weight was sufficient to ensure stability.

For the purpose of recommending wind speeds for stowing, the wind speed at first wheel lift has been adopted and figures not obtained for "Wind Speed at Instability". The actual wind speed at stowing should continue to be as existing (i.e. much more conservative than these figures), and a value of 30km/hr adopted. This is the figure nominated in Section 8.2 of this report. This also relates to the reported periodic failure of the electrical drive system due to the blowing of fuses which may constrain the operation of the telescope rather than the operation of gearboxes, brakes and structural strength which is the main subject of this report.

6.5 Ultimate Limit State Wind Speed

Calculations based on the minimum calculated telescope weight result in the telescope becoming marginally unstable at a wind speed of 52.5m/s, when in stow. This equates to a basic anemometer reading of 180km/hr. This is approximately the value given in the Freeman Fox design report (115mph = 184km/hr). This complies with stability requirements of present day limit-states structural engineering codes because the stability is marginal only for one wind direction. AS1170.2 permits a reduction factor of 0.95 to cater for such a case. This would reduce the 52.5m/s to 0.95 x 52.5 = 50m/s, at which speed the telescope is stable at stow for all wind directions.

Taking the above into account and including the Structure Importance Multiplier of 1.10, the ultimate design wind speed at 25 metre height that would be applied to the telescope (Terrain Category 2.5), would be: 50.0 x 0.95 x 1.10 x 1.035 = 54.1m/s. This may be overly conservative.

6.6 Probability of Ultimate Wind Speed Occurrence

The ultimate limit state wind speed, as defined by AS1170.2, has a 5% probability of being exceeded at least once in 50 years. By introducing the Structure Importance Multiplier, this probability is reduced to 1% in 50 years. Although the Structure Importance Multiplier is usually introduced for post-disaster operation of hospitals, communications, etc, the adoption of a factor of 1.10 for design of an installation such as the Parkes Radiotelescope, is reasonable.

As the calculations are conservative, it is not necessary to modify the telescope to improve the structural stability. Effectively, the Structure Importance Multiplier for structural stability of the telescope is calculated to be 52.5/(50.0 x 0.95 x 1.035) = 1.07 approximately. This corresponds to a basic wind speed with a probability of 1.5% of being exceeded at least once in 50 years.

6.7 Balance of Wind and Gravity Bias

The drive to stow in elevation is aided by the "gravity bias". The counterweight is sized larger than necessary for balancing of the telescope about the elevation axis. This is designed to remove backlash in the elevation drive gearing. At some wind speed for wind from behind the dish there will be a point at which the overturning moment due to wind will balance the gravity bias. This is calculated to occur at wind speeds of 60km/hr at EL = 30° and 50km/hr at EL = 60°. This is the opposite effect to that predicted by Freeman Fox (drawing No. 325/18).

	WIND SPEED FOR BALANCE (km/hr)	
EL	**Freeman Fox**	**Present Calculation**
30	50	60
60	65	50

A contradictory effect is also reported from Parkes (2 November 1992) in which, an occasion is described where with the telescope at EL = 35°, wind into the back of the dish at about 22km/hr, the dish was interpreted to be close to balance.

The recommended speed for stowing of 30km/hr should overcome this contradiction in predicted and observed behaviour and, as mentioned in the report from Parkes referred to above, it is possible to rotate the telescope in azimuth so that the wind is no longer from the rear and to stow to zenith.

7.0 MECHANICAL

7.1 Elevation Bearings

The capacity of the elevation bearings has been considered briefly. The size of the bearings indicates that they are adequate for the required service. Further investigation appears to be unwarranted.

7.2 Azimuth Wheels and Bearings

The strength of the azimuth wheels (rollers) and their support bearings has not been analysed in detail. The operation of the telescope has not been limited in the past by consideration of the wheel loads and the assemblies appear to have adequate capacity.

7.3 Elevation Drives

The elevation drive system has been checked for operation at a maximum operational wind speed of 15m/s and is calculated to have an adequate factor of safety. This is well above the recommended stow wind speed of 30km/hr.

7.4 Azimuth Drives

With the exception of the azimuth drive brakes when the dish is not stowed, the calculated safety factors indicate that all mechanisms can cope relatively easily with the wind loads.

Calculations show that the brakes are adequate for the specified operating wind conditions of 30km/hr, but are likely to slip when the wind reaches 40km/hr. At this wind velocity, the telescope should be in the stowed position in accordance with the operating procedures. These calculations are approximate due to the lack of all details of the brake springs.

If stronger brakes were fitted and the telescope was operated at excessive wind speeds, the limiting factor would become skidding of the locked drive wheels on the rail. This is not a recommended situation and would occur at approximately 65km/hr. It is preferable for the telescope to slew in the wind than to have wheel skid occur.

The telescope should also be stowed well before 65km/hr because wheel slip may occur, even if the motor torque is sufficient to stop the wheels rotating. Wheel skidding could cause damage to rail or wheels.

7.5 Electric Motors

The original design of the telescope provided for emergency power supply to reduce the chance of power failure and ability to drive to stow. Although electric drive systems were not part of the scope of this study, GE was approached to comment on the possibility of using the elevation drive motors for regenerative braking during emergency stow without power supply. The results of this was that after establishing the details of the elevation drive motors, GE indicated that regenerative braking could be used to stow the telescope.

As the telescope is gravity biased to zenith use of elevation drive brakes in manual control, when emergency power is lost, will allow the telescope to run back to the stow position with controlled braking. However, this procedure causes concern due to heating of the braking mechanism and the potential for operator error.

Regenerative braking could be used in place of the manual procedure, but would require additional equipment to switch in a load bank to dissipate the power generated during this mode of operation.

Regenerative braking would not assist in stowing the telescope if a rear wind situation arose when the gravity bias was overcome (Section 6.7 "Balance of Wind and Gravity Bias"). It would be preferable for the reliability of the drive system to be improved and UPS power used for stowing.

7.6 Azimuth Jacks

Regarding the operational problems that occurred in 1992, the question was raised whether the azimuth jacks should be used even if the telescope could not be stowed to zenith. It is considered preferable not to stow the telescope on its jacks unless it has been raised in elevation to within a few degrees of zenith. The possible skidding of the telescope in azimuth on its jacks is likely to cause more damage than would occur from slipping of the azimuth brakes.

The capacity of the azimuth jacking system has not been checked as part of this study.

8.0 RECOMMENDATIONS

Note: It is assumed that wind speeds notified to the telescope operators are equivalent to basic wind speeds as defined by AS1170.2, and that anemometer(s) are calibrated to give an output that corresponds to a wind speed at 10 metres height in Terrain Category 2.

8.1 Major Storm Activity

With the telescope stowed to zenith jacked off the track, and with elevation stow pin inserted, it is recommended that the general area be cleared of personnel if the indicated anemometer wind speed exceeds 100km/hr. This is a very conservative figure, but if such a wind speed is reached, there is more chance that gusts of 180km/hr could be reached or exceeded. Although the telescope is calculated to be stable at 180km/hr, an increase in velocity to 200km/hr would result in instability (Section 6.4 "Wind Speed for Stability").

8.2 Stowing Procedure

The existing stowing procedure should be maintained. The telescope should be turned into the wind and stowed to zenith when the indicated anemometer wind speed reaches 30km/hr. Jacking off the azimuth rail should follow once the telescope is within a few degrees of zenith.

Regeneration braking could be used in place of the existing manual emergency stow procedure (Section 7.5 "Electric Motors").

8.3 Mechanical/Electrical Problems

If difficulty is experienced in driving due to fuses blowing or another problem precludes driving to stow, the telescope will tend to blow around in azimuth ("wind sock effect") so that the wind blows from behind the reflector. In this position, the gravity bias is assisting to turn the telescope to zenith, but the wind is opposing this effect. As described in Section 6.7, there is uncertainty in predicting the wind speed at which the wind force takes over from the gravity bias, but it is predicted that hand-stowing (or regenerative braking if fitted) with drive failure may be impractical at wind speeds over say 45km/hr.

If for some reason, the telescope cannot be stowed to zenith, the telescope is stable at wind speeds of up to 110km/hr. If the indicated wind speed reaches 90km/hr and the telescope is not stowed, it is recommended that personnel vacate the general area. This is less than the recommended speed with telescope stowed (Section 7.1), and is much less conservatively obtained. It is assumed that if the indicated wind reaches 90km/hr, a further increase to an unstable condition could occur very quickly.

Jacking of the telescope is not recommended if stowing to zenith has not been achieved.

The overall reliability of the telescope and use of UPS power for stowing should be reviewed.

8.4 Truss Strengthening

As described in Section 5.1, the member that carries the tripod load into the backup structure is overloaded in some conditions. If the telescope is to remain in its present tripod configuration, strengthening of this member on each of the three trusses that support the tripod is recommended. If a quadrupod is installed, the trusses that support it should be evaluated for strengthening.

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8.5 Future Inspections

Inspections and tests such as those carried out by ETRS in 1989 are recommended to give advance warning of possible fatigue problems. Inspections should be included in the maintenance programme for the telescope on a long term basis, say every five years (1995, 2000, etc).

8.6 Information Availability

Information on telescope operation should be kept in centralised locations, possibly at both the control room and at a central point in the office and with a responsible person if off-site. Emergency procedures should be put up on notice boards as well as the SWEO room and at the elevation drives.

Staff should be trained in the emergency procedures with periodic training sessions on emergency stowing.

8.7 Maintenance Procedures

In view of the pending retirement of some of the Parkes personnel, it is recommended that data supplementary to this report be prepared by personnel at Parkes and that existing maintenance procedures be formalised and recorded in a suitable format.

FIGURES

m/s	km/hr	mph
1	3.6	2
2	7.2	5
3	10.8	7
4	14.4	9
5	18.0	11
6	21.6	14
7	25.2	16
8	28.8	18
9	32.4	20
10	36.0	23
11	39.6	25
12	43.2	27
13	46.8	29
14	50.4	31
15	54.0	34
16	57.6	36
17	61.2	38
18	64.8	40
19	68.4	43
20	72.0	45
21	75.6	47
22	79.2	50
23	82.8	52
24	86.4	54
25	90.0	56
26	93.6	59
27	97.2	61
28	100.8	63
29	104.4	65
30	108.0	68
31	111.6	70
32	115.2	72
33	118.8	74
34	122.4	77
35	126.0	79
36	129.6	81
37	133.2	83
38	136.8	86
39	140.4	88
40	144.0	90
41	147.6	92
42	151.2	95
43	154.8	97
44	158.4	99
45	162.0	101
46	165.6	103
47	169.2	106
48	172.8	108
49	176.4	110
50	180.0	113
51	183.6	115
52	187.2	117
53	190.8	119
54	194.4	122
55	198.0	124
56	201.6	126
57	205.2	128
58	208.8	131
59	212.4	133
60	216.0	135

km/hr	m/s	mph
5	1.4	3
10	2.8	6
15	4.2	9
20	5.6	13
25	6.9	16
30	8.3	19
35	9.7	22
40	11.1	25
45	12.5	28
50	13.9	31
55	15.3	34
60	16.7	38
65	18.1	41
70	19.4	44
75	20.8	47
80	22.2	50
85	23.6	53
90	25.0	56
95	26.4	59
100	27.8	63
105	29.2	66
110	30.6	69
115	31.9	72
120	33.3	75
125	34.7	78
130	36.1	81
135	37.5	84
140	38.9	88
145	40.3	91
150	41.7	94
155	43.1	97
160	44.4	100
165	45.8	103
170	47.2	106
175	48.6	109
180	50.0	113
185	51.4	116
190	52.8	119
195	54.2	122
200	55.6	125
205	56.9	128
210	58.3	131
215	59.7	134
220	61.1	138
225	62.5	141
230	63.9	144
235	65.3	147
240	66.7	150
245	68.1	153
250	69.4	156
255	70.8	159
260	72.2	163
265	73.6	166
270	75.0	169
275	76.4	172
280	77.8	175
285	79.2	178
290	80.6	181
295	81.9	184
300	83.3	188

Figure 3.1 SPEED CONVERSION TABLE

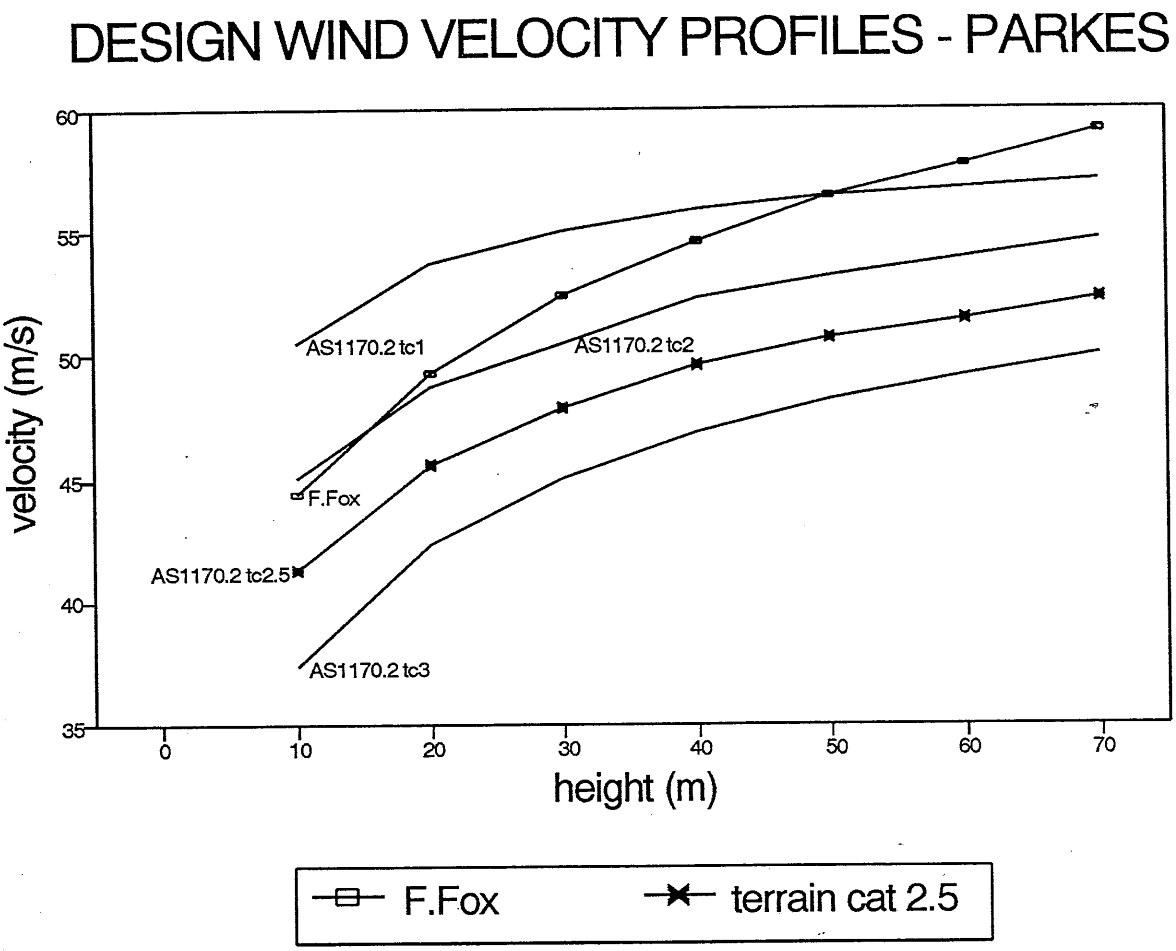

Figure 3.3 WIND VELOCITY PROFILES

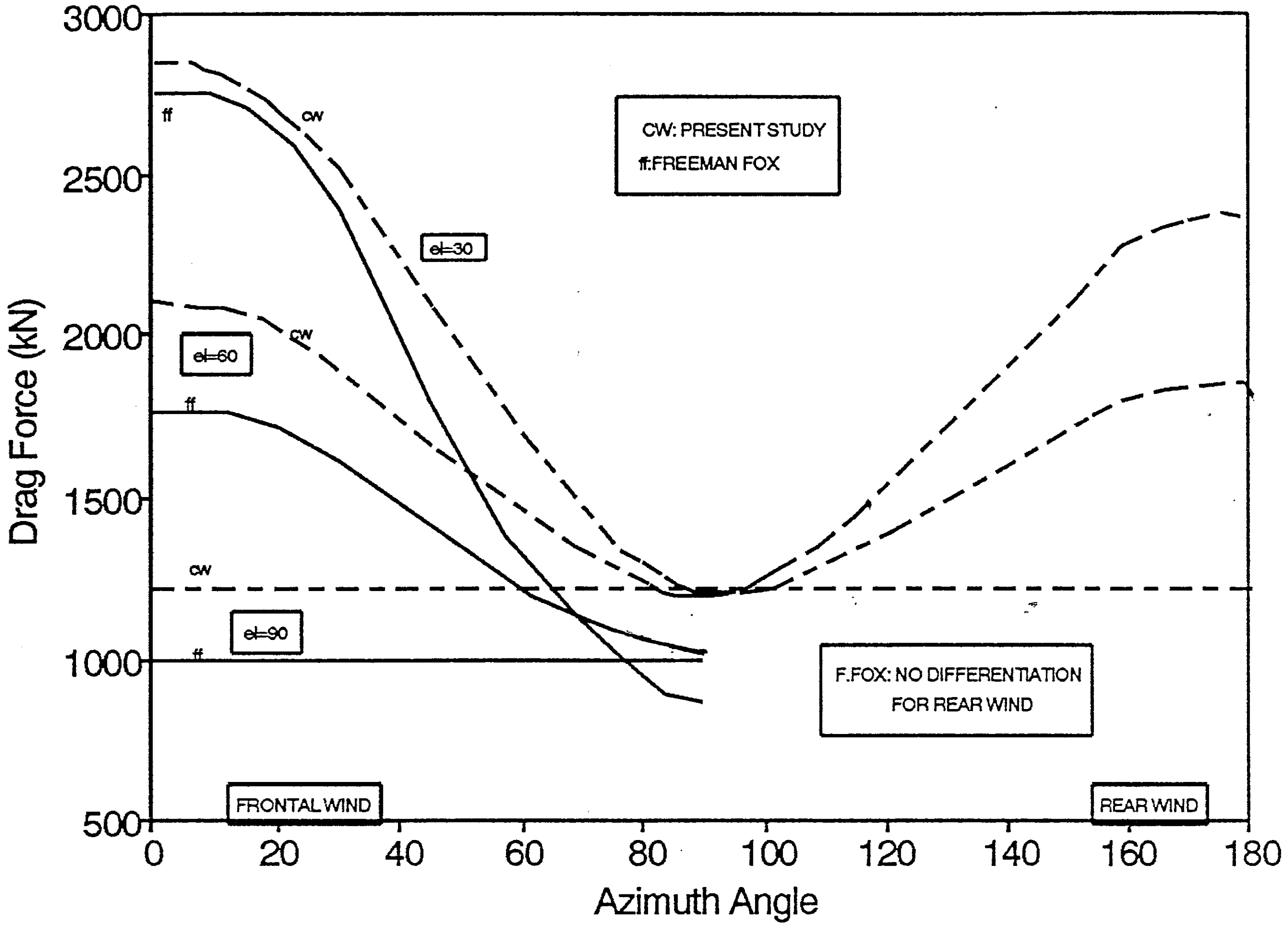

Figure 3.6(a) DRAG FORCE ON DISH DUE TO 50 m/s WIND
COMPARISON OF FREEMAN FOX AND PRESENT STUDY

PARKES TELESCOPE WIND FORCES

WIND SPEED:	44.5	MULT:	0.792

= 160 km/hr

ADDED WT (kN)
0

LOADS AND MOMENTS AT ELEVATION AXIS

AZ:		0	30	60	90	120	150	180
EL	FX	0	475	792	951	792	475	0
	FY	0	0	0	0	0	0	0
30	FZ	-2273	-1980	-1109	0	951	1663	1901
	MX	-11089	-9505	-5545	0	11882	20595	23763
	MY	0	9505	16634	19010	28516	23763	0
	MZ	0	-5545	-9505	-11089	-9505	-5545	0
	FX	0	475	792	951	792	475	0
	FY	0	0	0	0	0	0	0
60	FZ	-1663	-1426	-879	0	752	1307	1505
	MX	-19010	-16634	-9505	0	16634	28516	33268
	MY	0	5545	9505	11089	15842	11882	0
	MZ	0	-9505	-15842	-19010	-15842	-9505	0
	FX	0	400	693	800	693	400	0
	FY	-333	-333	-333	-333	-333	-333	-333
90	FZ	-800	-693	-400	0	400	693	800
	MX	-13901	-12039	-6951	0	6951	12038	13901
	MY	0	0	0	0	0	0	0
	MZ	0	-6951	-12039	-13901	-12039	-6951	0

WHEELBASE

WBZ	WBX	MASS E	MASS T	G.BIAS	ECCY
9.47	6.4	715	135	3500	0.499
HTUR					
8.915					

	FRONT	REAR	SUM
FROM EL TO AXL	3135	3874	7010
WHEEL:	1899	2268	8333

WHEEL LOADS

EL	WH	0	30	60	90	120	150	180
30	1	243	-300	-210	370	1679	3005	4048
	2	243	1229	2378	3427	4268	4533	4048
	3	3924	2938	1789	740	-101	-366	119
	4	3924	4466	4377	3797	2488	1162	119
	SUM	8333	8333	8333	8333	8333	8333	8333
							MAX:	4533
60	1	112	-724	-807	-249	1342	2946	4363
	2	112	1423	2772	4046	4920	5093	4363
	3	4055	2744	1394	121	-754	-926	-197
	4	4055	4891	4973	4415	2825	1221	-197
	SUM	8333	8333	8333	8333	8333	8333	8333
							MAX:	5093
90	1	871	198	3	338	1114	2122	3092
	2	871	1841	2850	3625	3960	3765	3092
	3	3462	2492	1483	708	373	568	1241
	4	3462	4135	4330	3995	3219	2211	1241
	SUM	8666	8666	8666	8666	8666	8666	8666
							MAX:	4330

Figure 3.6(b) WHEEL LOAD CALCULATION SPREADSHEET

PARKES TELESCOPE WIND FORCES
WHEEL LOADS FROM SPACEGASS ANALYSIS

WIND SPEED: 50 m/sec = 180 km/hr

WHEEL LOADS

EL	WH	AZ: 0	30	60	90	120	150	180
90	1	602	0	0	0	783	2181	3405
	2	602	1578	2605	4007	4626	4255	3405
	3	3775	2302	783	196	0	121	971
	4	3775	4872	5365	4550	3344	2196	971
	SUM	8754	8752	8753	8753	8753	8753	8752
							MAX:	5365

WIND SPEED: 52.5

90	1	459	0	0	TWO	410	2097	3571
	2	459	1334	2474	WHEELS	5175	4629	3571
	3	3941	2097	410	LIFT	0	0	828
	4	3941	5368	5914	OFF	3213	2073	828
	SUM	8800	8799	8798		8798	8799	8798
							MAX:	5914

WIND SPEED: 55

90	1	329	0	0	TWO	72	1910	3722
	2	329	1112	2355	WHEELS	5675	5079	3722
	3	4091	1910	72	LIFT	0	0	699
	4	4091	5818	6414	OFF	3094	1852	699
	SUM	8840	8840	8841		8841	8841	8842
							MAX:	6414

WIND SPEED: 57

90	1	200	0	TWO	TWO	TWO	1724	3873
	2	200	890	WHEELS	WHEELS	WHEELS	5530	3873
	3	4242	1724	LIFT	LIFT	LIFT	0	569
	4	4242	6269	OFF	OFF	OFF	1630	569
	SUM	8884	8883				8884	8884
							MAX:	6269

Figure 3.6(c) STABILITY CALCULATION SPREADSHEET

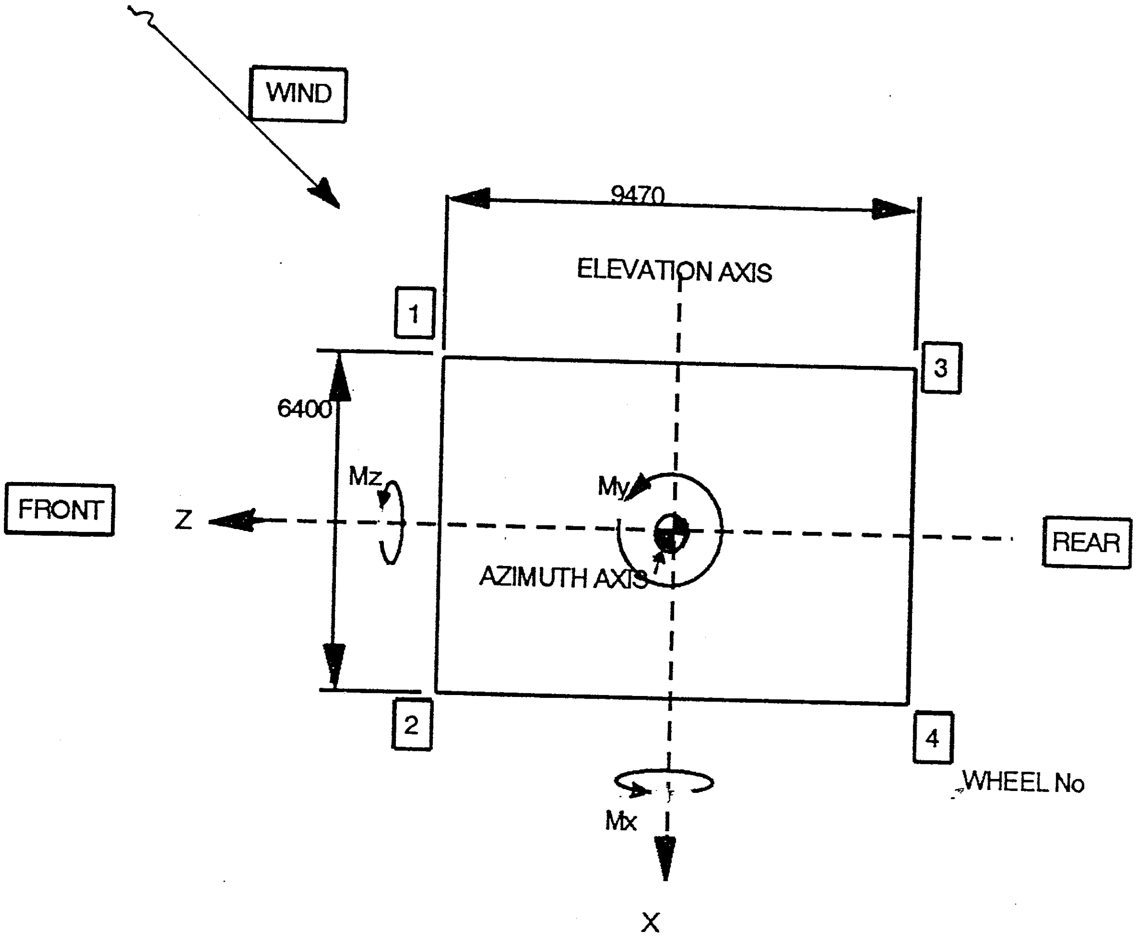

Figure 3.6(d) PLAN ON TURRET
SHOWING CO-ORDINATE SYSTEM
POSITIVE MOMENTS AS SHOWN
POSITIVE FORCES ACT IN THE POSITIVE AXIS DIRECTION

SPACE GASS 6.10 (386) - CONNELL WAGNER PTY LTD

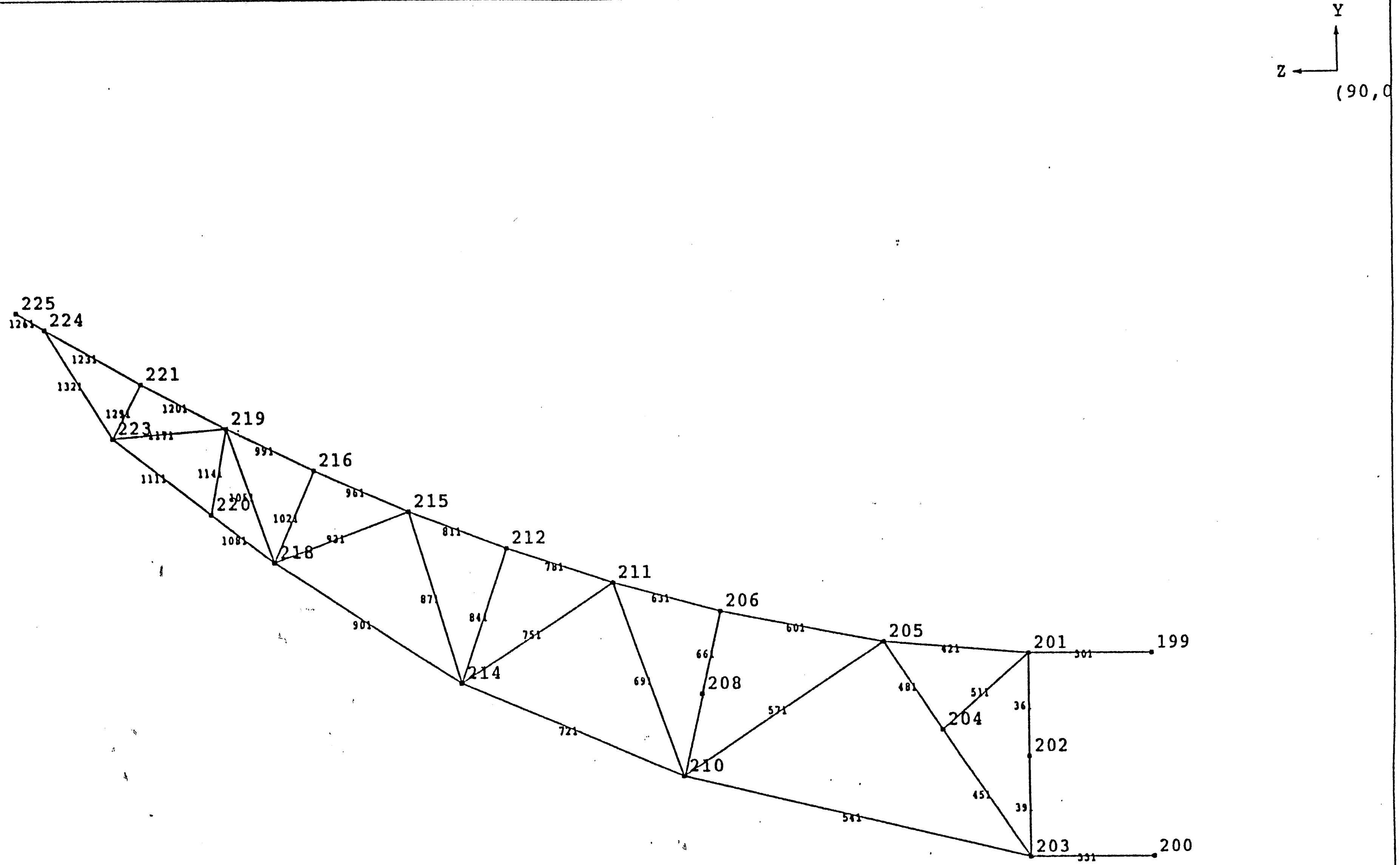

Figure 4.1(a)

truss on z axis

Job: DISHHDBE Designer: JTS Units: m,kN,kNm Scale: 1:125 Lc axes: XY
Load: None Disp: None Moment: None Shear: None Axial: None

SPACE GASS 6.10 (386) - CONNELL WAGNER PTY LTD

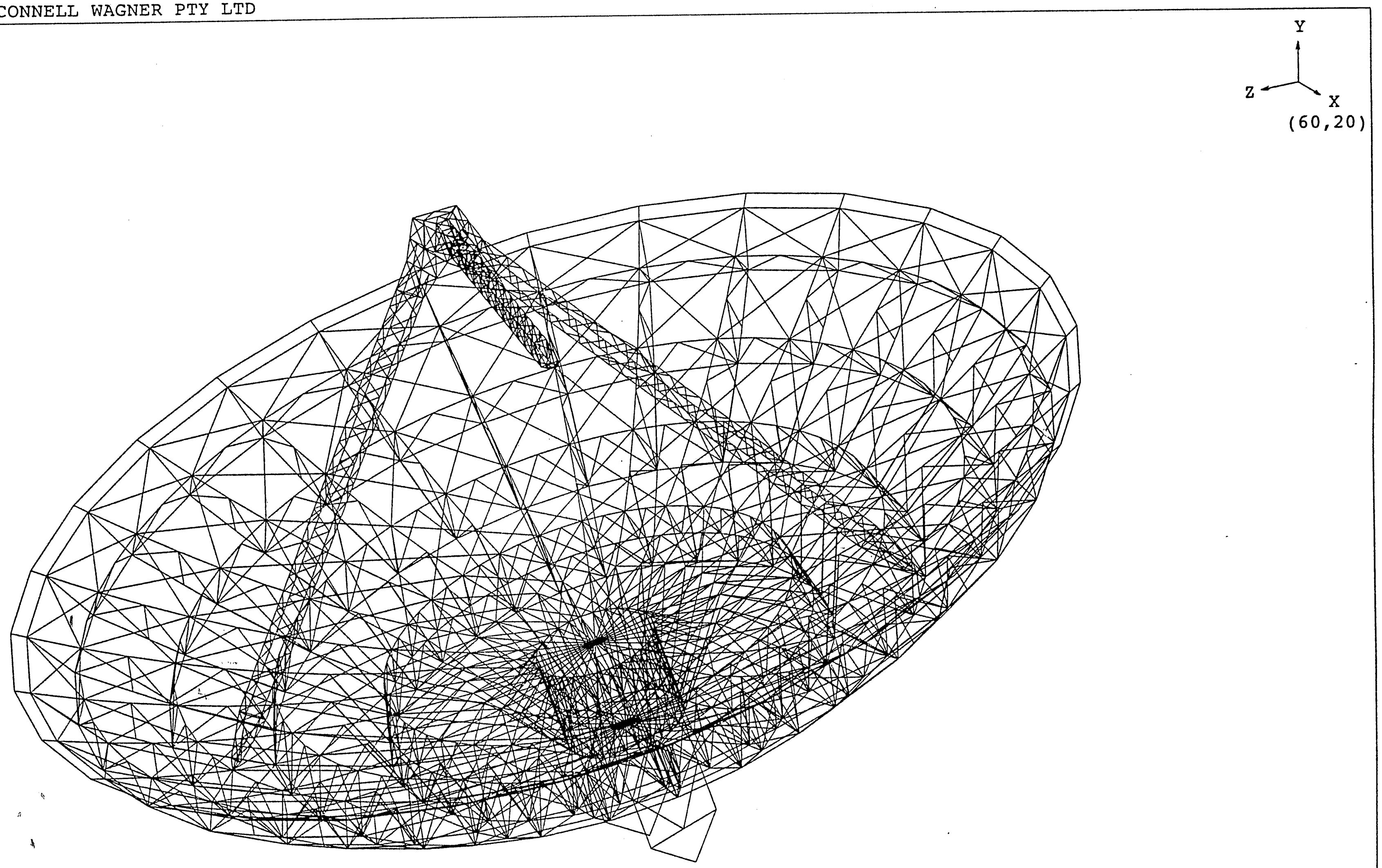

Figure 4.1(b)

Job: DPT Designer: JTS Units: m,kN,kNm Scale: 1:250 Lc axes: XY

Load: None Disp: None Moment: None Shear: None Axial: None

PARKES TELESCOPE GEN5 REFORMED

B.U.S. PLUS TRIPOD

19 Feb 1993, 3:00 pm

wind93.wk1 AS1170.2-1989 REGION A

Mz,cat: 1.035

RETURN PERIOD (yrs)	BASIC WIND SPEED (10m ht) T.C 2.0	PARKES DESIGN WIND SPEED (25m ht) T.C 2.5	PROBABILITY OF EXCEEDENCE IN YEARS 1	5	20	50	
5	34.0	35.2	0.200	0.672	0.988	1.000	
10	36.1	37.4	0.100	0.410	0.878	0.995	
15	37.3	38.6	0.067	0.292	0.748	0.968	
20	38.2	39.5	0.050	0.226	0.642	0.923	
25	38.9	40.2	0.040	0.185	0.558	0.870	
30	39.4	40.8	0.033	0.156	0.492	0.816	
35	39.9	41.3	0.029	0.135	0.440	0.765	
40	40.3	41.7	0.025	0.119	0.397	0.718	
45	40.6	42.0	0.022	0.106	0.362	0.675	
50	40.9	42.4	0.020	0.096	0.332	0.636	
55	41.2	42.7	0.018	0.088	0.307	0.600	
60	41.5	42.9	0.017	0.081	0.285	0.568	
100	43.0	44.5	0.010	0.049	0.182	0.395	
200	45.1	46.7	0.005	0.025	0.095	0.222	
300	46.3	47.9	0.003	0.017	0.065	0.154	
400	47.2	48.8	0.002	0.012	0.049	0.118	
500	47.8	49.5	0.002	0.010	0.039	0.095	
600	48.4	50.1	0.002	0.008	0.033	0.080	
700	48.9	50.6	0.001	0.007	0.028	0.069	
800	49.3	51.0	0.001	0.006	0.025	0.061	
900	49.6	51.3	0.001	0.006	0.022	0.054	
1000	49.9	51.7	0.001	0.005	0.020	0.049	**
1100	50.2	52.0	0.001	0.005	0.018	0.044	
1200	50.5	52.2	0.001	0.004	0.017	0.041	
1300	50.7	52.5	0.001	0.004	0.015	0.038	
1400	50.9	52.7	0.001	0.004	0.014	0.035	
1500	51.1	52.9	0.001	0.003	0.013	0.033	
1600	51.3	53.1	0.001	0.003	0.012	0.031	
1700	51.5	53.3	0.001	0.003	0.012	0.029	
1800	51.7	53.5	0.001	0.003	0.011	0.027	
1900	51.8	53.7	0.001	0.003	0.010	0.026	
2000	52.0	53.8	0.000	0.002	0.010	0.025	
2500	52.7	54.5	0.000	0.002	0.008	0.020	
3000	53.2	55.1	0.000	0.002	0.007	0.017	
3500	53.7	55.6	0.000	0.001	0.006	0.014	
4000	54.1	56.0	0.000	0.001	0.005	0.012	
4500	54.4	56.3	0.000	0.001	0.004	0.011	
5000	54.8	56.7	0.000	0.001	0.004	0.010	
5500	55.0	57.0	0.000	0.001	0.004	0.009	
6000	55.3	57.2	0.000	0.001	0.003	0.008	
6500	55.5	57.5	0.000	0.001	0.003	0.008	
7000	55.8	57.7	0.000	0.001	0.003	0.007	
7500	56.0	57.9	0.000	0.001	0.003	0.007	
8000	56.2	58.1	0.000	0.001	0.002	0.006	
8500	56.3	58.3	0.000	0.001	0.002	0.006	
9000	56.5	58.5	0.000	0.001	0.002	0.006	
9500	56.7	58.7	0.000	0.001	0.002	0.005	
10000	56.8	58.8	0.000	0.000	0.002	0.005	

** EXAMPLE: THE ULTIMATE LIMIT STATE WIND FOR PARKES (REGION A) IS 50m/s, A 1000-YEAR RETURN PERIOD WIND WITH A 5% PROBABILITY OF BEING EXCEEDED AT LEAST ONCE IN 50 YEARS.

Figure 6.6 WIND PROBABILITY TABLE

REFERENCES

1. Freeman Fox & Partners. "Proposed Radiotelescope - Design Study" London, September 1957.

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8. Blaylock RB. "Aerodynamic Coefficients for a Model of a Paraboloidal Reflector Directional Antenna Proposed for a JPL Advanced Antenna System". JPL Internal Memorandum CP-6, Jet Propulsion Laboratory, California Institute of Technology, May 1964.

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12. MAN Gustavsberg. Construction Drawings 1959 and 1960.

APPENDIX A

NOTES ON VISIT TO PARKES
18 FEBRUARY 1993

AUSTRALIA TELESCOPE NATIONAL FACILITY

NOTES ON VISIT TO PARKES ON 18 FEBRUARY 1993

DATE:	18 February 1993	
LOCATION:	Parkes	
PRESENT:	David Cooke	ATNF
	John Brooks	ATNF
	Brian Wilcockson	ATNF
	Andrew Hunt	ATNF
	Uwe Knop	ATNF
	Euan Troup	ATNF
	Ben Lam	ATNF
	Dick Mesley	Connell Wagner
	Peter Moore	Connell Wagner
	Jeff Schafer	Connell Wagner

PURPOSE OF MEETING: For members of Connell Wagner to gain a better appreciation of the concerns of Parkes Staff and the operation of the telescope especially under emergency conditions.

SCOPE

The following are some notes of discussions held on-site and are circulated for confirmation by others present that the information received has been recorded correctly.

AIM

Connell Wagner (CW) are presently preparing a report on the existing operating procedures for the telescope under adverse weather conditions (e.g. high wind), and intend to suggest strategies for protecting both equipment and staff in such situations.

WIND MEASUREMENTS

At present, wind speed and direction is measured at one location, approximately 250 metres from the telescope. Data is recorded by computer with sampling every 20 seconds. A proposal for further anemometer installations up to 5km from the telescope is being considered.

An instrument is to be acquired which will monitor lighting strikes and give a warning of approaching thunderstorm activity. This may not warn of all strong winds. (It was reported that winds at Narrabri of 150km/hr have arrived with clear skies). Some recent experience at Parkes was related, including that in December 1992 when there were peaks of 50, 60 and 75km/hr at 2 hour intervals.

ELECTRICAL PROBLEMS

The intermittent loss of power due to blown fuses has been a problem and when this coincides with an instruction to stow the antenna as in the event of 12 August 1992, difficulties may arise that require a decision on methods of hand stowing.

GRAVITY BIAS

The antenna is counter-weighted to return to zenith when the altitude drive brakes are released. This forms the basis of the hand methods of stowing. ("Hand" is used here as "Manual" means operator-instructed electrical driving as the alternative to computer-controlled electrical driving).

It was reported that with wind from the rear of the dish, a situation arises when the gravity bias effect to raise the dish to zenith is counteracted by a wind effect tending to push the dish towards horizon. This occurs at a (rear) wind of approximately 22km/hr.

QUESTIONS

Some questions were raised for consideration by CW regarding possible operating procedures in emergency situations. These included:

- Should the jacks at the azimuth wheels be employed before the antenna has been stowed in elevation?

- Should the dish be driven in azimuth to reduce wind torque before attempting to stow in elevation?

- Does the tendency for the antenna to "wind sock" to a wind-from-rear situation pose a problem? Is this occurrence (with presumed slipping of the azimuth brakes) better than a possible skidding of the antenna with brakes locked?

REGENERATIVE BRAKING

A proposal was raised that regenerative braking be used as an alternative to hand stowing.

HAND CRANKING

Although hand crank locations were originally provided in both azimuth and elevation gear boxes (with limit switches to shut down the appropriate electrical circuit if the hatch is opened), such hand cranking is not utilised.

Initial appraisal is that use of a hand crank in elevation would be UNSAFE, except for "tweaking" of the elevation angle near zenith. It was suggested that the hand stowing procedure results in the brakes getting hot. It is possible that the telescope could not be held against the gravity bias with a hand crank. The use of hand cranking in azimuth is unlikely to be useful as the high gear ratio precludes large azimuth movements (many turns of crank to produce any effect).

MOTOR CURRENT MEASUREMENTS

Present operating procedures include monitoring of motor currents and instructions to stow the telescope if certain limits are reached. B Wilcockson provided:

- a paper by Don Yabsley (9 October 1972)

- an operation instruction signed by W Butler dated 10 January 1974 which related to wind speeds in miles per hour and motor currents measured on the previous servo control system (prior to SWEO upgrade).

INTERIM REPORT

Some discussion was held on the interim report by CW dated February 1993. In brief, application of wind tunnel data collected since 1960 was discussed and the work to date. Items that require further investigation include:

- strength of truss member directly under the tripod legs

- strength of azimuth brakes.

MAINTENANCE MANUALS

No record exists of copies of six maintenance manuals specified to be provided to CSIRO by MAN (Freeman Fox Specification, p.79, copy attached). It is possible that this is a reference to electrical equipment only.

TELESCOPE INSPECTION

An inspection was made of the telescope structure and mechanical equipment. This showed that a member previously thought to be part of each truss only occurs at the tripod location as support for access platforms (confirmed in very small print in German on the MAN drawing).

An inspection of the drive brakes showed that these are custom-built and not easily accessible. It was reported that solenoid operators had burnt out and been rewired in the past.

The inspection showed that many features shown on the MAN drawings had been implemented. Section sizes were not checked.

The partial welding of box beam splices in the tunnel ("A frame") base was noted. This was the subject of part of a report by Macdonald Wagner in 1989.

DOCUMENTATION COPIES

Copies of the following were given to Peter Moore on site:

1. Emergency operating procedure from the manual kept in the control room.

2. Information on the telescope covering weight, diameter, etc from a familiarisation manual.

3. Operating instructions for DC motors.

PREVIOUS INVESTIGATIONS

A review of file information in the CW office has shown that two previous inspections and reports were made as follows:

- In 1989 by Charles Needham, Branko Gorenc and Leigh Walker when a noise had been reported during azimuth driving. A note was made that blowing of fuses was a problem at that time.

- In 1984 by Les Parker who reported on gear tooth wear and recommended a swap over of gears from one gear box to another. It was reported on site on 18 February 1993, that such a swap had been carried out, perhaps as a result of this report.

JEFF SCHAFER

The hoists shall be powered by 3-phase squirrel-cage induction motors, and contactor cubicles shall be effectively screened to suppress radio noise interference.

K.3.3. HOIST BLOCKS

Two 2-ton electric hoist blocks shall be provided for the lifting beams on the turret structure, and one 3-ton electric block for the lifting beam within the base tower. All three blocks shall be push-button controlled, with 2-speed hoisting, say 20 and 5-ft/min. Traversing may be manually operated.

They shall be powered by 3-phase squirrel-cage induction motors.

K.4. CALIBRATION OF ALTAZIMUTH ANGLES ON THE STRUCTURE

Angular calibration marks shall be placed on the finished structure so that the azimuth and altitude angles of the hub pointing direction may be directly read off at any time, as an overall check on positional accuracy.

In azimuth a suitable rigid pointer shall be affixed to the turret structure to read off against marks made on the edge of the azimuth roller track. A mark shall be made at every 20 minutes of arc, and the value punched on at every degree mark. The allowable angular error on any mark shall not be more than ± 1 min. of arc (about ±.07-ins. linear error at the outer edge of the roller path).

In altitude, similar calibrating marks to the same allowable angular error, shall be imprinted directly on a suitable surface near the rim of the counterweight structure. These marks shall be calibrated by some suitable means from reference to the angular inclination of the hub or error detector, so that the angular error due to gravity deflection of the counterweight structure itself shall be eliminated.

K.5. TOOLS AND SPARES

Any special tools required for assembly and maintenance of the equipment shall be provided, together with a set of normal tools required for maintenance.

The Contractor shall prepare a list of spares of normal replacement items of mechanical, electrical and electronic equipment for the approval of the Engineer, so that spares of non-stock items may be fabricated concurrently with those items where necessary or desirable.

K.6. OPERATION AND MAINTENANCE MANUAL

Six copies of an operation and maintenance manual shall be provided for the operation and maintenance of the drive and control equipment, and master equatorial system.

K.7. ACCOMMODATION AND ASSISTANCE FOR RESIDENT ENGINEER

Throughout the period of the work on site a suitable office shall be provided for the Resident Engineer, and his staff, and a suitable estate car shall be permanently placed at his disposal.

In addition, the Contractor shall provide any assistance required in the handling of instruments and the taking of measurements to establish the dimensional accuracy of the work.

K.8. PROGRESS PHOTOGRAPHS

The Contractor shall supply six unmounted 10-in. x 8-in. copies of each progress photograph, suitably inscribed, of such portions of the Works, in progress and completed, as may be directed by the Engineer. The negatives of the photographs shall be the property of the [illegible] may be supplied to any

APPENDIX B

INVESTIGATIONS 1989

(1)	Notes on Visit to Parkes (24 February)	(2 pages)
(2)	Inspection of the Parkes Telescope (28 March)	(15 pages)
(3)	Azimuth Wheels (3 May)	(2 pages)
(4)	Tripod Leg Members (16 May)	(5 pages)

ATP104
Parkes

ATP104VIS.MIN
28-Feb-89

NOTES ON VISIT TO

PARKES TELESCOPE ON 24TH FEBRUARY, 1989

PRESENT :	DAVID COOK	:	CSIRO
	ANDREW ? HUNT	:	CSIRO
	BEN ? LAM	:	CSIRO
	CLIFF ? SMITH	:	CSIRO
	BRANKO GORENC	:	MW
	LEIGH WALKER	:	MW
	CHARLES NEEDHAM	:	MW

1. David Cook confirmed that there are two principal reasons for CSIRO requesting inspection of telescope by MW:

   (a) General concerns regarding the safety of the antenna, following the collapse of the Greenbank, USA telescope in November 1988.

   (b) Occurence of strange noises emanating from the azimuth drives about one week ago.

2. There have been problems with drive fuses continuously blowing, however, David Cook confirmed that MW is not required to investigate this.

3. The strange noise occurred as follows:

   The antenna was being held stationary under computer control (feed back from encoder) after having previously slewed in azimuth through about 180^{o}. A banging noise, something like a shotgun blast, started which was heard in the control room. The noise repeated at a frequency of about 1 Herz, though sometimes was at a lower frequency. Motor currents appeared normal. Small movements in azimuth (1^{o}-2^{o}) did not stop the noise. Jacking in azimuth did not stop the noise. On investigation, the noise appeared to be coming from one of the azimuth gearboxes (left-hand gearbox when looking in the same direction as the dish, when in horizon), however, the noise was very diffuse and it was difficult to pinpoint the source (the vibration of the structure could be felt in the control room). After about 20 minutes the telescope was slewed a large amount in azimuth and the noise stopped. On returning to the original azimuth position the noise did not reoccur. Such a noise has never been known to occur in the past, nor has it occurred since this one event.

4. CSIRO have noted that the azimuth roller at this gearbox appears to be misaligned, with the roller axis intersecting the azimuth axis well below the level of the azimuth rail. This misalignment might have been present for anything up to one year. CSIRO will obtain footprints for all four rollers and send to MW.

5. It was noted that alignment of azimuth rollers about a vertical axis is fixed by dowels, and this has not been altered since original construction.

6. All azimuth and elevation drives were inspected with the dish both stationary and slewing. Other than the obvious misalignment of the roller described above, everything appeared to be in normal working order. Neither the current mechanical foreman (Ben ?) or his predecessor of 20 years experience with the telescope (Cliff ?), could discern any unusual noises. All accessible azimuth gearbox bearings had been replaced at the time of the elevation gearbox upgrade.

7. CSIRO advised that the updating of the servo system 2-3 years ago was carried out by Colin Jacka and Jon Abels of Radiophysics.

8. Some slippage in a major bolted joint on the structure above the roller had been noted some time ago and the joint had been partially welded up.

9. Inspection of elevation bearings revealed nothing unusual. Weld repair to structure at stub axles (as previously investigated) appeared to be in good order, however, (joint slippage?) noises could be heard emanating from this area as the dish was slewed in elevation.

10. It was reported that the dish is over-balanced by the counterweight by about 200 tonnes. If the dish is let go even at 89^{o} elevation, there is considerable vibration (from elevation buffer impact?).

11. MW advised that they will be recommending ultrasonic/magnetic particle testing of some structural welds. The first week in March 1989 would be a convenient time for this (CSIRO will forward to MW a copy of the scheduled operation with the telescope up until the tracking operation in August 1989).

CHARLES J. NEEDHAM.

c.c BEZ
LGW
NG

C S I R O

DIVISION OF RADIOPHYSICS

INSPECTION OF THE PARKES TELESCOPE

I N T E R I M   R E P O R T

CONTENTS

INSPECTION OF THE PARKES TELESCOPE

I N T E R I M   R E P O R T

---

1. SCOPE OF INSPECTION

Macdonald Wagner were engaged by the CSIRO Division of Radiophysics to inspect the Parkes Telescope and make recommendations on the following points of concern:

(a) What is the current condition of the telescope structure, and what preventative maintenance, if any, is required? Are there any other concerns regarding the safety and integrity of the telescope?

(b) What is the probable cause of the unusual noises recently reported during the operation of the telescope, and what remedial action, if any, is required?

(c) What is the probable cause of the apparent misalignment of one of the azimuth rollers, and what remedial action, if any, is required?

It is noted that these points of concern are raised in the context of:

- The recent catastrophic collapse of the Greenbank Telescope in the U.S.A.
- The planned use of the Parkes Telescope for tracking Voyager in August 1989, at which time 100% reliability of the telescope is imperative.

2. TELESCOPE STRUCTURE

2.1 Visual Inspection

During the site visit on 24/2/89 the structure was visually inspected with particular emphasis being placed on the most highly stressed elements of the alidade, hub and the dish.

Alidade Structure:

The base support frame was inspected for signs of structural over-stress and deformations. Visual inspection revealed that some repair work had been carried out prior to 1989. The repairs consisted of applying weld runs to some of the vertical butt joints between the base frame segments. Presumably the segments had moved with respect to one another and the maintenance crew attempted to lock these (bolted) joints against further movement. Some of these welds were found to be cracked, and some unwelded joints showed that slippage took place.

The fact that the previously laid welds across the segment butt joints have cracked is of some concern. While from the point of view of safety there is no worry, it is possible that growing misalignment of the azimuth rollers may occur.

All butt joints between the segments were marked for N.D.T. weld inspection.

Hub Structure:

The elevation bearing axle support plate was inspected visually and no further damage to the plate was observed.

The hub structure would appear to be in good repair.

Telescope Dish:

Due to the access problems, only the following elements could be visually examined:

- Bottom chords of the main ribs.
- Elements along the radial walkway.
- Bases of the tetrapods.

No external signs of structural damage were sighted, but the possibility of internal corrosion by water collecting inside the tubes was marked for further inspection.

2.2 Inspections Carried Out by Maintenance Crew

Tubular members accessible from existing platforms were drilled to see if any water has collected inside the tubes. Water logged tubes were found in:

- Bases of tetrapod.
- Some tubular chords in the dish back-up structure.

2.3 N.D.T. Inspection Carried Out by E.T.R.S.

Magnetic particle and ultrasonic inspection was carried out on the following joints:

- Base frame segments at the location of butt splices. These splices are nominally bolted by friction grip bolts.
- Elevation bearing gussets and plates.
- Connections of tubular chords to the hub.

The findings of the N.D.T. inspection are reproduced in the Appendix A. In summary, the inspection revealed:

- Welds over the segment butt joints in the base frame have cracked, indicative that bolted joints are not entirely rigid.
- Flange plates to girder web welds appear to be sound.
- Hub plates at the elevation bearing support show no signs of further damage.
- Chord to hub welds are sound, and tube wall thicknesses are not significantly affected by internal corrosion.

It is also noted that magnetic particle testing was carried out on a number of (randomly selected) elevation bull gear teeth, and no evidence of cracking was found.

3. UNUSUAL NOISES

3.1 Description

The unusual noises were reported on only one occasion as follows:

The telescope was being held stationary under computer control after having previously slewed approximately 120^{o} in azimuth. A loud banging noise, something like a shotgun blast was heard in the control room. The noise repeated at a frequency of about one Herz, though this varied. Small movements of 1^{o}–2^{o} in azimuth did not stop the noise. On inspection, the noise appeared to be coming from one of the azimuth gearboxes (left hand gearbox when looking in the same direction as the dish whilst in horizon position). The noise was, however, very diffuse and it was difficult to pinpoint the source. After about 20 minutes the telescope was slewed a large amount in azimuth, and the noise ceased. On slewing back to the original azimuth position, the noise did not reoccur.

3.2 Probable Cause

Given the duration and apparent severity of the noise and vibration (and ruling out a trivial explanation such as a banging door), it would appear to be certain that the noise was being generated by an external power supply (as against, for example, stored strain energy in the structure). As such, one of the axis drives - and presumably the azimuth drive - must be considered a likely source. This possibility was discussed with Dr. Colin Jacka of Radiophysics who has since inspected the telescope and recorded motor currents.

4. AZIMUTH ROLLER MISALIGNMENT

The axis of the azimuth roller driven by the gearbox described in 3. above is visually out of alignment, with the roller contacting the rail on the inner perimeter of the rail rather than the centre. It is not known how long this has been so, though it is known to be less than one year.

There is no evidence of movement at the shimmed connection of the roller to the structure, and internal movement within the roller frame would appear to be unlikely, given the otherwise smooth running behaviour of the roller. It, therefore, appears likely that the tilt is due to deformations of the structural base frame, whereby an initial misalignment of the roller from whatever cause, could induce parasitic radial forces into the base frame, further aggravating the misalignment.

5. RECOMMENDATIONS

5.1 Structural

It is recommended that the following procedures are carried out on the telescope structure:

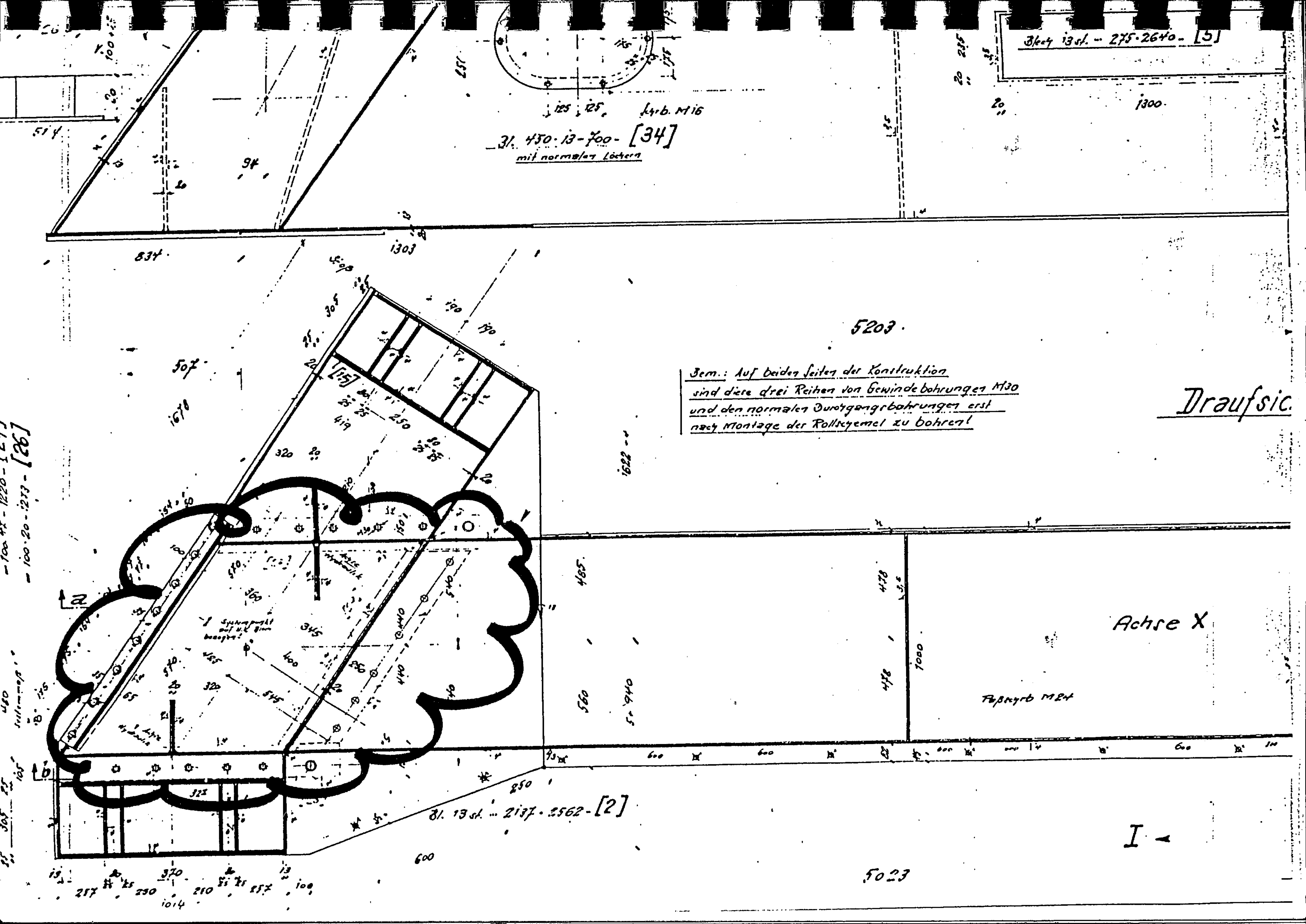
- The inside of the alidade A-frame base girders at each azimuth roller should be inspected for signs of rust, cracking or joint slippage (see attached sketch).
- The segment joints on the alidade A-frame base should be butt welded together. In such case, a brief specification would need to be prepared.
- All sealed structural tubes should be drained.

5.2 Unusual Noises

This item is still under discussion with Radiophysics personnel and no immediate action is recommended. it is assumed that the telescope operating personnel have been briefed as to the potential dangers should such a situation reoccur, and that the telescope should be immediately shut down in such a case.

5.3 Azimuth Roller Misalignment

Following completion of work as described in 5.1 above, all azimuth rollers should be checked for alignment, and realigned where necessary to the original specification.



Draufsic
Blech 13 st. ... 275·2640 - [5]
Gewb. M16
Bl. 450·13·700 - [34]
mit normalen Löchern
5203
Bem.: Auf beiden Seiten der Konstruktion
sind diese drei Reihen von Gewindebohrungen M30
und den normalen Durchgangsbohrungen erst
nach Montage der Rollschemel zu bohren!
Achse X
Paßschrb M24
Bl. 13 st. ... 2137·2562 - [2]
I
5023
- 100·20·1273 - [26]

2/9

Metallurgists, Materials Testing Technologists and Inspecting Engineers

TESTING RECORD

CLIENT: MACDONALD WAGNER

REPORT No.: NN89-123

PROJECT: PARKES RADIOTELESCOPE

SPECIFICATION: —

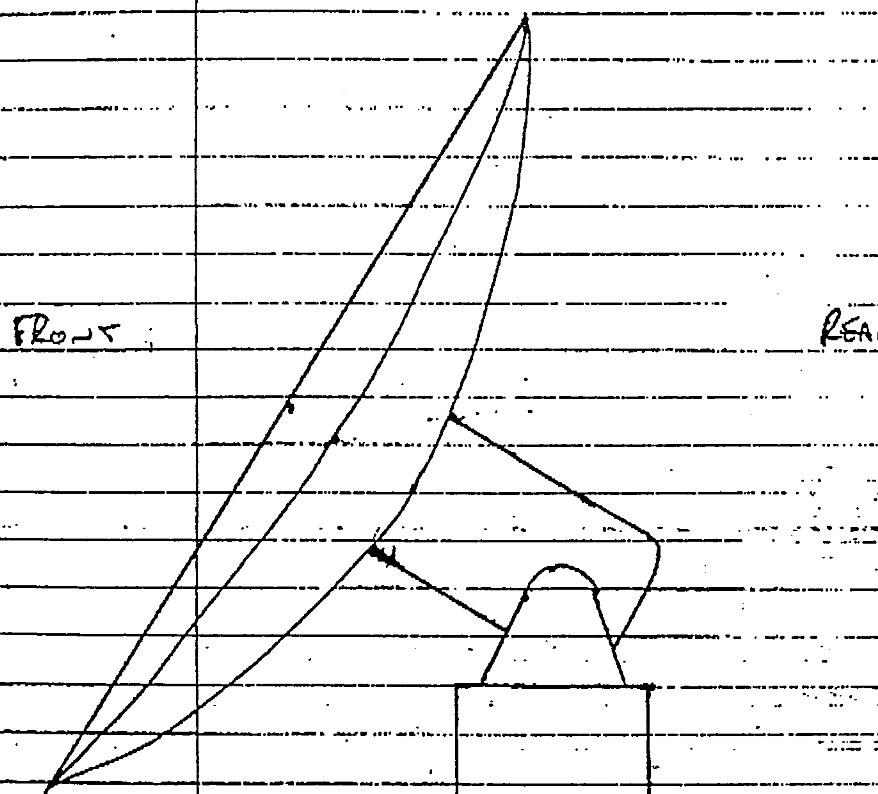
CLIENT JOB No.: CSIRO n° RP21276

TECHNIQUE: —

DATE: 1-3/3/89

TERMINOLOGY: —

SECTION No.	INTERPRETATION		QUALITY
	ORIENTATION		



LEFT + RIGHT TAKEN WHEN FACING FRONT.

'89 03/06 08:11 ☎ 61 2 647 2341 ETRS SYDNEY 03

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LIQUID ~~PENETRANT~~/MAGNETIC PARTICLE REPORT

T.F

Report No. NN89-123M/1	Client MACDONALD WAGNER	Date 1-3/3/89

Job Description M.P.I OF RING GIRDER FILLET WELDS AND THE RETRO BUTT WELDS AT BOLTED JOINTS. (8 POSITIONS)

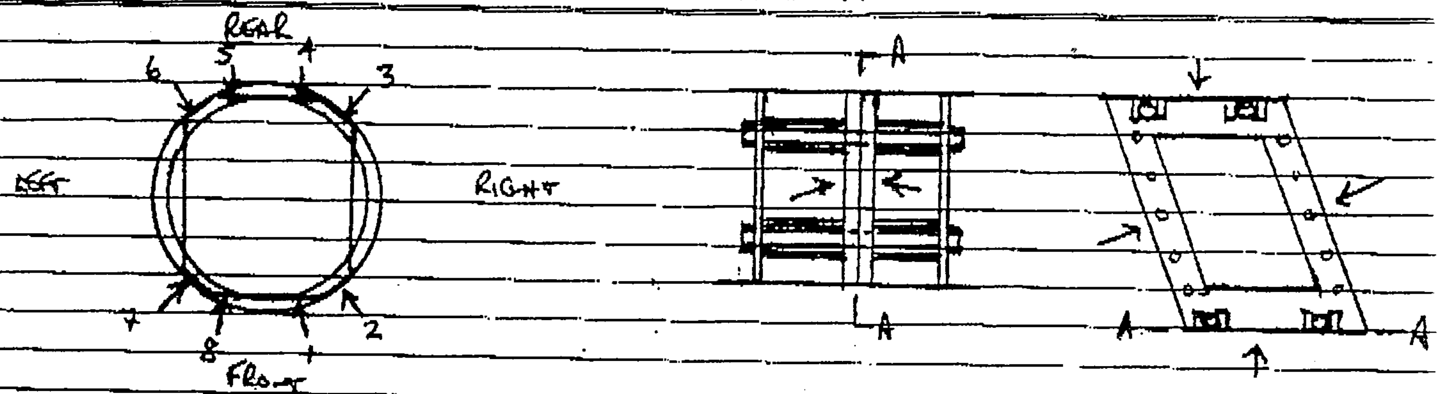
Job Location PARKES RADIO TELESCOPE.

Contact DAVE COOK	Order No. CSIRO O/No RP21276
Acceptance Criterion FOR CRACKING	Surface Condition AS PAINTED + WELDED

Examination Method

Magnetic Flaw Detection A.S. 1171-1976				Penetrant Flaw Detection A.S. 2062-1977				
1. TECHNIQUE		2. MEDIA		1. METHOD		2. MEDIA		
Current Flow AC/DC		Dry Powder		Dye Penetrant		Solvent Removable		Contact Time
Threaded Bar AC/DC		Fluorescent Ink		Fluorescent Penetrant		Water Washable		Development Time
Encircling Coil AC/DC		Non Fluor. Ink	✓			Post Emulsifiable		
Magnetic Flow AC/~~DC~~	✓							

Results of Examination



→ - AREA OF INSPECTION (APPROX 90°)

WELD 1:- INTERIOR FILLET - NO ACCESS SPACE FILLED WITH CONCRETE
EXTERNAL BUTT - 230mm OF WELD, NO EVIDENCE OF CRACKING FOUND
WELD 2:- INT. FILLET - NO EVIDENCE OF CRACKING FOUND
EXT BUTT - 140mm OF WELD, NO EVIDENCE OF CRACKING FOUND
WELD 3:- INT. FILLET - NO EVIDENCE OF CRACKING FOUND
EXT BUTT - 100mm OF WELD, NO EVIDENCE OF CRACKING FOUND
WELD 4:- INT FILLET - NO EVIDENCE OF CRACKING FOUND
EXT BUTT - 100mm OF WELD, CRACKED RIGHT THROUGH
WELD 5:- INT FILLET - NO EVIDENCE OF CRACKING FOUND
EXT BUTT - 420mm OF WELD, NO EVIDENCE OF CRACKING FOUND
WELD 6:- INT FILLET - NO EVIDENCE OF CRACKING FOUND
EXT BUTT - 110mm OF WELD, CRACKED FOR 50mm FROM BOTTOM EDGE
WELD 7:- INT FILLET - NO EVIDENCE OF CRACKING FOUND
EXT BUTT - 140mm OF WELD, NO EVIDENCE OF CRACKING FOUND
WELD 8:- INT FILLET - NO EVIDENCE OF CRACKING FOUND
EXT BUTT - 420mm OF WELD, NO EVIDENCE OF CRACKING FOUND

REMARKS

TECHNICIAN: SHANE M. RANDALL

SIGNED: S.M. Randall

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~~LIQUID PENETRANT~~/MAGNETIC PARTICLE REPORT

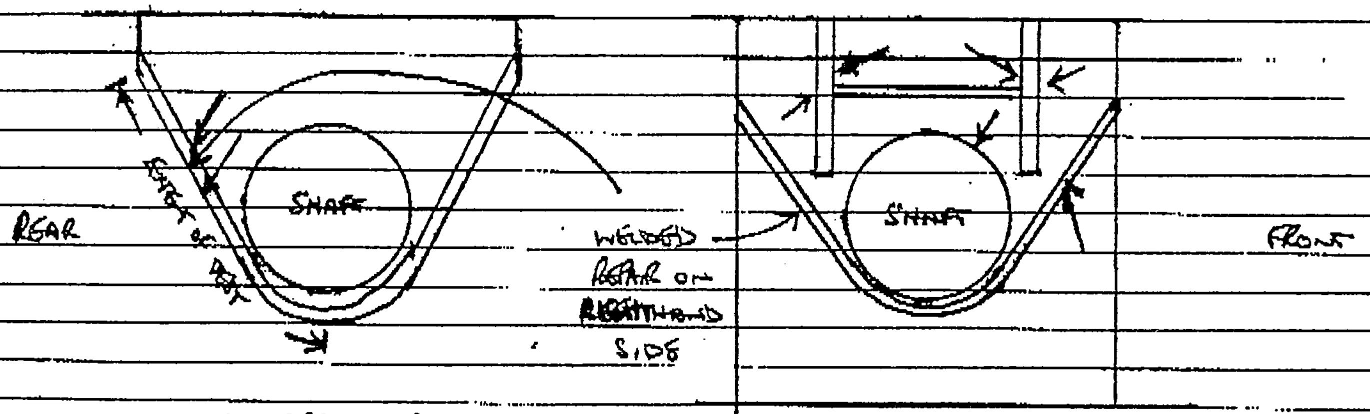
T.P.C

Report No. N 89-123 M/2	Client MACDONALD WAGNER		Date 1-3/3/89
Job Description	MPI of ELEVATION BEARING GUSSET AND PLATE WELDS BOTH INTERNAL AND EXTERNAL.		
Job Location	PARKES RADIO TELESCOPE.		
Contact	DAVE COOK.	Order No.	CSIRO O/No RP21276
Acceptance Criterion	FOR CRACKING	Surface Condition	AS PAINTED + WELDED

Examination Method

Magnetic Flaw Detection A.S. 1171-1976					Penetrant Flaw Detection A.S. 2062-1977				
1. TECHNIQUE			2. MEDIA		1. METHOD		2. MEDIA		
Current Flow	AC/DC		Dry Powder		Dye Penetrant		Solvent Removable		~~Contact Time~~
Threaded Bar	AC/DC		Fluorescent Ink		Fluorescent		~~Water Washable~~		Development Time
Encircling Coil	AC/DC		Non Fluor. Ink	✓	Penetrant		Post Emulsifiable		
Magnetic Flow	AC/~~DC~~	✓							

Results of Examination



→ AREA TESTED

LEFT HAND SIDE EXTERNAL – NO EVIDENCE OF CRACKING FOUND
INTERNAL – " " " " "

RIGHT HAND SIDE EXTERNAL – " " " " "
INTERNAL – " " " " "

N.B. WELD BELOW SHAFT ON BEARING PLATES (EXTERNAL) APPEAR OF POOR QUALITY VISUALLY (ORIGINAL WELD)

REMARKS

TECHNICIAN: SHANE M. RANDALL

SIGNED: S.M. Randall

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s/c

LIQUID PENETRANT/MAGNETIC PARTICLE REPORT

T.P.C

Report No. NA89-123 M/3	Client MACDONALD WAGNER	Date 1-3/3/89

Job Description: MPI OF CONNECTIONS OF RIBS TO TURRET. (SAMPLE ONLY)

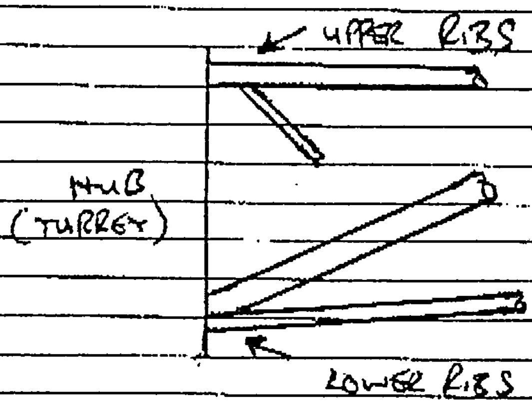
Job Location: PARKES RADIO TELESCOPE

Contact: DAVE COOK	Order No. CSIRO O/N° RP21276
Acceptance Criterion: FOR CRACKING	Surface Condition: AS PAINTED + WELDED

Examination Method

Magnetic Flaw Detection A.S. 1171-1976					Penetrant Flaw Detection A.S. 2062-1977					
1. TECHNIQUE			2. MEDIA		1. METHOD		2. MEDIA			
Current Flow	AC/DC		Dry Powder		Dye Penetrant		Solvent Removable		Contact Time	
Threaded Bar	AC/DC		Fluorescent Ink		Fluorescent		Water Washable		Development Time	
Encircling Coil	AC/DC		Non Fluor. Ink		Penetrant		Post Emulsifiable			
Magnetic Flow	AC/DC									

Results of Examination



RIBS NUMBERED ANTI-CLOCKWISE FROM VERTICAL LADDER BETWEEN UPPER AND LOWER RIBS

UPPER RIB 3 – NO EVIDENCE OF CRACKING FOUND
15 – " " " " "
23 – " " " " "

LOWER RIB 4 – " " " " "
5 – " " " " "
12 – " " " " "
13 – " " " " "
25 – " " " " "
26 – " " " " "

REMARKS

TECHNICIAN: SHANE M. RANDALL

SIGNED: S.M. Randall

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~~LIQUID PENETRANT~~/MAGNETIC PARTICLE REPORT

T.P

Report No.	NN89-123/M4
Client	MACDONALD WAGNER
Date	1-3/3/89
Job Description	MPI OF RANDOM SAMPLE ON TOOTH OF LEFT AND RIGHT RACK SEGMENTS. (5 TEETH ON EACH)
Job Location	PARKES. RADIO TELESCOPE.
Contact	DAVE COOK
Order No.	CSIRO O/N°RP21276
Acceptance Criterion	FOR CRACKING
Surface Condition	M/C. DEGREASED.

Examination Method

Magnetic Flaw Detection A.S. 1171-1976

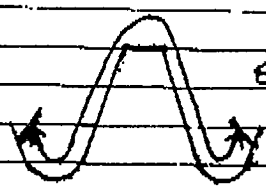
1. TECHNIQUE			2. MEDIA	
Current Flow	AC/DC		Dry Powder	
Threaded Bar	AC/DC		Fluorescent Ink	
Encircling Coil	AC/DC		Non Fluor. Ink	
Magnetic Flow	AC/DC			

Penetrant Flaw Detection A.S. 2062-1977 (struck through)

1. METHOD		2. MEDIA		
Dye Penetrant		Solvent Removable		Contact Time
Fluorescent Penetrant		Water Washable		Development Time
		Post Emulsifiable		

Results of Examination

~~TEETH~~ NUMBERED FROM REAR.



EXTENT OF TEST ON EACH TOOTH.

LEFT HAND SIDE, TOOTH 31 – NO EVIDENCE OF CRACKING FOUND
34 – " " " " "
37 – " " " " "
42 – " " " " "
48 – " " " " "

RIGHT HAND SIDE, TOOTH 28 – " " " " "
32 – " " " " "
33 – " " " " "
36 – " " " " "
40 – " " " " "

REMARKS

TECHNICIAN: SHANE N. RANDALL.

SIGNED: [signature]

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1859

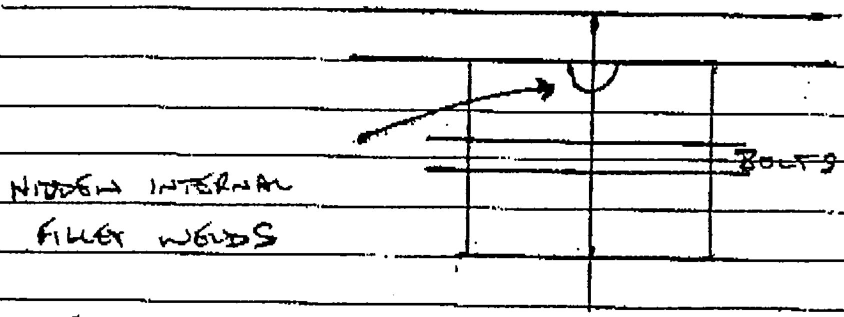
T.P.

"ULTRASONIC INSPECTION REPORT"

Report No. NN89-123 W/1 — Client MACDONALD WAGNER	Date 1-3/3/89
Job Description U/S'D of HIDDEN INTERNAL FILLET WELD ON RING GIRDER.	
Job Location PARKES RADIO TELESCOPE	
Contact DAVE COOK	Order No. CSIRO O/N PPZ1276
Acceptance Criterion: FOR CRACKING	Test Procedure —
Thickness Range: 13 - 20mm	Calibration Range 0 - 100mm
Ultrasonic Unit: KK USK 6 S/No 1672	Probes MB CD 10/0/4 KK MWB 45°
Couplant: POLYCELL PASTE.	Scanning Positions FROM EXTERNAL FACE.
Sensitivity: 2mm D.W.E TO F.S.H + 1.5mm HOLE @ M.S.D TO F.S.H.	Manufacturing Details —

Results of Examination

RANDOM 25% (APPROX) OF EACH WELD.



FOR LOCATIONS REFER TO NN89-123 W/1 WORKSHEET NO 3480

WELD 1 - WELD CONFIRMED - NO EVIDENCE OF CRACKING FOUND
2 - " " - " " " " "
3 - " " - " " " " "
4 - " " - " " " " "
5 - " " - " " " " "
6 - " " - " " " " "
7 - " " - " " " " "
8 - " " - " " " " "

REMARKS:

TECHNICIAN: SHANE M. RANDALL

SIGNED: S. Randall

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(Incorporated in Victoria)
Metallurgists, Materials Testing Technologists and Inspecting Engineers

8/9

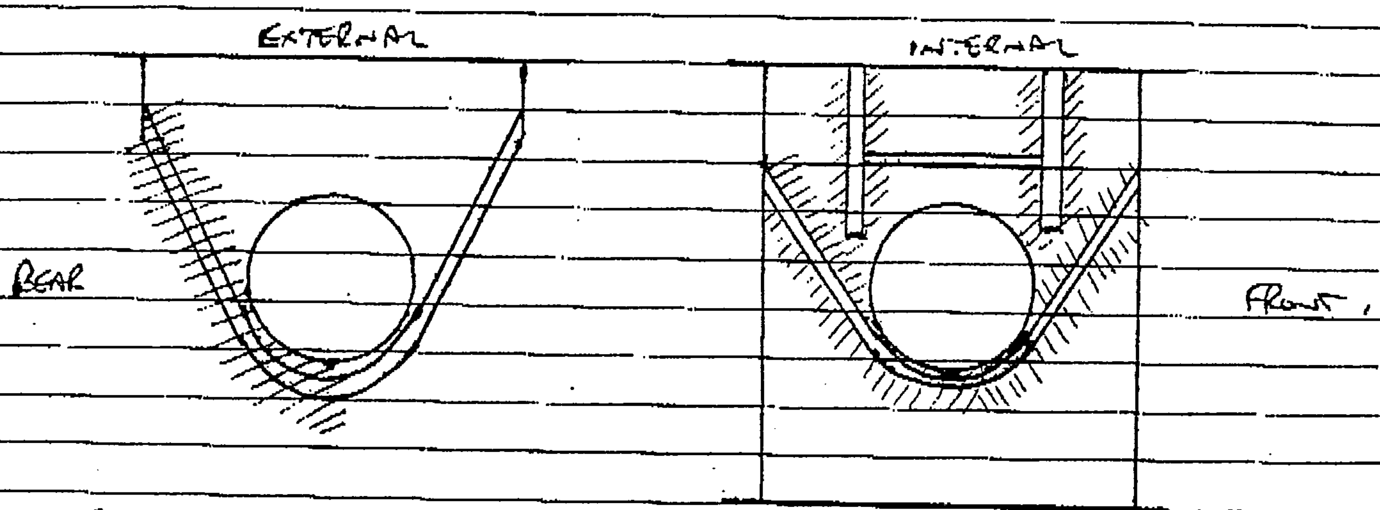
1860

"ULTRASONIC INSPECTION REPORT"

T.P.

Report No. WN89-123 4/2	Client MACDONALD WAGNER		Date 1-3/3/89
Job Description USFD OF THE ELEVATION BEARING GUSSETS AND PLATES.			
Job Location PARKES RADIO TELESCOPE			
Contact DAVE COOK.		Order No. CSIRO O/No RP21276	
Acceptance Criterion: FOR CRACKING		Test Procedure ✓	
Thickness Range: - 25mm		Calibration Range 0-100mm	
Ultrasonic Unit: KK USK 6 S/No 1642		Probes MS CD 10/0/4 KK MWB 45°	
Couplant: POLYCELL PASTE.		Scanning Positions WITHIN 50mm OF EDGE OF PLATE	
Sensitivity: 2nd B.W.E TO F.S.H AND 1.5mm HOLE AT MAX. TEST. DIST TO F.S.H.		Manufacturing Details	

Results of Examination



SHADED AREAS SHOW EXTENT OF TEST.

LEFT HAND SIDE EXTERNAL – NO EVIDENCE OF CRACKING FOUND
INTERNAL – " " " " "

RIGHT HAND SIDE EXTERNAL – " " " " "
INTERNAL – " " " " "

REMARKS:

TECHNICIAN: SHANE H. RANDAN
SIGNED: S N R...

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9/9

1861

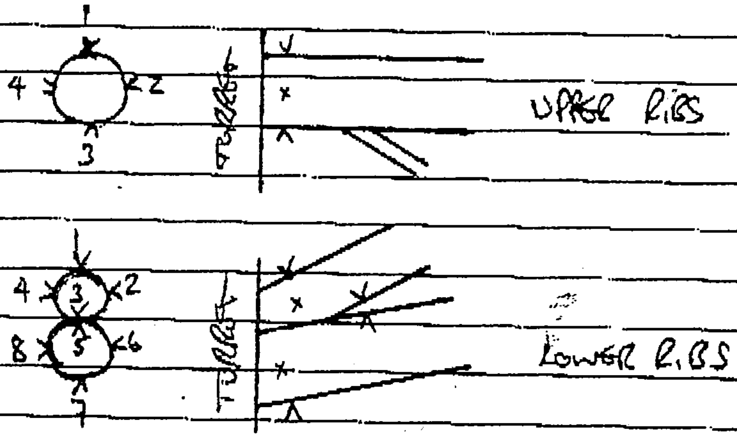
"ULTRASONIC INSPECTION REPORT"

T.P.

Report No. NN89 - 123 M/3	Client MACDONALD WAGNER		Date 1-3/3/89
Job Description UTT OF RIBS AT CONNECTION WITH TURRET.			
Job Location PARKES RADIO TELESCOPE			
Contact DAVE COOK		Order No. CSIRO O/No RRP 2276	
Acceptance Criterion: NO SPEC.		Test Procedure AS 2542.3-1985	
Thickness Range: 7.0 - 9.0 mm		Calibration Range 0 - 25 mm	
Ultrasonic Unit: KRAUTKRAMER USK 6 S/No 1672		Probes MG CD 10/6/4	
Couplant: POLYCELL PASTE		Scanning Positions SEE DIAGRAM	
Sensitivity: 2ND B.W.E.		Manufacturing Details —	

Results of Examination

VIEWED LOOKING TO CENTRE OF TELESCOPE.



RIBS NUMBERED AS PER NN89-123 M/3 WORKSHEET No 3482

		1	2	3	4	5	6	7	8
UPPER RIB	3	7.5	8.0	7.75	7.75	—	—	—	—
	15	8.0	8.5	8.5	8.25	—	—	—	—
	23	7.25	7.5	7.75	7.5	—	—	—	—
LOWER RIB	4	8.25	8.25	8.25	8.0	7.5	7.5	7.5	7.75
	5	8.25	8.0	8.25	8.0	7.75	8.25	8.0	7.5
	12	8.5	8.5	8.75	8.25	8.0	8.75	8.25	7.75
	13	8.5	8.5	8.5	8.5	8.0	8.0	7.75	7.5
	25	7.25	8.0	8.5	8.0	8.25	7.5	7.75	8.0
	26	7.5	7.5	8.0	8.0	7.25	8.25	8.25	7.75

REMARKS:

TECHNICIAN: SHANE H. RANDALL

SIGNED: [signature]

ATP 104
Parkes

M E M O R A N D U M

TO: Mr J Brooks, CSIRO

FROM: Mr C Needham, Macdonald Wagner

COPIES: Messrs N Guoth, B Gorenc, Macdonald Wagner

DATE: 3 May 1989

SUBJECT: PARKES TELESCOPE, AZIMUTH WHEELS

Dave Cooke has recently produced "footprints" for the Parkes Telescope azimuth wheels to indicate the wheel/rail contact area.

The footprints indicate (for this set of measurements at least) that the two (diagonally opposed) idler wheels have significantly higher load than the two driven wheels. This would be consistent with a distorted alidade due to incorrect vertical shimming at the wheels.

The maximum footprint width measured is approximately 440 mm, which would correspond to a theoretical Hertzian wheel load of 4,500 KN (see attachment), versus a nominal design load of 2,600 KN. Distortion of the alidade to this extent would clearly be of major concern. The accuracy associated with the footprint method is however quite low - given total vertical wheel/rail surface deformations of about 0.25 mm, the finite thickness of the paper will tend to exaggerate the footprint size - Prussian Blue onto the wheel with a well-cleaned rail may be more accurate.

Preferably however, the wheel loads should be measured more directly and it should be possible to utilise the azimuth hydraulic lifting facility via pressure gauges to accomplish this. Depending on the features of the lifting facility it may be possible to establish :

a) the total rotating weight

b) individual wheel loads for zenith position

c) individual wheel loads for 30 degree elevation position

d) (hence) approximate total counterweight imbalance

e) wheel load sensitivity to vertical alidade deflection at any particular corner. Depending on these results, a rail surface survey may be advisable.

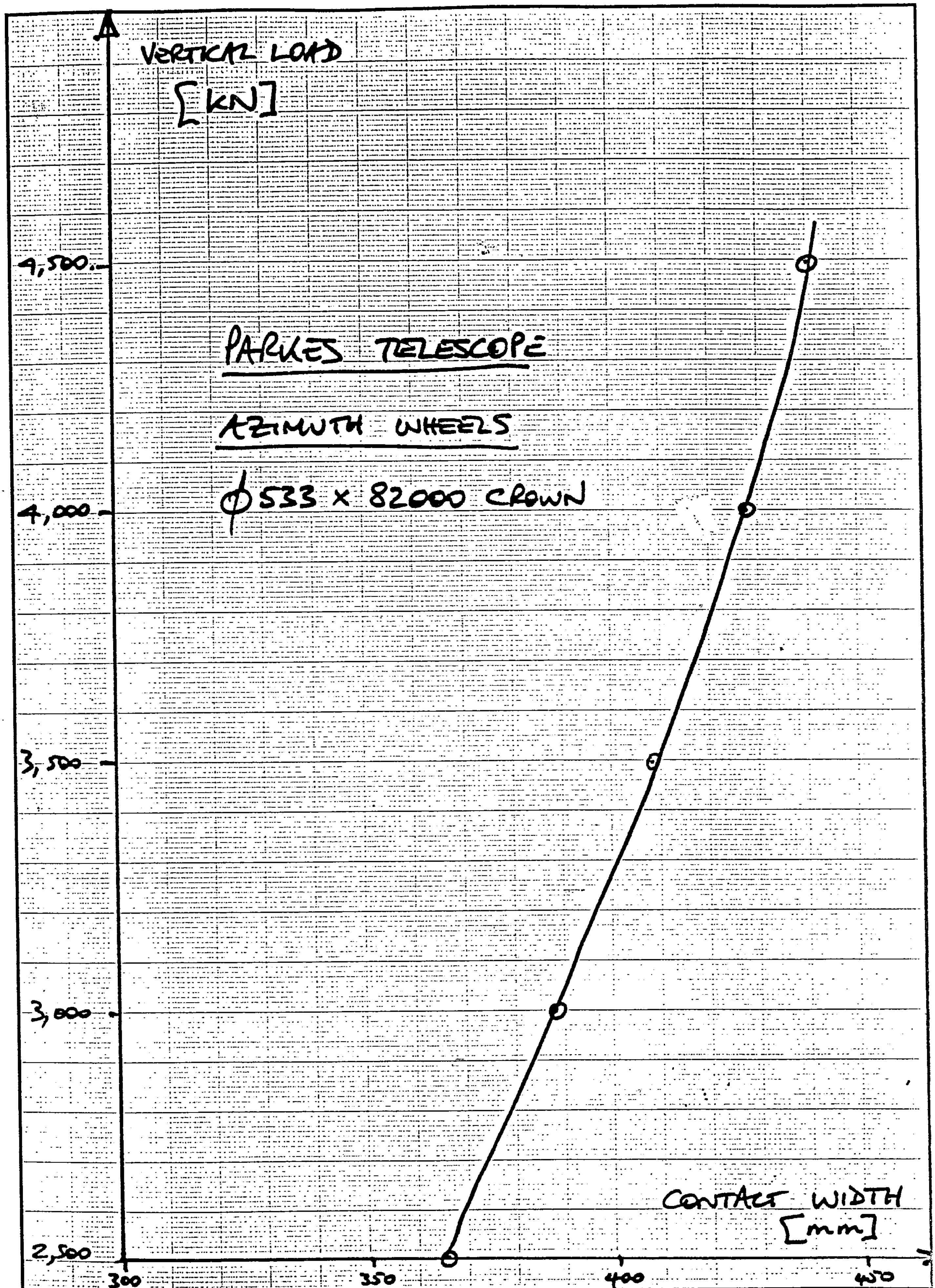
Item d) above will no doubt be of use in the proposed investigation of emergency elevation stowing/brake failure.

We recommend these measurements be carried out as soon as convenient, and we would be happy to assist if required.

Regards,

CN

Charles Needham



Macdonald Wagner
Engineers Managers

Telephone (02) 929 5599 Telex AA120836

Macdonald Wagner Pty Limited
Incorporated in New South Wales
Level 29 Northpoint Building
100 Miller Street North Sydney
PO Box 398 North Sydney
NSW 2060 Australia

Designed		
Drawn		
Checked		
Approved		
	Init.	Date
Scale		

Job No. ATP104

Drawing No.

AT

Parkes

Macdonald Wagner Group Ltd
Engineers Managers
Incorporated in New South Wales

116 Military Road
(PO Box 538)
Neutral Bay
NSW 2089 Australia

Telephone (02)909 5599
Telex AA120836

FACSIMILE: National: (02) 908 2044
International: 61 2 908 2044

Facsimile Transmission

TO: CSIRO, Division of Radiophysics — FAX NO.: 868.0457

ATTENTION: Mr J Brooks — DATE: 16 May 1989 14.33

FROM: C J Needham — JOB NO.: ATP104

COPIES: BEG, NG — NO. OF PAGES: 5 (incl. this page)

REF: Inspection of Parkes Telescope

MESSAGE:

Attached is ETRS report NN89-123U/4 on metal thickness of tripod leg members adjacent to the dish surface at the Parkes Telescope.

Assuming that the thickness of tubular sections was controlled by the manufacturers to be within ± 5% of nominal thickness, we would conclude that the remaining thickness as measured ultrasonically falls within the manufacturer's tolerances. It would seem unlikely that loss of metal due to corrosion is significant from the structural point of view. However, localised corrosion pitting of the inside wall surface should not be discounted. Such pitting would not be easily detected by ultrasonics. Even so there would be no significant loss of strength.

We recommend that these wall thicknesses be monitored, with another inspection to be carried out in about 2 years time.

Regards,

Charles Needham

C Needham

1-3 Egerton Street,
SILVERWATER, N.S.W. 2141
Telephone: (02) 647 1077
Telex: AA 145655
Facsimile: (02) 647 2341

ENGINEERING TESTING & RESEARCH SERVICES PTY. LTD.

(Incorporated in Victoria)

ETRS
A Commitment to Quality

RECEIVED 12 MAY 1989 Macdonald Wagner Sydney Office

REPORT NUMBER: NN89-123U/4 (Page 1 of 3) 10th May 1989

CLIENT: Macdonald Wagner Pty Limited

ORDER NUMBER: CSIRO RP21276

DESCRIPTION: The Ultrasonic Thickness Testing of tripod leg members, adjacent to dish surface - Parkes Radio Telescope.

DATE OF TEST: 8th May 1989

TECHNICIAN: S M Randall

CLIENT JOB REFERENCE: ATP 104

ETRS WORKSHEET NUMBERS: U 6412

FABRICATION SPECIFICATION: Not Specified

MATERIAL SPECIFICATION: Steel - Not Further Specified

METHOD: AS 2452.3 - 1985

THICKNESS RANGE: 2.75mm - 6.00mm

SURFACE FINISH: As Painted, Paste Couplant

FLAW DETECTOR: Krautkramer USK 6

SERIAL NUMBER: 1672

PROBES: ME CD 10/0/4

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REPORT NUMBER: NN89-123U/4 10th May 1989

RESULTS OF EXAMINATION: Detailed results of the examination are tabulated below:

LEG 'A'

	'B' SIDE	'C' SIDE
75mm Diameter 1	5.00	5.25
75mm Diameter 2	5.75	5.75
75mm Diameter 3	5.50	5.25
75mm Diameter 4	5.75	5.75
75mm Diameter 5	5.75	5.50
75mm Diameter 6	5.75	5.25
75mm Diameter 7	4.75	5.50
75mm Diameter 8	5.75	5.75
75mm Diameter 9	5.75	5.75
75mm Diameter 10	5.75	5.75
75mm Diameter 11	5.75	5.75
75mm Diameter 12	5.50	5.75
75mm Diameter 13	5.50	5.50
75mm Diameter 14	5.50	5.75
60mm Diameter 15	3.50	3.25
40mm Diameter 16	3.25	3.00
40mm Diameter 17	3.25	3.25
40mm Diameter 18	2.75	3.00

Refer to Figures 1 & 2 for Orientation and Positions.

LEG 'B'

	'A'SIDE	'C' SIDE
75mm Diameter 1	5.75	5.50
75mm Diameter 2	5.25	5.50
75mm Diameter 3	5.50	5.25
75mm Diameter 4	5.50	5.50
75mm Diameter 5	5.75	5.50
75mm Diameter 6	5.25	5.50
75mm Diameter 7	5.50	5.50
75mm Diameter 8	5.25	5.75
75mm Diameter 9	5.75	5.75
60mm Diameter 10	3.75	3.25
40mm Diameter 11	3.25	-
40mm Diameter 12	-	3.00

REPORT NUMBER: NN89-123U/4 10th May 1989

RESULTS OF EXAMINATION: (Continued)

LEG 'C'

	'B' SIDE	'A' SIDE
75mm Diameter 1	6.00	5.50
75mm Diameter 2	6.00	5.00
75mm Diameter 3	5.75	5.50
75mm Diameter 4	5.75	5.75
75mm Diameter 5	5.75	5.50
75mm Diameter 6	5.75	5.50
75mm Diameter 7	5.75	5.75
75mm Diameter 8	5.75	5.75
75mm Diameter 9	5.75	5.75
60mm Diameter 10	3.75	3.75
40mm Diameter 11	3.25	-
40mm Diameter 12	-	3.00

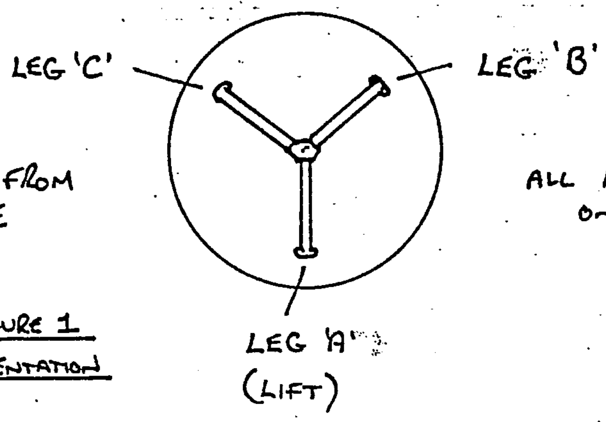
Refer to Figures 1 & 3 for Orientation and Positions.

S.M. Randall

S M RANDALL
NDT TECHNICIAN

1093 NATA

VIEWED FROM ABOVE



ALL READINGS TAKEN ON UNDERSIDE

FIGURE 1
ORIENTATION

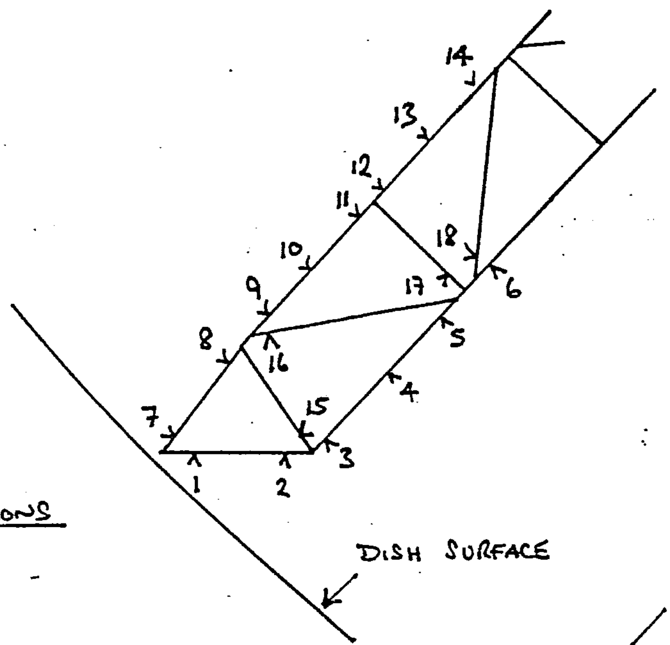


FIGURE 2
LEG 'A' POSITIONS

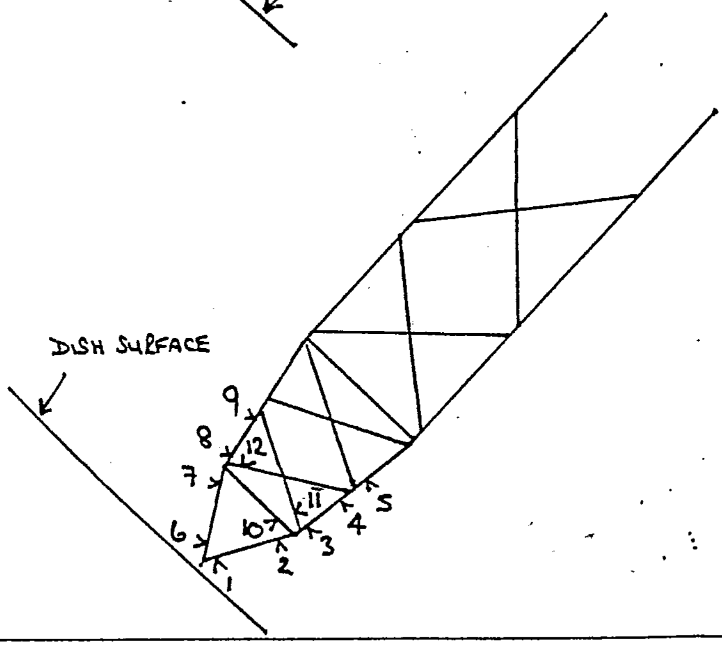


FIGURE 3
LEGS 'B' + 'C' POSITIONS

ETRS ENGINEERING TESTING & RESEARCH SERVICES PTY. LTD.

ULTRASCNIC THICKNESS TESTING OF TRIPOD LEG MEMBERS

REV.	DESCRIPTION	DATE	SCALE		SIZE	REPORT No.	Rev.
	ADJACENT TO DISH		DRAWN SMR	DATE 9.5.89	A4	NN89-123U/4	
	SURFACE		CHECKED	APPROVED			

APPENDIX C

INVESTIGATIONS 1984

(1) Letter to Dr Cooper dated 23 March 1984

(2) Report on Visit to Parkes on 15 March 1984

MACDONALD WAGNER & PRIDDLE PTY. LTD. (INC. IN N.S.W.)

CONSULTING ENGINEERS

LEVEL 29, NORTHPOINT, 100 MILLER STREET (P.O. BOX 398)
NORTH SYDNEY, N.S.W. 2060 AUSTRALIA

TELEPHONE (02) 929 5599
TELEX AA20836

CABLES "MACDAS", SYDNEY
DX 10574 NORTH SYDNEY

CSI104:LGP:mb

23 March, 1984

The Chief,
CSIRO Division of Radio Physics,
P.O. Box 76,
EPPING. NSW 2121

Attention: Dr. D.N. Cooper

Dear Sir,

RE: 64 METRE RADIO TELESCOPE AT PARKES

We wish to thank you for your verbal instructions to inspect the elevation gearboxes on the above telescope. You will be aware that the undersigned visited the observatory on 15 March with your Mr. Barry Parsons.

We now have pleasure in enclosing a report on this visit as requested. You will notice in the report that we have made recommendations covering both the immediate action that should be taken to keep the telescope in operation and the longer term overhaul which should be attended to during the next shut-down of the telescope.

We hope you will find the report to be in order and in accordance with your requirements but are at your disposal should any further clarification or assistance on this matter be required.

Yours faithfully,
MACDONALD WAGNER & PRIDDLE PTY. LTD.

L.G. PARKER
Associate

enc.

R E P O R T ON V I S I T

TO

AUSTRALIAN NATIONAL RADIO OBSERVATORY AT PARKES

ON 15 MARCH, 1984

OBJECT OF VISIT

A. To inspect and report on the condition of the elevating drive gearboxes and racks of the 64 metre telescope.

B. To recommend such action as considered necessary to extend the life of the gearboxes.

A. 1. INTRODUCTION

The undersigned was accompanied on the visit to Parkes by Mr. Barry Parsons, a mechanical engineer from CSIRO at Epping and was joined on the site by Dr. Jon Abels, the Director and Mr. Colin Jacka an engineer of the Parkes establishment. The assistance and hospitality provided by these officers and by Cliff Smith was very helpful and much appreciated.

1.1 History

Problems had been experienced with the output pinions of the Renk elevation drive gearboxes and their mating racks continuously since the commissioning of the telescope around 1961, but there had been no internal problem with either of the two elevation gearboxes.

The first indication of such a problem occurred during a visual inspection of the gear teeth when the gearbox oil was last changed. This was early in this month. The oil is replaced every 2 years and no indication of a problem had been observed during the previous oil changes. It would appear any damage or excessive wear must have occurred over a period of 2 years or less.

Our understanding of the present situation is that the telescope must if possible be kept in operation until October of this year when it will be shut down for a scheduled 2 month period. During that period, such permanent repairs as are considered necessary should be made to the gearboxes so that at the end of the 2 month period, both boxes would be in a good and reliable condition.

Meanwhile, such measures as are required should be implemented to maintain the telescope in operation until the scheduled shutdown.

2. INSPECTION

2.1 General

Only the gear teeth nearest to the inspection ports could be visually inspected which represents a small proportion of the total number of teeth. Unfortunately it was not possible to rotate the gears, as the telescope was locked in its storm position. In any event the gearbox cannot be run with its inspection covers removed due to its oil sprays, which are provided with lubricant through a pump powered by an interlocked motor.

It should be recorded that the gears inspected in the left and right hand boxes exhibited almost identical wear patterns and it would be reasonable to assume that the unseen teeth on each wheel and pinion would be in a condition similar to those observed on the same components.

2.2 Arrangement of Gears

A diagram showing the arrangement of the gearbox has been prepared and is attached as Appendix A. Each wheel and pinion has been numbered on the Appendix for reference and component identification.

2.3 Hardness of Teeth

It was not possible to establish the hardness of the teeth due to the difficult access and the absence of hardness testing equipment. However, a rough check with a smooth three cornered file indicated that pinions 3 and 5 could be very marginally harder than the wheels 4 and 6 which were probably not hardened at all. It is usual for pinions to be harder than their mating wheels, particularly where ratios of 6 and 10 to 1 are involved.

2.4 Wear on Teeth

Pinion 1 could not be inspected through the inspection port, but its mating wheel no. 2 appeared to be in good condition. It would be reasonable to assume therefore that the pinion would also be in good condition. From the data in Appendix A it will be seen that the reduction ratio of this pair is 18.35 to 1 but this is satisfactory as the gears are of the single helical type.

Pinions 3 and 5 had radial rubbing marks - light scoring - on their working surfaces. These marks continued to the tips of the teeth which terminated in sharp edges.

Wheels 4 and 6 showed radial scoring at the tooth roots, with a deformed or "orange peel" surface at mid height which is probably pressure deformation or erosion. Polishing with some score marks was observed near the tooth tips which terminated in sharp edges. A freehand sketch illustrating the occurrence of this wear is included on Appendix A.

The wear was greater on wheel 4 than on wheel 6 but on the latter the wear was more pronounced on the output pinion sides of the teeth. The greater wear on wheel 4 could possibly be attributed to its reduction ratio of 10 to one which is high for this type of gearing.

3. CONCLUSION

The wear patterns on the teeth observed could be indicative of incorrect meshing. There is, however, no report of tooth wear being observed in the past, so possibly subsequent bearing wear has permitted some shaft movement which has contributed to, or even created the problem.

The diagram on Appendix A shows wheel 6 to be supported on the cantilevered end of a shaft which is in turn supported by a bearing on either side of the external output pinion. This pinion has very heavy tooth loads and a third bearing would have been advantageous in maintaining the shaft alignment. The outermost bearing is mounted in a housing attached to the gearbox casing and this housing should be checked for horizontal and vertical movement under load by using 2 magnetic based clock micrometers, both mounted on the gearbox casing. Relative movement between this housing and the gearbox casing will change the output shaft alignment and should be minimised by the addition of welded gusset plates.

4. LUBRICATING OIL

It is unfortunate that the oil last removed from the gearbox oil tanks had been disposed of. However the discs were removed from the oil filter and washed in a suitable solvent. The amount of oil trapped in the filter discs would have been about 20 cc or so. The solution/suspension was very dark in colour and was filtered by Dr. Abels through a domestic filter paper. Few of the solids were trapped, the bulk passing through the paper.

A rough check on the filtrate with a permanent magnet showed that most, if not all the solids, were magnetic.

B. RECOMMENDATIONS

1. Immediate Action

The discovery of fine magnetic particles, which had passed through the filter mesh, but were trapped in the filter discs and the discovery of some fine solid particles in the oil which had been in the gearboxes for only a few weeks shows that iron/steel particles are being circulated through the oil system. This is detrimental to the rolling surfaces of the gears and to the bearing rollers and races.

It is suggested the drain pipe from the gearbox to the oil tanks should be modified to incorporate a permanent magnet. This magnet should be removed occasionally for inspection so that, in addition to its purpose of removing abrasive magnetic particles from the lubricant, it would also serve as a means of monitoring the wear occurring in the gearbox. It is also suggested that the oil tanks and gearbox casing be carefully cleaned out to remove any residual fine metallic deposits which may have accumulated and could be disturbed later.

As similar gearboxes are fitted on the Azimyth drives these could also be modified by the addition of permanent magnets in their drain pipes.

The existing bearings should, if possible, be checked for wear and a complete new set of bearings for each of the two elevation gearboxes obtained so that they are available in the event of a premature bearing failure. New bearings should certainly be available, at the latest, by the shutdown of the Telescope in October.

The gearbox teeth should initially be inspected fortnightly or monthly to establish the progression of wear so that some correlation can be established between the amount of iron particles picked up by the magnets and the visual change in the amount of tooth wear. As the oil is fairly viscous and the metallic particles very fine, it may not be possible to remove the iron particles as they are created. Oil samples should therefore be analysed fortnightly or monthly to establish whether there is an increase or decrease in the amount of entrained solids.

2. Rehabilitation of Gearboxes

It is understood the Telescope will be required to operate for a further 20 years and unless there is a dramatic reduction in the wearing rate of the gears as the result of the above immediate action, the gearboxes should be overhauled during the October/November shutdown.

The gearboxes should be removed to a workshop - possibly at Epping - and dismantled.

Worn bearings should be replaced and replacement gears fitted if these can be manufactured in the time available.

Alternative

There is some light under-cutting of the teeth on wheels 4 & 6. This is near the tooth roots and may have reduced the mechanical strength of the teeth by reducing their section moduli. The amount of under-cutting could not be measured on site but it is not felt to be very extensive and may not be significant to the strength of the teeth. This should be measured when the gearboxes are dismantled.

The design of the Telescope is such that only one surface of each tooth is used, there being a counterweight on the dish assembly which provides bias in one direction.

This means that we do in fact now have two sets of gears which are worn in one direction only and provided there has been no significant mechanical weakening of the teeth through wear there would appear to be no reason why, assuming that the boxes are identical and opposite hand only, that the gears could not be changed from one gearbox casing to the other. This arrangement would then provide unworn gear teeth surfaces to transmit the gearing loads.

It is not recommended that the unworn surfaces of the output pinions should be allowed to mesh with the worn surfaces of the elevation racks and we suggest the output pinions be changed so that the worn surfaces work with the same worn surfaces on the existing racks as they do at present.

In the event this gear changeover is feasible, we recommend that on reassembly, the gearboxes should be driven against a rope brake to create light tooth loading and the teeth lapped in with a fine grinding paste and relieved as necessary by hand to obtain good meshing and bedding. After the lapping process had been completed, we recommend the teeth be treated properly with molybdenum disulphide to provide a dry lubricated surface. Provided the gear teeth have not been weakened by undercutting a lengthy useful life should be expected from both gearboxes. We recommend that all gearbox bearings be replaced by new components at the time of this overhaul.

3. Output Pinion and Rack

Problems were experienced with these components from the very early stages of operation as is recorded in a number of photographs taken at various times. The problems also led to correspondence with the various organisations involved.

The problem appears to have been overcome by the use of molybdenised grease, the installation of a special lubricator which applies this grease continuously to each rack, and occasional dressing of the pinion teeth by a power drill fitted with an abrasive disc.

An inspection of the rack teeth during the visit showed that the loaded site of the teeth after passing the pinion were dry, the grease having been squeezed out by the high pinion/rack tooth pressures. The only lubricant remaining was then the molybdenum disulphide with which the rack teeth surfaces had become coated.

The addition of a second similar rack lubricator to the opposite side of each pinion would grease these dry teeth and improve the operation of the elevation drive. These additions are therefore recommended.

L.G. PARKER
Associate
Macdonald Wagner & Priddle Pty. Ltd.

MACDONALD WAGNER & PRIDDLE PTY. LTD.

APPENDIX M

JOB NAME A.N.R.O - PARKES

CONTRACT NO.

SUBJECT ELEVATION GEARS OF 64 M DIA TELESCOPE

JOB NO. C.S.I. 104

PAGE

DATE 19/3/83

ENGR. L.G.P.

REF	TYPE.	NO OF TEETH	FORM
1	PINION	17	SINGLE HELICAL
2	WHEEL	312	"
3	PINION	16	STRAIGHT SPUR
4	WHEEL	160	"
5	PINION	16	"
6	WHEEL	96	"
7	EXTERNAL OUTPUT PINION		

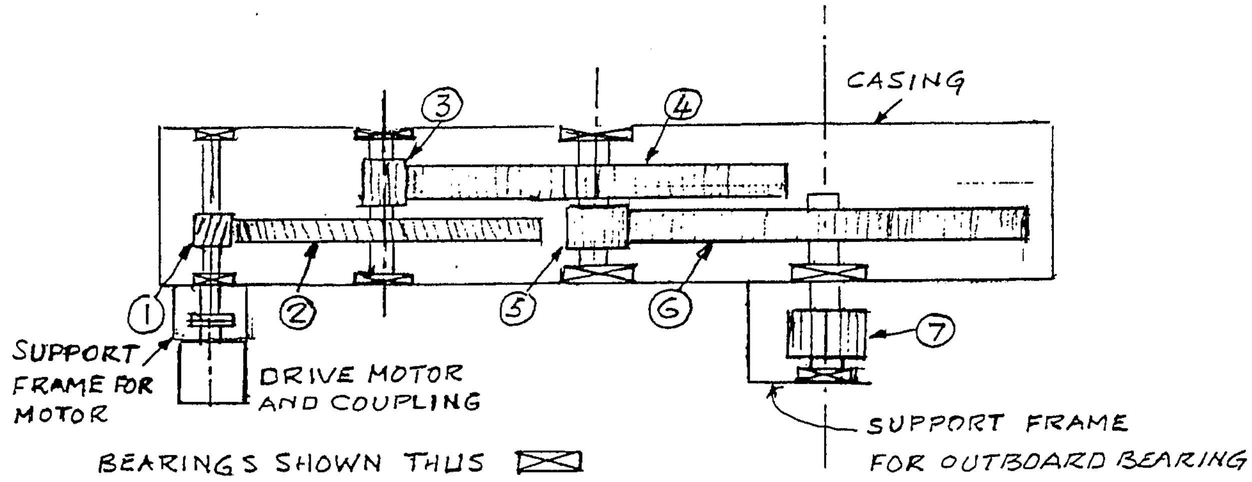
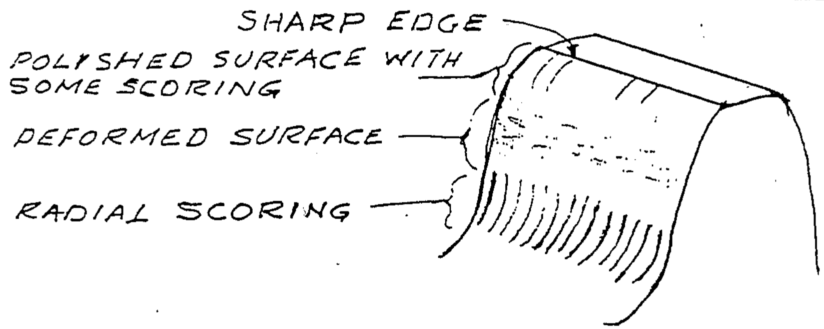


DIAGRAM SHOWING ARRANGEMENT OF GEARING



WEAR ON WHEELS 4 AND 6