Specification for the Maintenance of the Counterweights on the Chilbolton Observatory 25m antenna

1 Introduction

1.1 Background

The STFC Chilbolton Observatory 25m steerable antenna was designed, built and commissioned in the nineteen sixties. It was a one-of-a-kind instrument built by A.E.I. (Associated Electrical Industries) to support scientific research. The antenna has been in use since 1967 conducting research (radio astronomy, rain radar, and satellite tracking).

The antenna is capable of moving at up to 3 degrees per second, whilst accurately pointing to any part of the sky. The elevation structure (the part that moves up and down) compromises the parabolic reflector, and the steel work that rigidly supports it. It has a total mass of 125 tonnes. It relies on counterweight mass to partially balance the load to reduce the maximum torque on the drives and yet maintain minimal backlash. The counterweight mass is made up of concrete and steel shot contained in ballast tanks, and steel plates bolted underneath the tanks.

Figure 1 shows the 25m antenna, and the green oval shows the location of the ballast tanks and the red outline shows the counterweight blocks.

Each side of the antenna has 16 counterweight blocks, and each block consists of 5 counterweight plates. Each counterweight plate has a mass of 85 kg, resulting in each counterweight block having a mass of 425 kg. The total mass of counterweights is 13,600 kg (6,800 kg per side).

In July 2017, a structural survey of the 25m steerable antenna at Chilbolton identified a need to refurbish the counterweights on the movable structure because there was a risk of them falling off and causing injury to personnel, or damage to the antenna system.

On Monday 25th November 2019, one counterweight block fell off. There was damage to a handrail on the access ramp. This incident resulted in a Serious or Potentially Serious Incident Investigation. The outcome is that the antenna was declared out of action until the repair is satisfactorily completed. The area around the antenna has been cordoned off with Heras fencing to prevent access to the danger area below the antenna, where other counterweights are at risk of falling.

A close up of the counterweights (Figure 2) indicates the missing block. Figure 3 shows the location of the fallen counterweight. Also, note that the block on ground only comprises 4 plates, and that the 5th plate is still suspended from the fixing. This fifth plate has subsequently fallen.

The situation has been made temporarily safe by the installation of cables slung underneath the counterweights, with each block welded onto the cable using pad eyes.

Figure 4 shows the temporary fix to prevent the blocks from falling to the ground if they break away.

Figure 1. View of Chilbolton Observatory 25m Antenna showing the ballast tank (green) and the counterweight blocks (red).

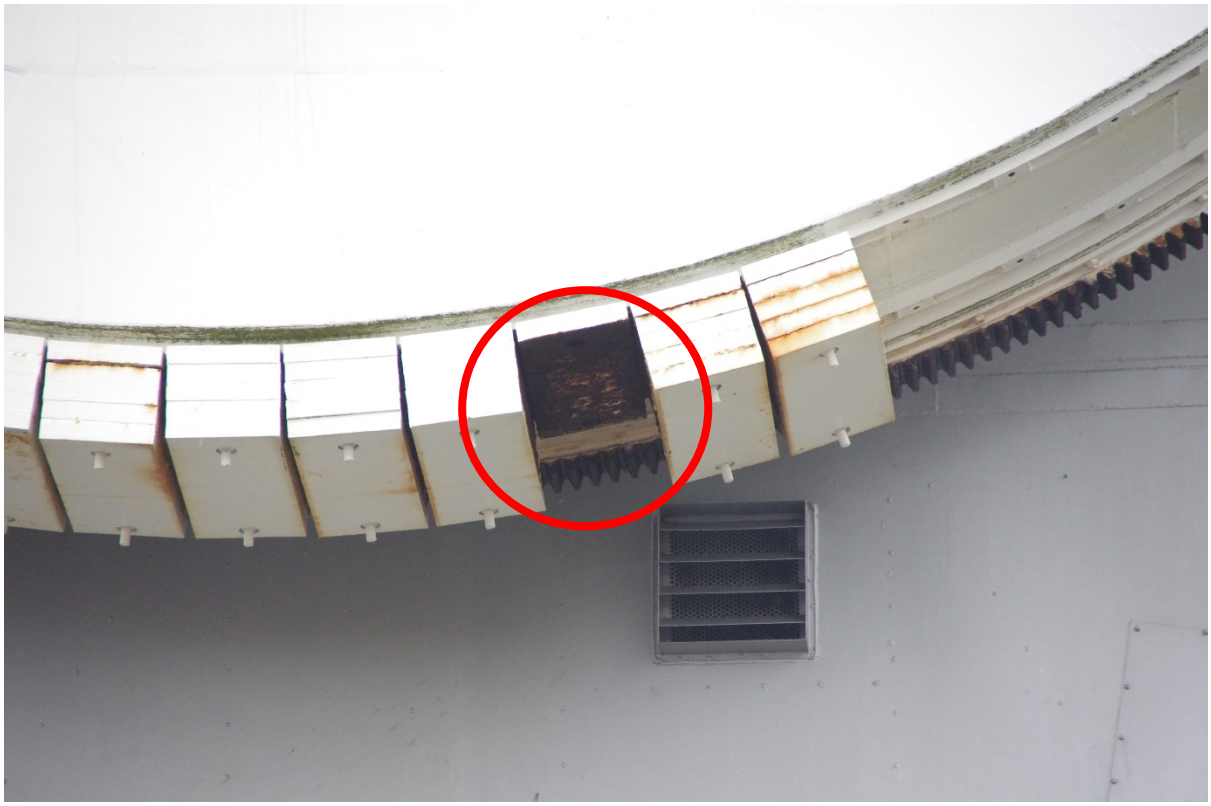

Figure 2. Close up of the missing counterweight block.

Figure 3. View of fallen counterweight block on apron below 25m antenna.

1.2 Objectives

The objectives of this contract are to completely refurbish the counterweights on the 25m antenna so that safe operation of the antenna can resume.

However, examination of the fallen block and plate indicate that they are badly corroded, requiring new ones to be made. It is anticipated that the new plates can be manufactured whilst the old ones are being removed, shortening the timeline for completion.

This maintenance contract requires the following tasks:

1. The removal of all the counterweights,
2. The manufacture of a new set of counterweights,
3. A survey of the structural elements that support the blocks to ensure that they are strong enough to safely and to reliably support the weights,
4. Preparation and painting of all affected surfaces impacted by the removal,
5. The re-installation of all the counterweights.

1.3 Outputs

The outputs for this contract will be:

1. A project management plan to be agreed by the client prior to the commencement of any work,
2. Daily updates on progress and issues once the work has started. These can be verbal or written, whichever is deemed most appropriate,
3. A report on the structural survey findings at the completion of the survey task.
4. Upon completion, documentary evidence of the certification of the materials, fabrication processes, and surface finishes.

1.4 Timetable

There is a science project requirement to have the antenna system back in full operation by July 2020. It is a priority that the maintenance work described in this proposal is completed in accordance with the timetable provide in FM20064 tender documentation.

Figure 4. View of the temporary fix to make the situation safe from further block falls.

2 Detail of the Maintenance Job

We do not have full drawings of the antenna and documented detail of all aspects of the counterweight installation. Drawings have been produced based on in-situ measurements made where possible, and measurements acquired by from scaled photographs.

2.1 Access

The counterweights will only be accessible by a suitable means of work at height as they are at least 11m above the ground level. The photograph in Figure 5 shows the heights of various points above the ground. There is a platform on the left side of the photograph, but it is to provide access to the elevation rack gears for inspection and greasing. It does not have a load rating. Note that Figure 5 also shows an alternate location of the counterweights if the antenna reflector were to be moved to point at the horizon. This can be clearly seen in Figure 10 and Figure 11. It is a point for consideration that the antenna could be parked in this orientation for the counterweight removal.

The blocks have a mass of 450 kg and mechanical aids will be required to support them during removal and transfer to the ground. The base of the concrete tower extends beyond the position of the counterweights. This will restrict the type of structure or lifting equipment that can be used effectively to access the blocks. The general assembly drawing in Figure 5 shows the rear profile of the antenna structure and the position of the counterweights relative to the base of the concrete tower.

2.2 Dish safety

The antenna is a steerable structure that is driven by electric motors through high ratio gearboxes. The motor drives will be disabled by removal of an interlock key, so that the antenna cannot be moved while the work is being conducted. The antenna is held in place by the brakes on the ends of the motor shafts.

Removal of the counterweight mass will increase the static load on the motor brakes. Under normal conditions, even with the removal of the counterbalance mass, the brakes will hold the antenna, but

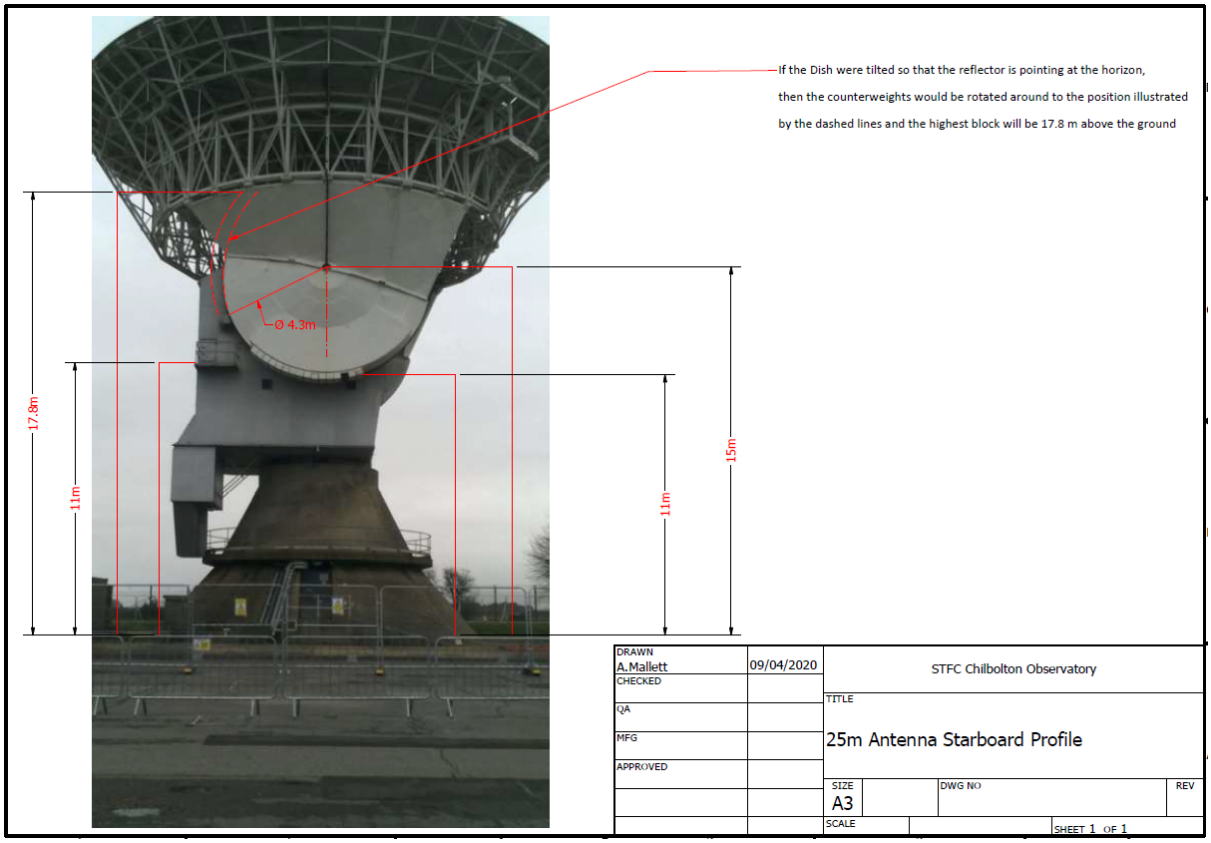

Figure 5. Profile of the starboard side of the antenna structure with heights indicated from ground level.

a severe windstorm event would increase the load on the brakes to the point where they might begin to slip. During the maintenance work, the final stage elevation gearbox will be locked solid to enable the antenna to withstand any such conditions. The antenna can be locked off in any position. Once the gearbox is locked off in this way, it is not possible to move the antenna to change its position.

2.3 Removal of the Counterweights

Each counterweight block is made up of 5 plates supported on two threaded studs bolted onto the underside of the ballast tank. The stud thread is likely to be 1 ¼" UNC (this will need to be confirmed). The stud is bolted into a fixing block, which has been welded into a guide channel. The guide channel is a "U"profile channel that was bent to the curved shape of the ballast tank and welded on. The threaded hole in the block is blind, hence does not extend into the tank. Figure 7 is an annotated photo of an unused fixing block at the upper end of the rail. The photo was taken from the Elevation rack greasing platform.

Figure 8 is a drawing of a counterweight plate. Figure 9 is a photograph of an old counterweight plate that was never fitted. The plates are individually held with a pair of nuts, which are recessed into the counter bore on the underside of the plate. Figure 10 is a close up of the nut in the counter bore of the fallen block. The limited clearance around the nut will require a pipe spanner or similar tool to be used to remove the nuts. As each plate is removed, the spanner will need to reach 50 mm further over the stud. The nuts have not been touched in decades and are unlikely to come free easily or if at all. Figure 11 shows that there is obvious evidence of corrosion having weakened the stud, so force on them while removing the plates will potentially result them breaking and the block

coming free from the structure. The blocks are linked to the temporary cable, so they cannot fall to the ground and cause damage or injury.

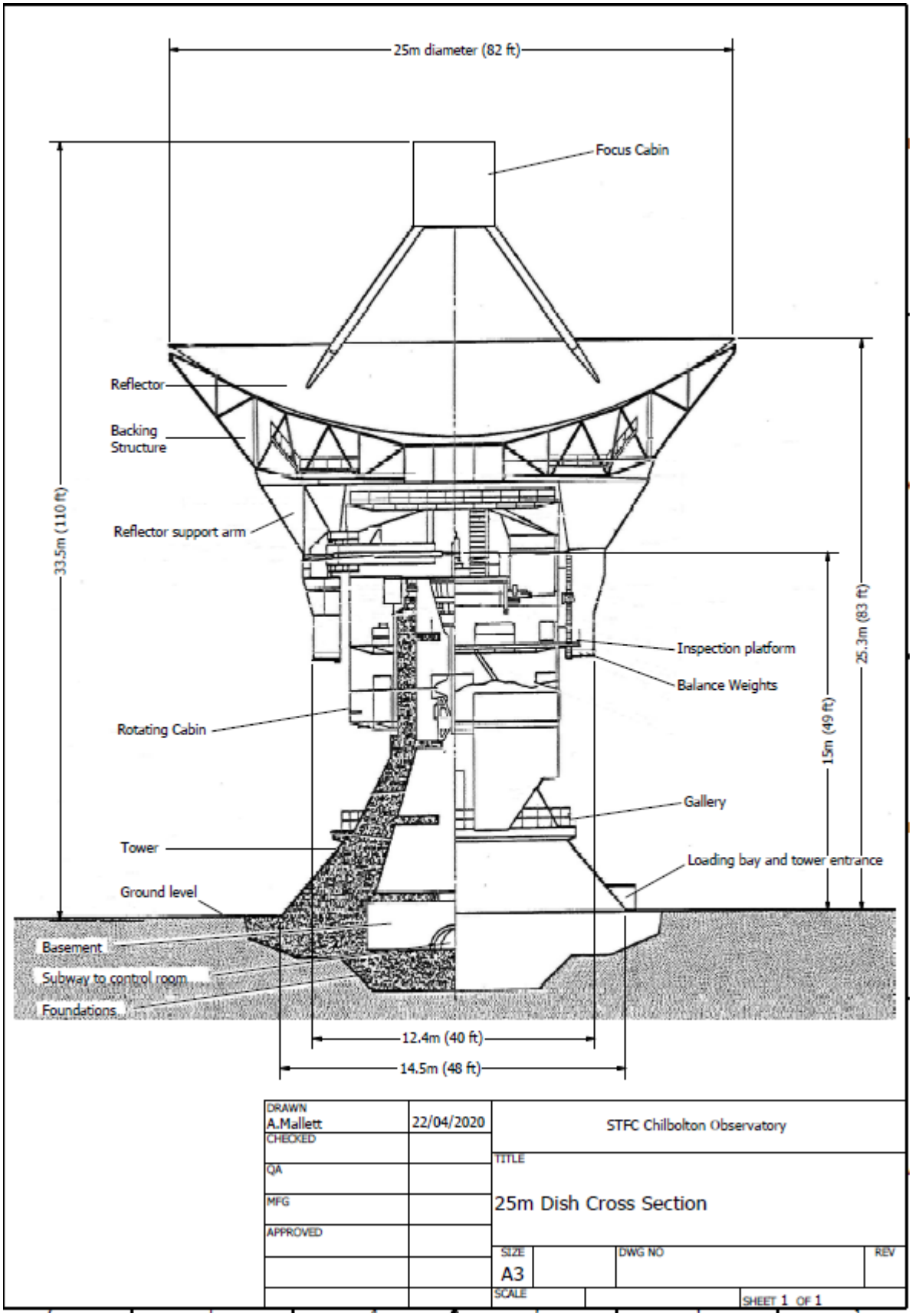

Figure 6. Scaled GA drawing showing the rear profile of the antenna structure with heights indicated from ground level.

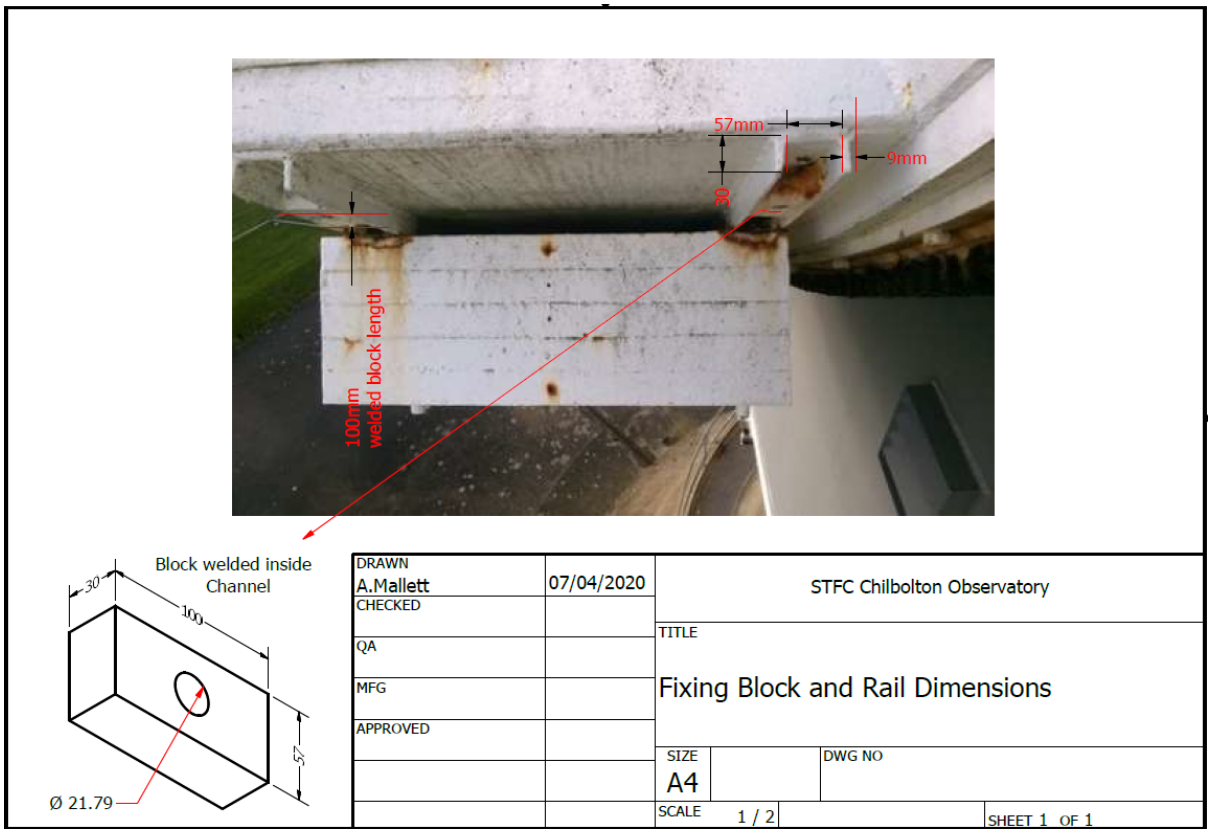

Figure 7. Dimensioned photo of counterweight fixings.

There is no clearance between the first plate and the fixing block guide channel. Cutting the stud at this point will damage the guide channel and the fixing block, which will need to be re-instated before the blocks are replaced.

All of the studs, which support the counterweight plates, will need to be removed. The wire rope and fixings that were installed to implement the temporary fixing will also need to be removed.

2.4 Structural Survey of the Fixing Point

Once the blocks have been removed, it is necessary to survey and inspect the elements of the support structure that support the blocks. The surveying shall employ visual inspection, as well as NDT methods where necessary. A brief engineer's report shall be produced to document the findings, an assessment of the structure, and suggestion of rectification work required. It is important to ensure there is sufficient structural integrity to support the blocks once the new ones are in-situ.

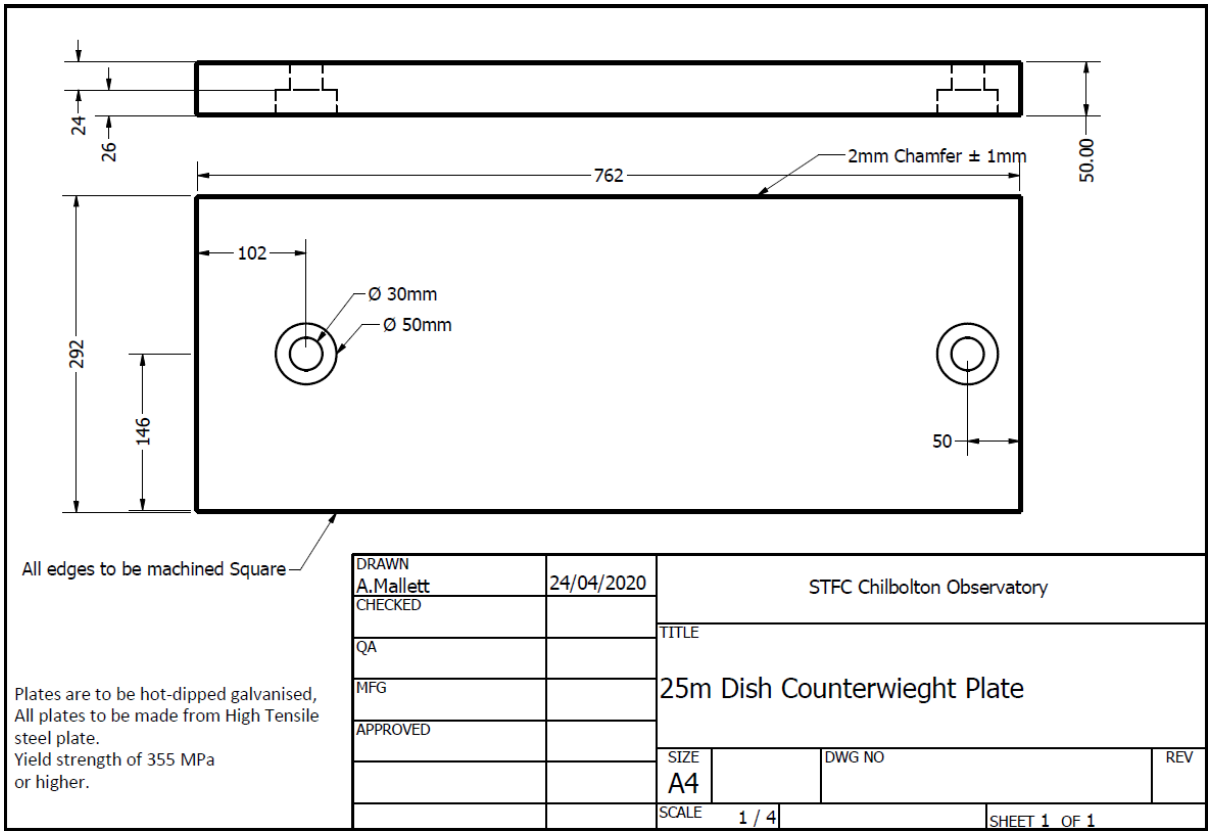

Figure 8. Drawing of counterweight plate.

Figure 9. Photo of old counterweight plate.

2.5 Manufacture of New Counterweight Plates

The new plates will be manufactured to be identical in size to the original plates. The plate must be surveyed for accurate dimensions and a drawing approved by the customer prior to manufacture. The hole sizes may vary depending on the thread size of the replacement stud bars and fasteners. Mild steel that is suitable for shot-dip galvanisation to BS EN ISO 1461 shall be used. Figure 8 is a drawing of the counterweight plate measured up from the old one on the ground.

Figure 10. Close-up of stud and nut holding plate.

2.6 Painting to Protect the Region Exposed by the Removal of the Counterweight Plates

Painting to tidy the areas uncovered by the removal of the blocks, or where damage to the painted finish has occurred must be done. The painting needs to follow the paint specification.

When the antenna structure was last painted in 2011, a specialist paint contractor prepared a paint specification for the structure. This system was effectively applied, and it has endured very well for nearly 9 years without evidence of failure.

2.6.1 Paint specification

Note that shot blasting and spray painting should not be used unless the areas being worked on can be completely enclosed to prevent grit and dust from entering sensitive parts of the antenna system, and to prevent paint overspill from drifting and contaminating the surrounding area (in particular people's cars). The preference is for manual and power tool preparation of the surface, and brush or roller application of paint.

The paint manufacturer is Sherwin Williams Protective and Marine Coatings (formerly Leighs Paints). Contact details are:

Web: https://protectiveemea.sherwin-williams.com/
Address: Tower Works, Kestor Street, Bolton, BL2 2AL, UK
Telephone: +44 (0)1204 521771
Email: sales.uk@sherwin.com

2.6.1.1 Surface preparation

Remove all dust and debris. Before painting commences, ensure all surfaces are abraded, clean and dry and onto a firm sound substrate. The surfaces shall be prepared to a minimum standard of St3 BS EN ISO 8501-1:2007

2.6.1.2 Spot prime

Spot prime bare metal areas with one brushed coat of Macropoxy M902 Surface Tolerant Primer [aluminium] to achieve a 125µ dry film thickness.

2.6.1.3 Apply undercoat

Over the Ballast tank and Counterweight region, brush or roll one coat of Macropoxy M905 High Build Undercoat [light grey] to achieve a 125µ dry film thickness

2.6.1.4 Apply topcoat

Paint over the region by brushing or rolling 1 or 2 coats of Acrolon C137V2 Acrylic Urethane Gloss Finish [white] to achieve a 50µ dry film thickness for each application of paint.

2.7 Replacement of the Counterweight Plates

Once the ballast tank surfaces have been repainted, the counterweights can be refitted. New threaded studding and fasteners must be used. The studding and fasteners must be high tensile steel with a zinc plating.

In order to future proof the addition of new equipment on the reflector, the replacement studding shall be long enough to accommodate the addition of two extra plates (7 plates in total). The selection of studding and fasteners shall reflect the increase in mass.

3 Health and Safety

It is essential that during the contract that risks are effectively managed and that all relevant health and safety legislation and STFC safety codes are adhered to. It has been decided that this project will be subject to Construction and Design Management regulations.

Suitable reference documents are:

- L153 - HSE CDM Guidance - https://www.hse.gov.uk/pUbns/priced/l153.pdf
- CITB CDM Guidance for each dutyholder role - https://www.citb.co.uk/about-citb/partnerships-and-initiatives/construction-design-and-management-cdm-regulations/cdm-regulations/

STFC have also published a booklet called SHE for Contractors: SHE for RAL Contractors booklet - https://www.she.stfc.ac.uk/Pages/SHE_Booklet_Contractors_RAL.pdf.

Figure 11. Close-up showing severe corrosion on nut and stud at point where the stud failed.

Figure 12. Photo of rear of antenna with reflector pointing at horizon.

Figure 13. Photo of side of antenna with reflector pointing at horizon.

Document prepared by Darcy Ladd – 24 April 2020