



Cupula

GTC Dome Shutters Upgrade.
Preliminary Implementation Plan

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GTC Dome Shutters Upgrade

PHASE II: PRELIMINARY IMPLEMENTATION PLAN

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ABBREVIATIONS

AD	Applicable Document
FAT	Factory Acceptance Tests
GTC	Gran Telescopio de Canarias
HPU	Hydraulic Power Unit
MTTF	Mean Time To Failure
MTBF	Mean Time Between Failures
MTTR	Mean Time To Repair
N/A	Not Applicable
NC	Not Compliant
ORM	Observatorio de Roque de los Muchachos
PA	Product Assurance
PHA	Preliminary Hazards Analysis
RAMS	Reliability, Availability, Maintainability and Safety
RD	Reference Document
ROM	Rough Order of Magnitude
SOW	Statement of Work
TBC	To Be Confirmed
TBD	To Be Determined
TBR	To Be Revised
UPS	Uninterrupted Power System
VSD	Variable Speed Drives

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1 SCOPE OF THE DOCUMENT

This document describes the Preliminary Implementation Plan for the proposed upgrade of the GTC Dome Shutters. It outlines the scheduled activities for the detail design, manufacturing and procurement, on-site assembly and commissioning of the system modifications.

This plan has been developed during the preliminary design phase of the project, thus the detailing of the activities, in particular the procedure for on-site installation, cannot be envisaged and completely defined at this stage. Therefore, this document should be revised and completed once the Detail Design is finished (actually, the development of a Detailed Implementation Plan has been considered in the present document as one of the tasks in the schedule of activities).

Together with the Preliminary Design Report (18242-TRE-011-01), the Preliminary Cost Estimation (18242-LIS-014-01) and the Reliability Analysis (18242-TRE-012-01), this document constitutes the Final Delivery Package for the Definition of the GTC Dome Shutters Upgrade project.

2 APPLICABLE AND REFERENCE DOCUMENTS

2.1 APPLICABLE DOCUMENTS

	Title	Reference	Iss.	Date
AD 1	Statement of Work for the definition of GTC Dome Shutters Upgrade	ESP/EDIF/0200-R	1.A	20/03/2013
AD 2	Current Status of the Dome Shutters	RPT/EDIF/0386-R	1.A	18/03/2013

2.2 REFERENCE DOCUMENTS

	Title	Reference	Iss.	Date
RD 1	1 st Progress Meeting Presentation	18242-PRE-001	1	11/10/2013
RD 2	1 st Progress Report	18242-TRE-002	1	9/10/2013
RD 3	1 st Progress Meeting Minutes	18242-MIN-003	1	16/10/2013
RD 4	Phase I: Analysis of Alternatives Report	18242-TRE-004	1	25/11/2013
RD 5	End of Phase I Meeting Presentation	18242-PRE-005	1	29/11/2013
RD 6	End of Phase I Meeting Minutes	18242-MIN-006	2	02/12/2013
RD 7	Phase II: Preliminary Cost Estimation	18242-LIS-014	2	11/04/2013
RD 8	Phase II: Reliability Analysis	18242-TRE-012	2	11/04/2013
RD 9	Phase II: Preliminary Design Report	18242-TRE-011	2	11/04/2013
RD 10	Addendum-to-Prelim-Design-Report	18242-TRE-018-01	2	11/04/2013
RD 11	The Complete Guide to Chain (http://chain-guide.com)			
RD 12	Michael Hess – Replacing the K1 Dome Shutter drive system	Proc. SPIE 6273-17		

3 INTRODUCTION

3.1 BACKGROUND

The current shutter system of the GTC dome does not fully comply with the expected requirements. The problems detected are essentially: a) a restricted range on main shutter opening, which limits the telescope observation angle to 70 deg. above horizon; b) premature damage on shutter bogies; c) the unfeasibility of deploying the windscreen, which has not been commissioned yet; d) damages (cracks, corrosion, deformations) in the dome arch beams. These problems are described by GRANTECAN in document AD2.

GRANTECAN has launched this project consisting of: a) an analysis of alternatives aimed to finding solutions to the current problems of the GTC dome shutters; b) selecting the best solution in terms of performance, cost and implementation time and developing it up to a preliminary design.

During the Phase I of this project the diagnostics developed by GRANTECAN was analysed and completed and individual actions were identified aimed to solve each problem detected. In order to evaluate the feasibility of these actions, they were combined into 3 particular packages, intended to configure 3 potential solutions that were physically developed up to a conceptual design stage to check and illustrate their applicability. A final trade-off analysis was developed to evaluate the pros and cons of each solution. All this work is compiled in RD4.

At the end of Phase I, GRANTECAN reviewed the delivered documentation and decided on the solution out of the 3 proposed options which will be further developed up to a preliminary design stage. The solution selected was the first alternative proposed (**Option A**), **but modified to include some additional actions:**

- **Bogies design upgrade**
- **Possibility of excluding the counterweight system**
- **Prevision of emergency systems for the lower shutter operation**

Option A consists in basically keeping the existing drive system typology but introducing a set of incremental actions aimed to improve the current performance and solve the main problems. The safety and reliability of each of the components (chains, motors, gearboxes) is increased as their demanding loads will be lower than the allowable values. The actions include:

- Replace current upper shutter chains by others with higher strength
- Implement a counterweight system to reduce load at the last part of upper shutter travel
- Improve load sharing between drives by a proper control system strategy.
- Install a take-up system in chains to reduce the required preload
- Install axial supplements in the guiding rails to reduce the rail runout
- Replace motors and gearboxes of Lower shutter by others with higher power
- Move the location of windscreen latching system to avoid overlapping
- Reduce the windscreen weight
- Replace current windscreen rollers cam followers for friction reduction
- Modify the bottom profile of the windscreen guides
- Monitor crack propagation, register a crack inventory and take actions according to the propagation speed (grind-repair, crack arrest drilling, structural reinforcement...)

3.2 OVERVIEW OF THE PROPOSED DESIGN

The GTC Dome Shutters proposed modifications affect to:

- The drive system, control system and guiding system of both upper shutter and lower shutter.
- Enhancement of the Windscreen
- Proposed actions for the defects detected on the dome arch beams and shutters structure

Upper & Lower shutters:

- Regarding the drive system, the upgraded design includes:
 - Reduction of the chain pre-load of the upper shutter chains by means of installing a Lower take-up mechanism in chains M4 & M6 and an upper take-up mechanism in chains M5 & M7 (not required for lower shutter)

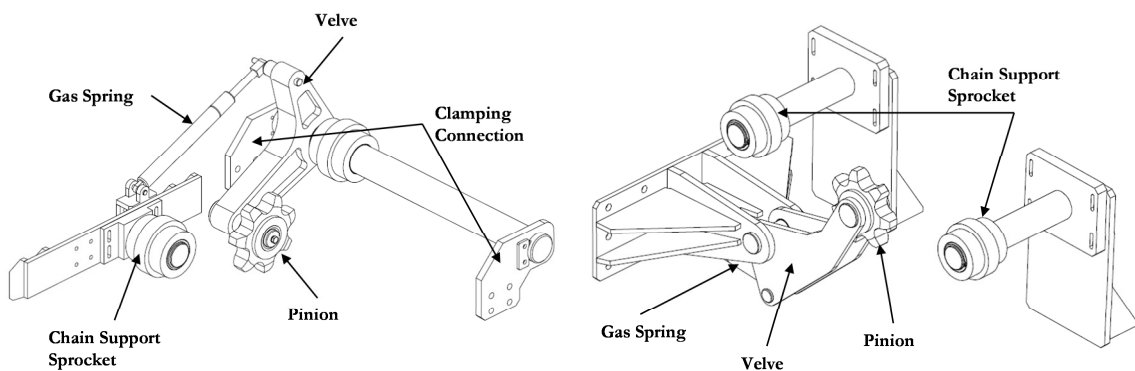


Fig. 3-1 Upper shutter Take-up system

- Replacement of current roller chains by higher capacity chains, in both upper and lower shutter
- In addition, for the lower shutter:
 - Replacement of main motors for higher power motors
 - Replacement of current gearboxes for double input gearboxes to include an auxiliary gear-motor for redundancy, which will enable emergency operation in case of failure of the main motor.

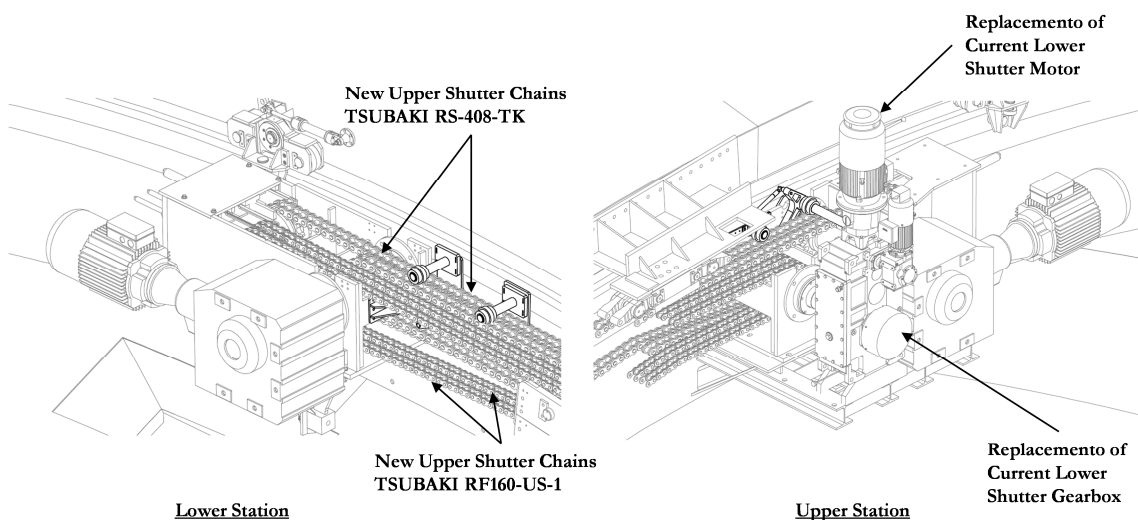


Fig. 3-2 Actions in shutters drive systems

The proposed redesign also includes an optional counterweight system, which would contribute to reduce the loads in the last stage of the upper shutter travel.

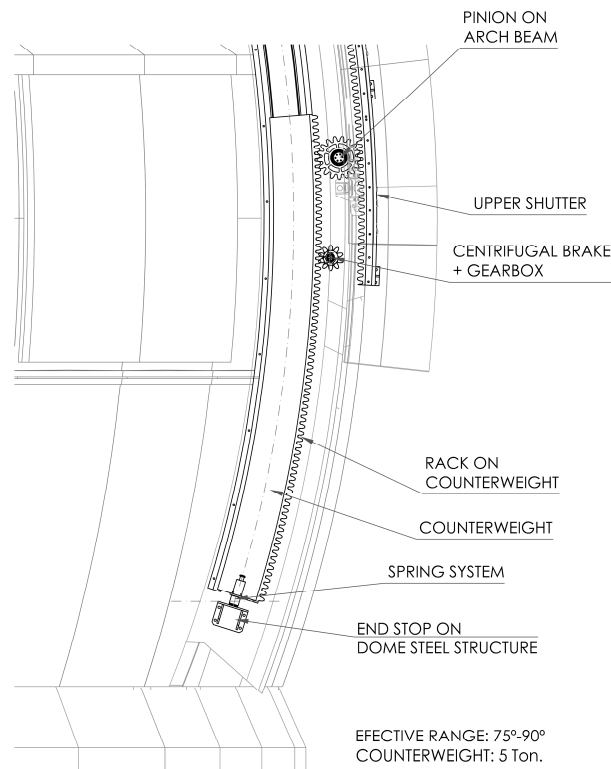


Fig. 3-3 Counterweight system

- For the guiding system, an improved bogie design is proposed with capability to absorb the rail radial misalignment by means of a hydraulic equalization system. For each shutter, four hydraulic equalization groups (each one including 5 bogies for the upper shutter and 2 bogies for the lower shutter) have been defined.

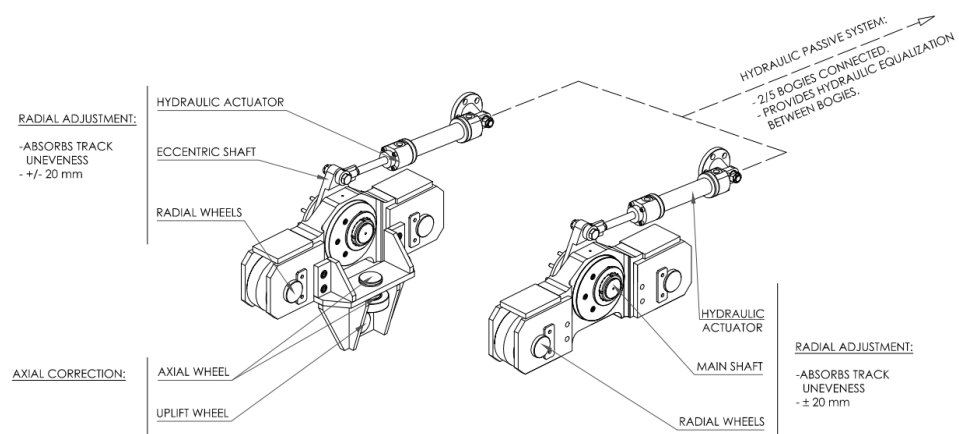


Fig. 3-4 Guiding system upgrade

Apart from the hydraulic actuator and the eccentric shaft for radial adjustment, the new bogie design includes two radial wheels instead of one, for additional strength under the acting loads.

The shutters lateral guidance is also improved by means of axial correction supplements welded to the rails.

- For the control system, an optimized control strategy (“Speed Trim Follower”) is proposed aimed to provide a better load sharing between drives. This configuration consists of:
 - the master drive is operated in speed regulation
 - the slave drives are operated in speed regulation with a speed trim that is function of the difference between the master drive and each slave drive torque.

The equal load distribution between drives achieved with this new control strategy, together with the replacement of drive chains and the improvement on shutter lateral guidance provided by the axial correction supplements, can enable the operation of the upper shutter with only three out of the four drives in emergency conditions.

Enhancement of the Windscreen:

After a diagnostic of the Windscreen deficiencies was carried out the following modifications are proposed in order to improve the current Windscreen performance.

- Latching system redesign
- Modification of Windscreen guides profiles
- Replacement of the current rollers for cam followers

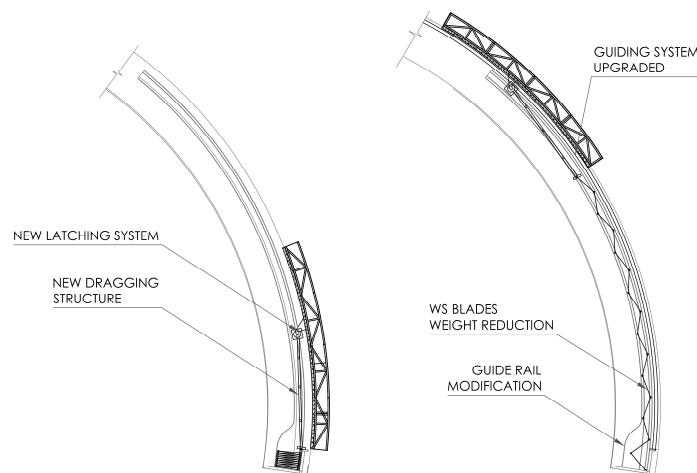


Fig. 3-5 Modification in the Windscreen

Actions for the damages on the dome arch beams and shutters structure:

An action plan has been outlined to monitor and tackle the potential propagation of existent cracks and repair the corrosion effects.

3.3 DOCUMENT STRUCTURE

This document is structured as follows:

- Chapter 4 defines the proposed schedule for the implementation of the GTC Dome Shutters Upgrade, based on the 2-phase plan (summer 2014/summer 2015) anticipated by GRANTECAN and describing the main tasks towards completion.
- Chapter 5 describes the activities and proposed plan for the completion of the Detail Design of the Shutters Upgrade, including the definition of Manufacturing Drawings and final Bill of Materials with off-the-shelf components and detailed mechanical/structural verification and analyses.
- Chapter 6 is focused on the purchasing and fabrication phase. It defines milestones to launch the procurement/fabrication of the different materials in order to comply with the expected schedule. It also includes the procurement/fabrication of any assembly tooling required for the

installation on site and the procedure for the FAT (Factory Acceptance Tests) for validation of some critical components (new bogies, counterweight system).

- Chapter 7 defines the tasks to be performed on site for the installation of the Shutters Upgrade. It includes the initial conditioning of the current system (removal of any item to be replaced, required modifications in existing parts to avoid interferences with the new subsystems, installation of any ancillary provisional system which can allow operation during the on-site works) as well as the high-level definition of the upgraded systems integration process. It also outlines the protocol for SAT (Site Acceptance Tests) and final commissioning.
- Finally, Chapter 8 summarizes the main tasks and milestones, concluding with the critical points to be considered, for the implementation of the GTC Dome Shutters Upgrade.

4 IMPLEMENTATION PHASES AND OVERALL SCHEDULE

4.1 SUMMARY

The main driver for scheduling the activities for the implementation of GTC Dome Shutters Upgrade is the available periods defined for the installation of the proposed actions on-site. As previously mentioned, the final on-site assembly is based on a 2-phase plan: Phase I, during summer 2014, and Phase II during summer 2015.

- Phase I (June 2014 – Aug 2014) includes the following actions:
 - Correction of rail axial misalignment
 - Local reparation of shutter sealing to avoid interference with dome structure.
 - Cleaning and reparation (if required) of the detected damages on dome and shutters structure (cracks, corrosion).
- Phase II (May 2015 – Oct 2015) comprises the rest of modifications:
 - Replacement of the current bogies for the new bogies and the associated hydraulic system.
 - Installation of take-up systems for the upper shutter
 - Assembly of the counterweight system (optional system; decision should be made about its final development and installation)
 - Modifications on windscreen system
 - Shutters drive system:
 - a) Replacement of roller chains in both shutters and motors and gearboxes for lower shutter.
 - b) Optionally, replacement of control system electric cabinets (including upgraded drives).

The planning of the tasks related to the detail design and manufacturing/procurement is determined going backwards from the on-site assembly dates. Thus, the proposed start date for a specific task is actually the latest date possible to meet the on-site installation predefined dates. The resulting schedule is included in next Section 4.2.

Other restrictions to the Implementation Plan are the following:

- 1) No works shall be performed on site at night. External illumination is not allowed in the observatory during night time.
- 2) Works on site shall be compatible with telescope observation as much as possible. Each day, after finishing the shutters retrofit assembly operations, the dome shall be left operative for night time operation. When this is not possible (for actions implying major modifications in shutters drive and guiding systems), the tasks should be simultaneous as much as possible and carefully planned to minimize the number and duration of the stops in the observation time.
- 3) The use of heavy lifting equipment (cranes) shall be minimized by optimizing the weight of parts and subsystems during the detail design phase to avoid the need of external cranes or, when they are strictly required, plan the individual operations to minimize the period of use.

4.2 GENERAL SCHEDULE

Next figure shows the general schedule for the implementation of GTC Dome Shutters Upgrade. It includes the Detail Design, Manufacturing and Procurement and Final On-Site Installation and Commissioning. Activities have been identified as belonging to Phase I or Phase II.

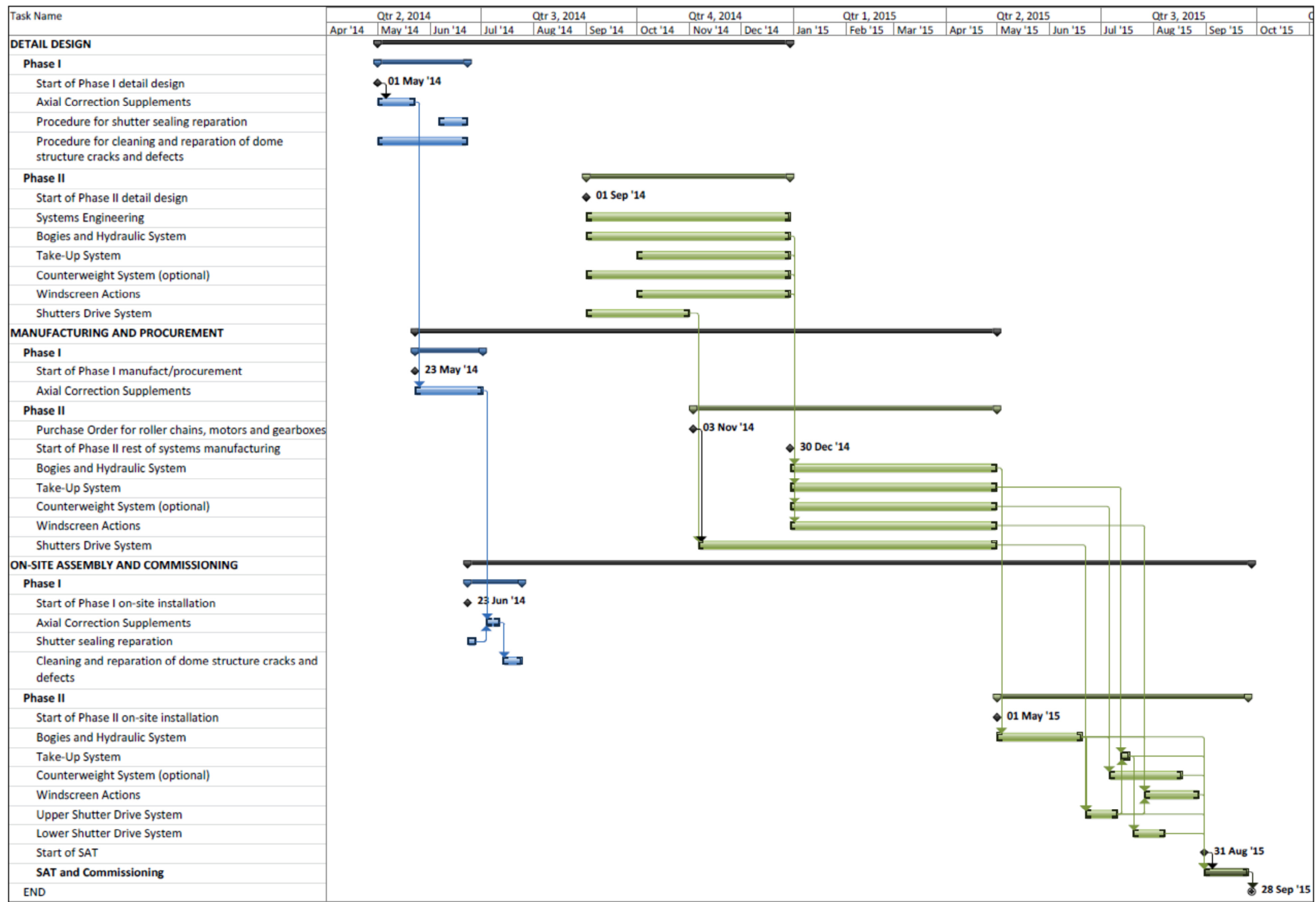


Fig. 4-1. Schedule for GTC Shutters Upgrade Implementation. In blue, tasks of Phase I; in green, tasks of Phase II.

5 DETAIL DESIGN

5.1 INTRODUCTION

The Detail Design for the Shutters Upgrade should be attempted as an entire system, to consider the interaction between the different subsystems and the sum of the individual actions to guaranty the compliance with the requirements. This is particularly important for the modifications to be implemented during the Phase II (the ones with major impact). For this purpose, a task named “Systems Engineering” – which considers the integration of all the subsystems, their potential interfaces and cross dependencies – has been included in the general schedule shown in Fig. 4-1.

The Detail Design will include the following activities:

- **Detailed Calculations and Analysis** to verify the structural integrity and correct mechanical performance of the proposed subsystems and modifications. Optimization or reinforcement (as convenient) of the preliminary design should be considered.
- Further definition of the subsystems design and production of the **Manufacturing Drawings, Bill of Materials** and **Specifications** for fabrication/procurement of all the parts and subsystems.
- **Definition of Procedure** for local sealing system repair and **detailed Action Plan** for the structural damages (cracks, corrosion, ...)
- Definition of the **Validation Plan** (Factory Acceptance Tests) for some critical mechanisms as bogies, take-up mechanism and counterweight system.
- Development of a **Detailed Implementation Plan** for on-site installation, updated for the detail design of the system, and including procedures, instructions and training (if needed) to workers, together with the specification of the required human and material resources, ambient conditions and any additional restrictions. It will also cover the envisioning and detail design of any tooling required for the assembly process.

Next sections describe in more detail the particular tasks to be carried out inside each phase of the Detail Design.

5.2 PHASE I

The actions to be implemented during Phase I (axial correction supplements, local sealing system repair and solution for the cracks and corrosion damages) are not interconnected and thus the Detail Design of each one can be developed separately. However, the final correction achieved in the rail axial misalignment (checked after installation on-site) should be considered for the Phase II detail design.

5.2.1 Rail Supplements for Axial Correction

Estimated start date: 1 May, 2014

Estimated end date: 22 May, 2014 (duration= 3 weeks)

The preliminary design of the rail supplements for axial correction, defined in the corresponding drawing of the Appendix B of the Preliminary Design Report (RD 9), can suffice for the

procurement of the necessary material for fabrication. However, it is recommended to revise, during the detail design phase, the strategy for axial correction (sections of the rail to be corrected) and the corresponding thickness of each supplement to verify they match the measured misalignment of rails.

According to the preliminary design, these supplements have been defined with variable thickness that will adjust to the actual misalignment of each part of the rail, as represented in figure below.

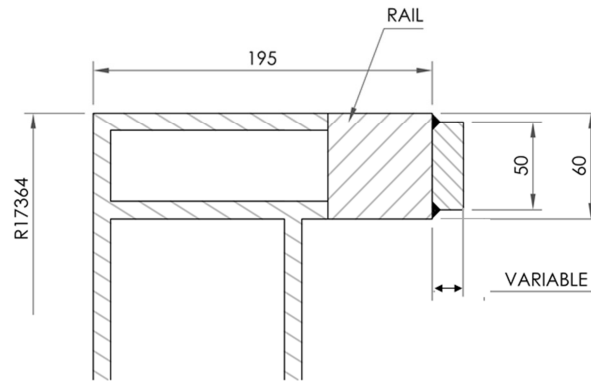


Fig. 5-1. Definition of axial supplements, according to the preliminary design

Each supplement will be identified by an individual reference code associated with the place on the rail where it will have to be positioned.

During the detail design phase, final manufacturing drawings (based on the ones provided in the preliminary design) should be produced and detailed procedures should be elaborated for the welding process to be implemented on-site.

5.2.2 Upper Shutter Local Sealing Reparation

Estimated start date: 6 June, 2014

Estimated end date: 22 June, 2014 (duration= 2,5 weeks)

Next figure shows the risk of contact of the upper shutter sealing with the dome arch beam during the shutter motion. The zone most prone to collision, which consequently needs reparation, is located in side B at the bottom part of the shutter.

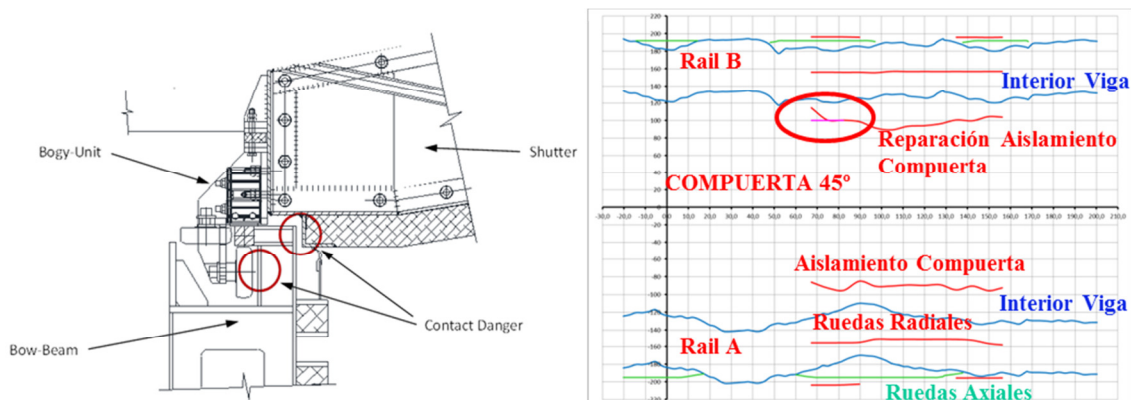


Fig. 5-2 Potential interference of the upper shutter sealing with the dome arch beam (extracted from AD2)

During the detail design phase, a procedure shall be defined to cut part of the upper shutter sealing material in this bottom area and adjust the cover to the modified seal. Also, the convenience of

doing this modification in other shutter areas with risk of contact with the dome should be evaluated not only during the Phase I detail design, but also during Phase II (to be implemented in the second stage of on-site assembly) to consider the expected rotation/displacement of shutter structure for the final redesign of shutter supporting system.

5.2.3 Procedure for monitoring/reparation of structural damages

Estimated start date: 1 May, 2014

Estimated end date: 22 June, 2014 (duration= 7 weeks)

As explained in RD 9, it seems no action is required for the moment for the cracks detected on the dome arch beams and shutters structure. Results from an inspection performed by GRANTECAN in January 2014, showed no significant crack growth in one year, what apparently indicates the cracks are stationary. Also, the beginning of most of these cracks is not on the weld beads, so they do not seem to be fatigue cracks, most probably they were generated during the dome assembly or even manufacturing processes.

However, a periodic monitoring of these cracks is convenient to confirm this hypothesis. During the detail design phase, a procedure for the inspection and register of results, together with an action plan to define measures to be taken in case any significant changes are detected, should be defined. For this, the recommendations given in RD 9 can be used as reference.

The corrosion damages should be repaired. During the detail design phase, decision should be taken about which ones require urgent action, and a procedure should be defined for the reparation.

5.3 PHASE II

4 months are estimated for the Phase II Detail Design. As previously stated in the introduction to this chapter, for this phase an integrated design approach is convenient, to consider the contribution of the different redesigned subsystems to the compliance with requirements and potential interfaces/interactions between them. Thus an important task to be developed during the entire duration of the Detail Design is the Systems Engineering. Parallel to this activity, the detail design of each particular subsystem (bogies, take-up mechanism, windscreen and counterweight and drive system) will be developed.

5.3.1 Systems Engineering

Estimated start date: 1 Sept, 2014

Estimated end date: 29 Dec, 2014 (duration= 4 months)

The Systems Engineering activity will ensure the correct integration of all the individual design work performed for each subsystem. In this case, it will also evaluate the final performance of the complete Shutters Upgrade, in terms of compliance with the specifications by considering the contributions of the improvements in each subsystem.

The tasks to be developed inside this activity will also include:

- Establishment of the specifications to be complied by each subsystem.
- Determination of any calculations and analyses to be performed to evaluate the integration of different subsystems.
- Identification and management of interfaces between subsystems.

- Revision of the final detail design, manufacturing specifications and drawings of each subsystem.
- Development of a Detailed Implementation Plan and Schedule for final installation on-site.

5.3.2 Bogies and Hydraulic System

Estimated start date: 1 Sept, 2014

Estimated end date: 29 Dec, 2014 (duration= 4 months)

The new bogies preliminary design includes a hydraulic system to equalize loads among 5 consecutive bogies in the upper shutter and between 2 bogies in the lower shutter. This has been selected as the most appropriate supporting strategy in the preliminary design phase. During the detail design phase, this strategy will be revised together with the number of bogies at each side of shutters. Now, the extreme positions of the upper shutter are not supported, due to interferences of the new bogies design with the chain fixed point. The potential need of including extreme supporting (by means of smaller bogies or simple wheels) should be evaluated during the detail design phase.

The design of the bogies and hydraulic system should be developed to the detailing needed for manufacturing, including manufacturing drawings, bill of materials and manufacturing/procurement specifications.

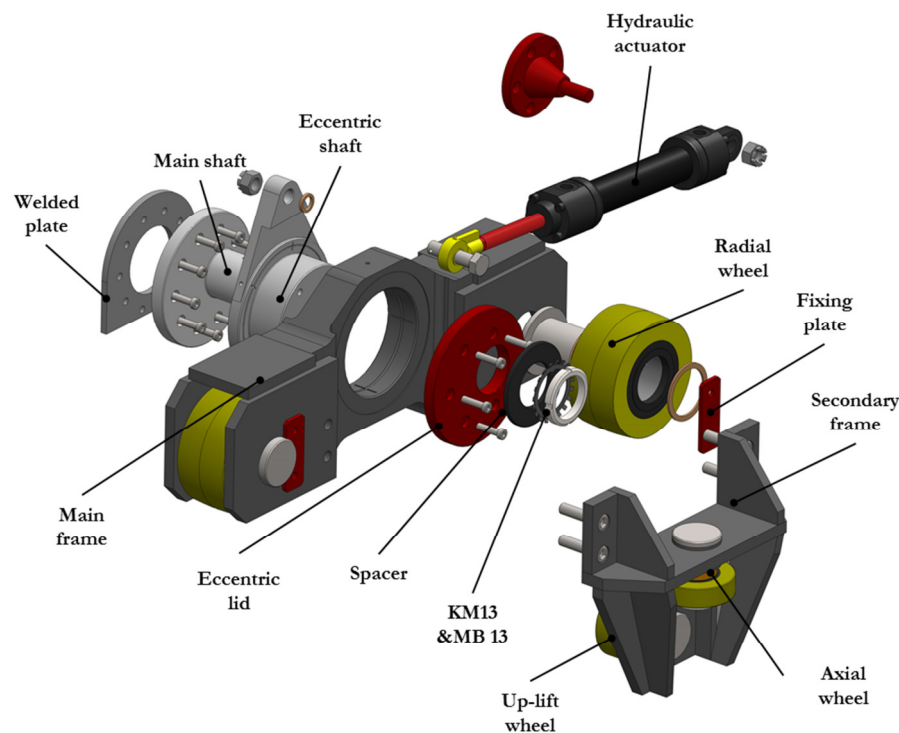


Fig. 5-3. Preliminary Design of New Bogies

It is convenient to optimize the design conceived during the preliminary phase, mainly to reduce the weight of each bogie, which will facilitate the assembly operations.

According to the preliminary calculations performed, there is margin for optimization in the bogie structure design. In any case, detailed analysis should be performed, including also the design wind loads in addition to the dead loads. The wind loads should be also used for verifying potential uplifts.

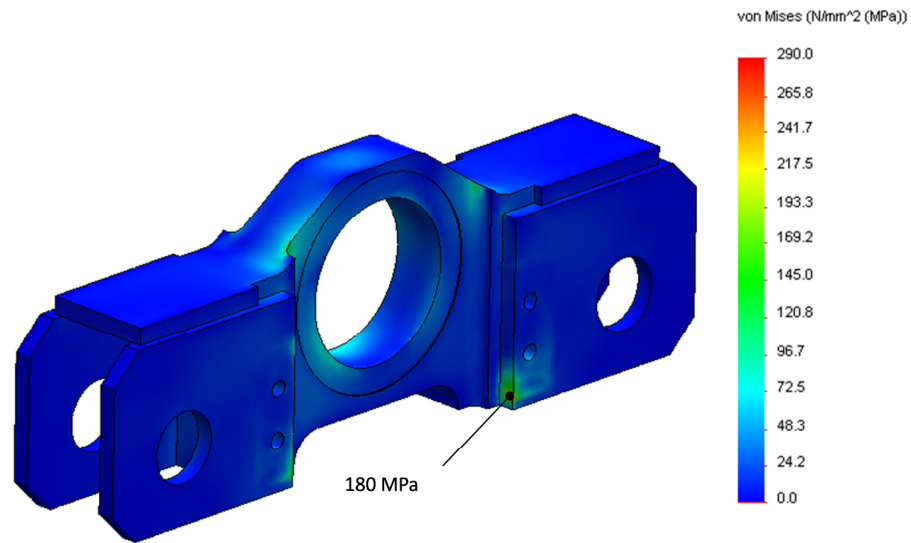


Fig. 5-4. Preliminary analysis of bogie structure under extreme working conditions (dead loads)

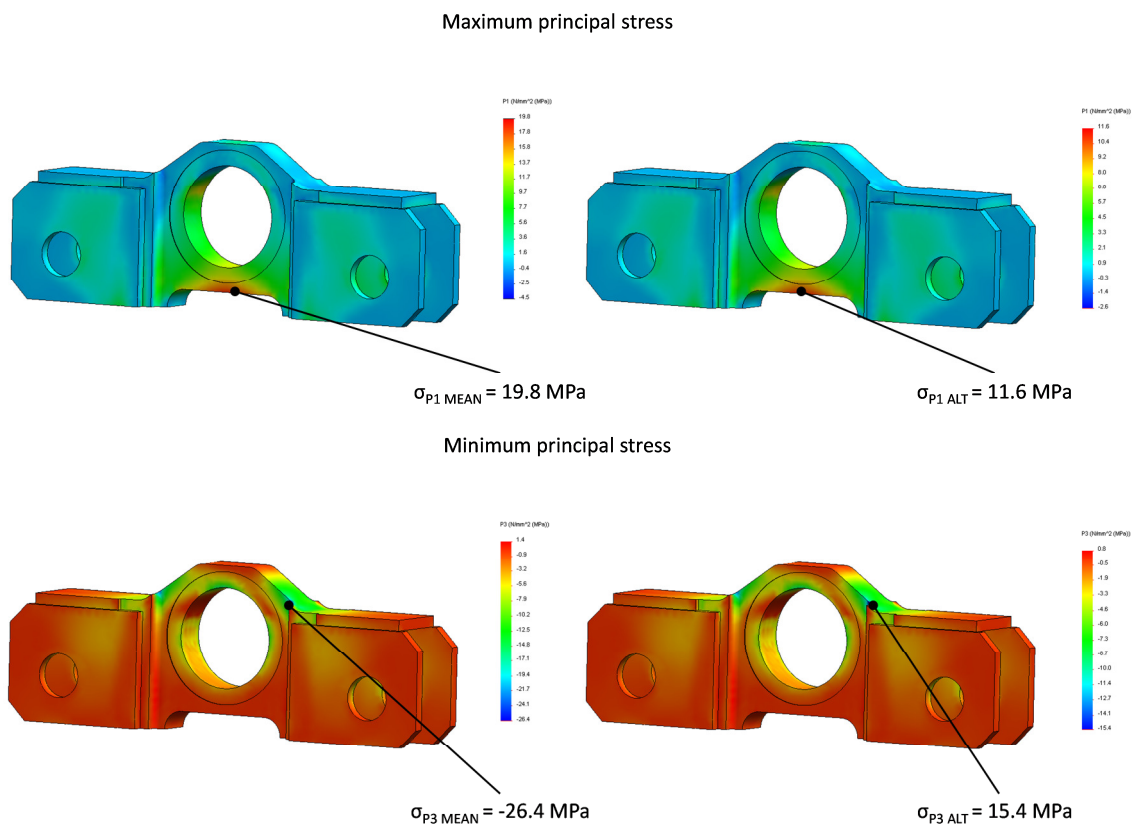


Fig. 5-5. Preliminary analysis of bogie structure under estimated fatigue loads (dead loads)

The detail design phase must also include the definition of the validation process (Factory Acceptance Tests) for acceptance of the final manufactured bogie.

For the alternative bogie design please see RD 13 document.

5.3.3 Take-Up System

Estimated start date: 1 Oct, 2014

Estimated end date: 29 Dec, 2014 (duration= 3 months)

The preliminary design of the upper shutter take-up mechanisms is depicted in the figure below.

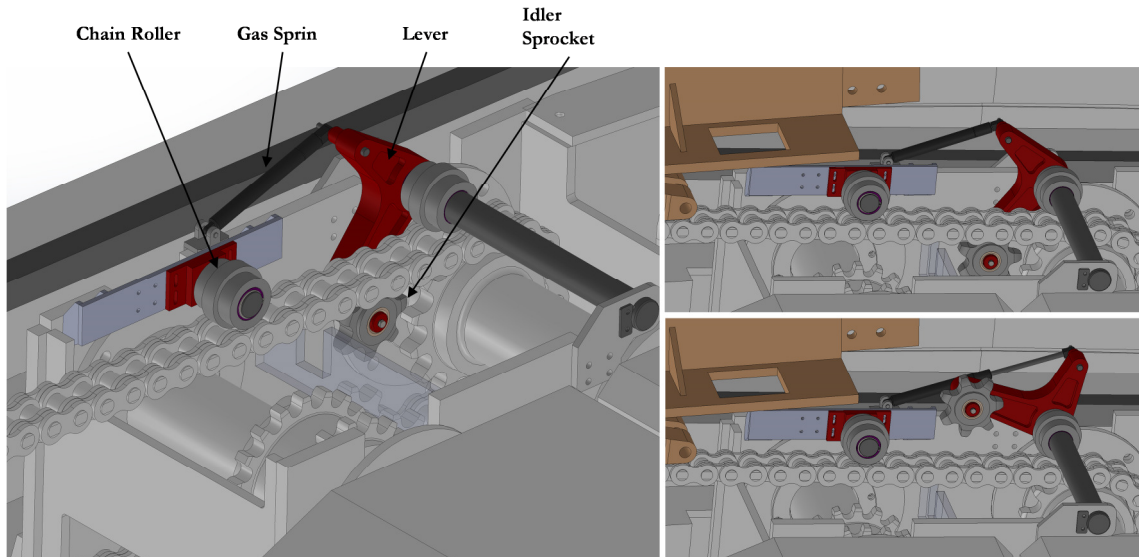


Fig. 5-6. Upper take-up mechanisms preliminary design

The preliminary design of the lower shutter take-up mechanisms is depicted in the figure below.

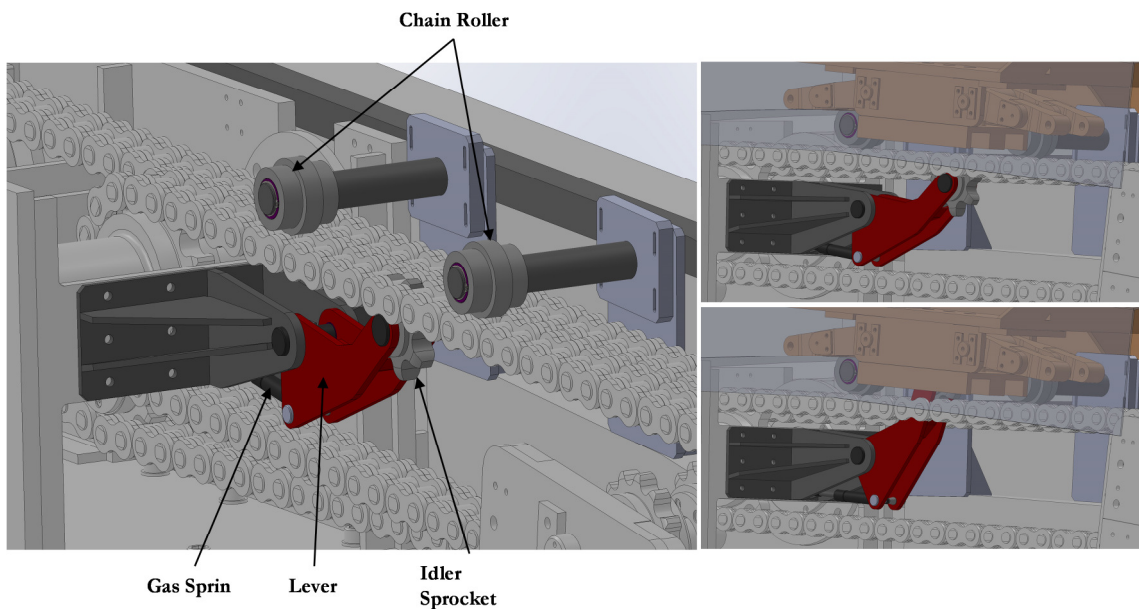


Fig. 5-7. Lower take-up mechanisms preliminary design

The position of these mechanisms is shown in the figure below.

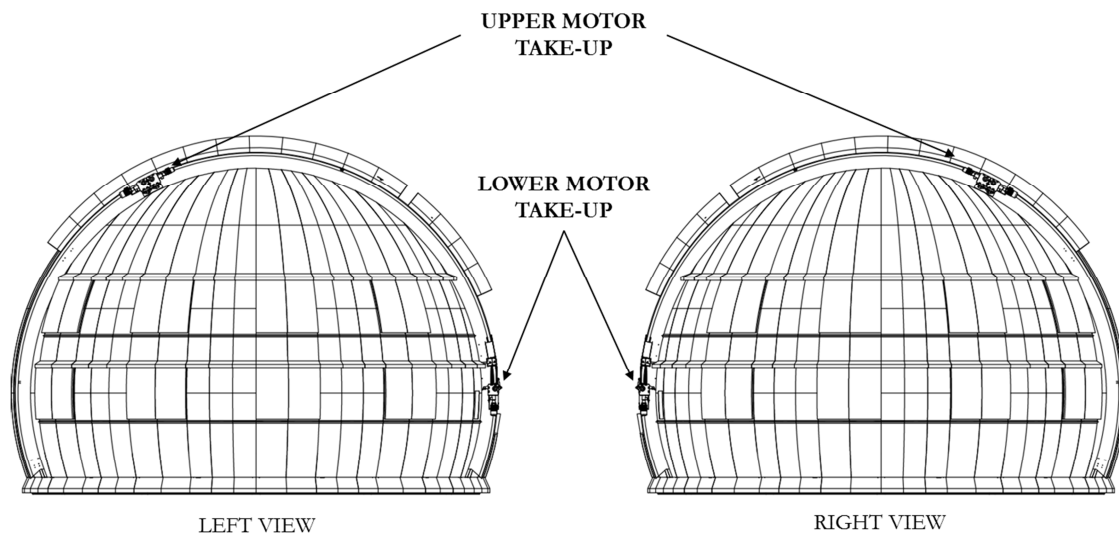


Fig. 5-8 Position of Take-Up mechanisms

Analogously as the bogies system, the current preliminary design should be further defined to the detail design phase prior to manufacturing. This includes the verification of the gas spring preselected, mechanical/structural calculations, manufacturing drawings, bill of materials and manufacturing/procurement specifications.

Should any FAT (Factory Acceptance Tests) be required to validate the correct performance of the fabricated mechanism, it will be also developed during the detail design phase.

5.3.4 Counterweight System

Estimated start date: 1 Sept, 2014

Estimated end date: 29 Dec, 2014 (duration= 4 months)

The counterweight system has been envisaged as a solution to reduce the loads on the upper shutter drive system during the last stage of upper shutter travel. The pre-selection of a higher capacity roller chains, the shutter guiding improvement and the optimized control system strategy for more equal distribution of loads among the drives, has led to the possibility of manage without the counterweight system. So, as this system is not strictly required to comply with the requirements, decision should be taken about its final implementation.

In case it is finally decided to install it, detail design should be developed including detailed analysis and verifications, manufacturing drawings, bill of materials and manufacturing specifications. Critical aspects as the capacity for the absorption of rail radial misalignments of the racks-pinion engagement should be carefully evaluated and, if necessary, checked by means of a mock-up or prototype. A procedure should be also defined for the factory acceptance tests.

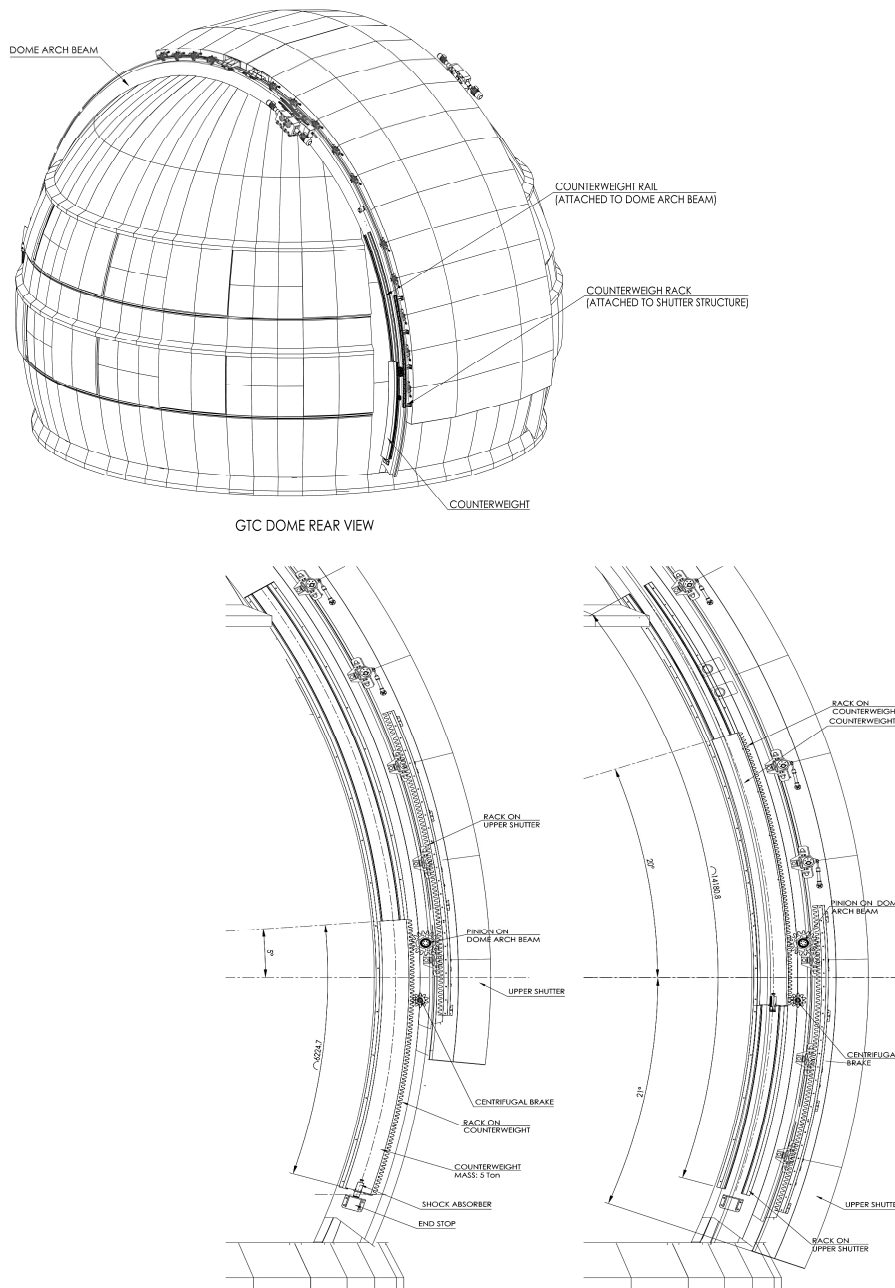


Fig. 5-9. Preliminary design of the counterweight system

5.3.5 Windscreen

Estimated start date: 1 Oct, 2014

Estimated end date: 29 Dec, 2014 (duration= 3 months)

The windscreen modifications should also be developed till the detailed design stage, including:

- New latching system with dragging structure.
- Modification of the initial part of guides profile
- Redesign of the guiding system
- Blades weight reduction.

The required works will include the required structural/mechanical verifications, manufacturing drawings, bill of materials and manufacturing specifications.

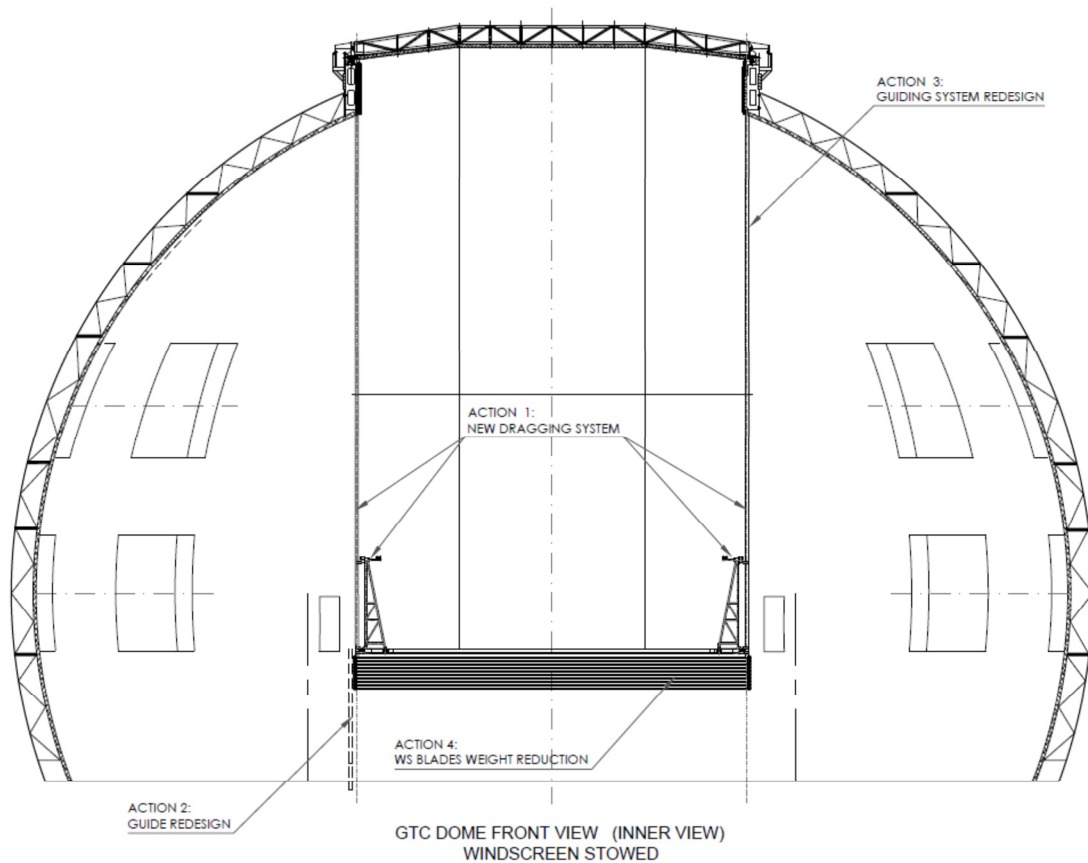


Fig. 5-10. Overview of windscreen actions developed during the preliminary design

5.3.6 Shutters Drive System

Estimated start date: 1 Sept, 2014

Estimated end date: 31 Oct, 2014 (duration= 2 months)

During the preliminary design phase, the actions for enhancement of the shutters drive system have been defined as:

- New roller chains with higher capacity for the upper and lower shutters
- New motors for the lower shutter
- New gearboxes for the lower shutter, with an additional input for an auxiliary motor.

This new equipment has been selected according to the available system in the market. In particular, the roller chains for the upper shutter are based on a customized design with higher working load than the corresponding catalog chains. During the detail design phase this preselection of equipment should be revised and all the necessary data to take the final decision should be asked to the manufacturer. Considering the delivery dates, in particular of those long chains, it is advisable to take the final decision as soon as possible (in 2 months) to place the order with sufficient time.

6 MANUFACTURING AND PROCUREMENT

6.1 INTRODUCTION

Milestones to launch the procurement/fabrication of the different materials in order to comply with the expected schedule. It also includes the procurement/fabrication of any assembly tooling required for the installation on site.

6.2 PHASE I

Axial Correction Supplements

The supplements shall be designed in detail during the Detail Design phase, following the philosophy established in the Preliminary Design phase.

Each of the supplements will be mechanized and identified in order to maintain a control of the location of them. It shall be identified by A or B depending on the Dome side it will be installed and with a number so all supplements for each side is identified (example: A8 – Supplement number 8 from side A)

The supplements will be then packaged and delivered.

6.3 PHASE II

6.3.1 Purchase order for roller chains, motor and gearbox

Roller chains

In this project the long lead time items are the upper shutter chains, with a delivery period of 20 weeks.

This procurement will involve:

- Upper shutter chains (20 weeks)
- Lower shutter chains (15 weeks)
- Driving/Driven sprockets if required (10 weeks)

An additional 1 week period should be included in order to account for the transport to the destination.

Although the Detail Engineering phase is finished at an earlier stage, so the period to the desired delivery time is longer 20 weeks, the drive system components can be purchased establishing the delivery period as required.

Lower shutter motor and gearbox

The delivery time for the new gear-motor system is estimated in 12-14 weeks.

This involves:

- Main motors
- Gearboxes with auxiliary input

Auxiliary gear-motor
Electromagnetic clutch

6.3.2 Start of Phase II Rest of Systems Manufacturing

The rest of the systems involve a longer manufacturing period, and the purchasing of the commercial components requires shorter time.

Bogies and Hydraulic system:

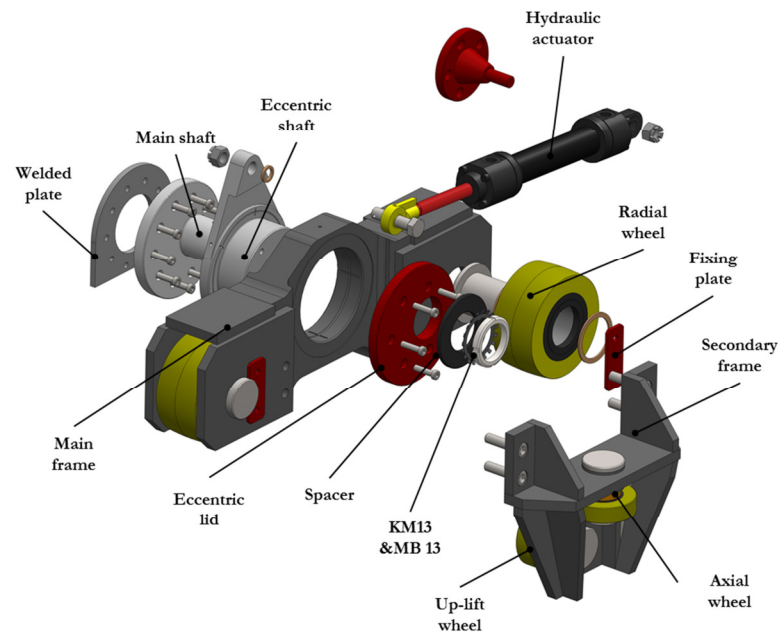


Fig. 6-1 New bogie main components

• Bogie:

The main frame of the bogie is manufactured out of a mechanized part in which the steel sheets that support the wheels are welded. During the welding the wheel holes need to maintain coaxial. No need of special treatment is required for this component.

Regarding the main shaft and the eccentric shaft, these are initially proposed to build up by mechanizing. During the Detail Design it shall be assessed the most convenient process. The eccentric shaft will be surface nitrured in order to maintain its integrity.

The secondary frame will be built up welded plates and the wheel shafts, the eccentric lids and the actuator supports are turned.

The proposed wheels (radial, axial and up-lift) are INA-FAG commercial wheels and shall be purchased.

Prior to the delivery of the bogie it shall be assembled and packaged in the manufacturer installations. The packaging will be defined in the Detail Design phase.

For the alternative bogie manufacturing process please see RD 14 document.

• Hydraulic system:

The main hydraulic system components need to be purchased: hydraulic actuator, valves, manometers, manifold, manual pump, pipe (rigid and flexible), purges....

The rigid pipe parts will be welded and the pipe supports shall be prepared prior to their installation in the shutter. This work is expected to be done on site.

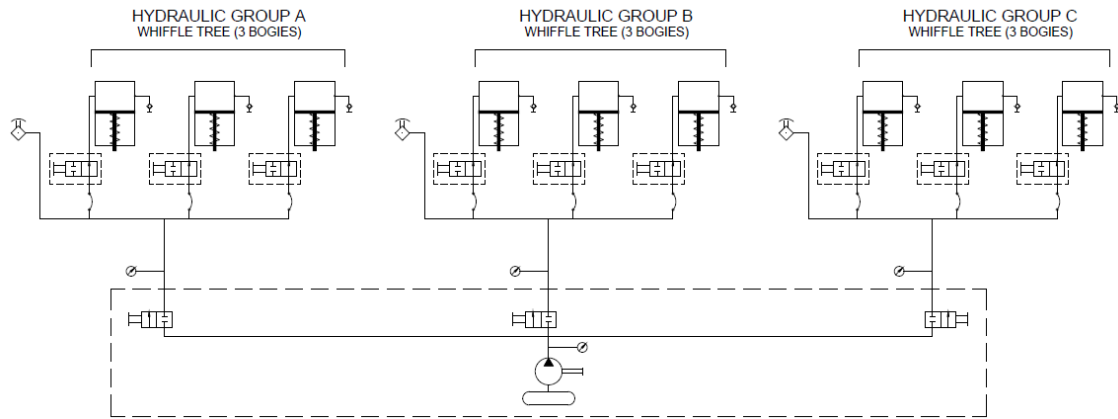


Fig. 6-2 Hydraulic system schema (Upper shutter – Group A and B)

Take-up system:

The Take up system requires mainly mechanizing of the components:

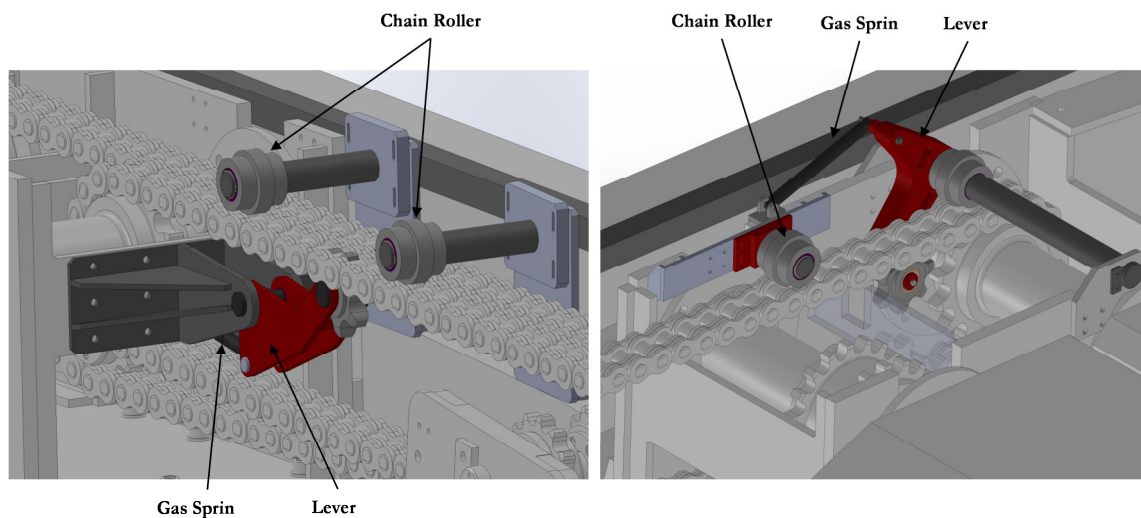


Fig. 6-3 Lower Take-up (left) and Upper Take-up right

The manufacturing process of the Take up system will involve:

- Mechanizing: Upper Take-up main frames (levers)
- Mechanizing and Welding: Lower Take-up main frames (levers)
- Mechanizing of the other components: clamping plates, fix plates...
- Turning: shafts and spacers
- Welding: Gas spring and roller supports

The procurement of the commercial components (Spring gas, Pinions (if possible), Bearing and/or bushings (TBD in the Detail Design phase)) does not required long delivery time.

Prior to the delivery of the take-up it shall be assembled and packaged in the manufacturer installations.

Counterweight system:

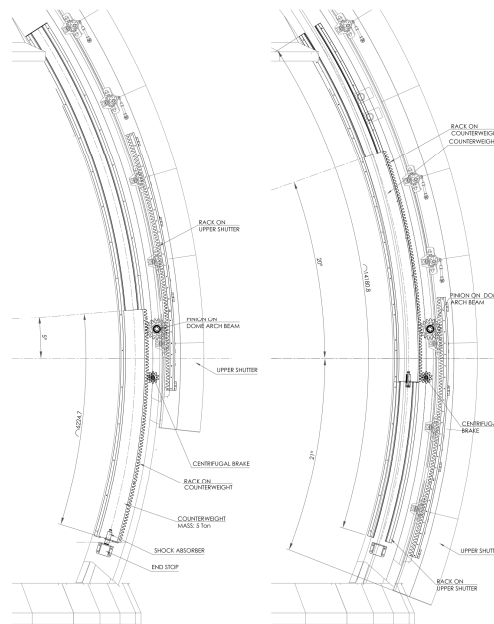


Fig. 6-4 Counterweight

Procurement of the commercial components:

Curved guides

Wheels

Centrifugal brake and gearbox for the emergency system

Belleville washers

Manufacturing:

Four racks (two for the shutter and two for the counterweights), the main pinions (x2) and the brake pinions (x2) need to be mechanized. The need of special treatments shall be assessed during the detail engineering.

The pinion shafts and the main structure of the spring system will be turned and then mechanized

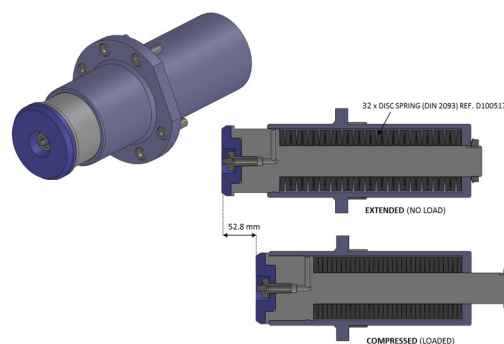


Fig. 6-5 Spring system

The supports of the shutter racks, the main pinion, the spring systems and the centrifugal brakes are composed by welded plates. There shall be packaged for the delivery.

The counterweight will be built up welded steel plates. The steel sheets will be previously drilled at the wheel shaft and spring system locations.

The subsystems shall be assembled and packaged in the manufacturer installations prior to delivery.

Windscreen Actions

Procurement of the commercial components:

Linear actuator (x2)

Cam followers (x50)

Manufacturing:

The preparation of the dragging frame profiles and mechanizing of the parts is required. Afterwards the different parts will be welded at the manufacturer installations.

Regarding the rest of the components, there will be mechanized (shafts, spacers, latching system support parts...), the latching system will be assembled and packaged at the manufacturer installations. The final assembly of the latching system on the dragging frame and the cam followers shall be done on-site.

7 ON SITE ASSEMBLY & COMMISSIONING

7.1 INTRODUCTION

The following chapter comprises the summary of the installation of the different upgrades that have been designed for the GTC. All the tasks have been separated in two phases according to the Grantecan decision, the first one will take three months starting on June 2014, and the second one will take 5 months starting on May 2015. For more detailed information see the implementation schedule Fig. 4-1.

7.2 PHASE I

During the first assembly period the following tasks are going to be executed:

- Shutter Sealing Reparation.
- Axial Correction Supplements.
- Cleaning and reparation of dome structure cracks and defects.

7.2.1 Shutter sealing reparation

The reparation of the Shutter sealing will be done taking into consideration the survey done by the GTC personnel. The extra material will be removed from the Arc Beam in the locations that is required. This reparation will be carried out during the day without interrupting the telescope performance. Prior to start operating the telescope a visual inspection will be required with the aim to ensure that all the material and tools have been removed from the working place.

7.2.2 Axial Correction Supplements

Once the sealing reparation works are finished, the correction of the axial deviation will be carried out. The estimated reparation period will be a whole week interrupting the performance of the telescope during the whole week. Prior to start with the reparation, the personnel shall verify that the working conditions are within the GTC quality plan; additionally the following aspects shall be taken into consideration:

- All the necessary material is on-site: a) make a recount of the supplements quantity verifying that all the parts have been received. b) The necessary welding equipment, including welding material is available. The most suitable welding process will be defined in the detailed design, defining the welding equipment and filler material. All the welding processes and welders must be within the required welding standard and qualifications.
- Verify if supplements can be carried up to the final position by two workers. If not a lifting platform or a small crane shall be necessary.
- All the personnel who are going to be working installing the supplements at heights shall fulfill with the Telescope “Working and Security” standards and will be equipped with the required personal protective clothing and equipment.
- After every working day, all the working material and assembly part shall be collected and removed from the dome. Bear in mind that the telescope performance will not be interrupted during this task.

For the installation of the Supplements the following working team will be required:

- 2 workers at the top of the dome, for the supplements installation.
- 1 worker on the lifting platform or small crane (if required).

The recommended Supplements assembly process:

- Check that all the personnel are equipped with the required safety equipment.
- Carry up the necessary welding equipment.
- Carry up the necessary fixing equipment (clamping tools, “dogs”).
- Carry the Supplements up one by one (use the lifting platform if required). Any supplement will not be carried up before the previous one is fixed.
- Position the Supplement in the correct position, referencing them with the trace marks that already are on the old rails from the rails state survey.
- Fix the Supplement with clamping tools.
- Place some spot welds on the Supplement to fix it.
- Repeat the process with all the supplements along the entire guide rail.
- Once all the Supplements are already installed, make a final verification checking that all parts are where they need to be.
- If any part is misaligned make the corresponding reparations. If all the Supplements are correctly installed proceed with the final welding process, following the sequence approved by Grantecan.
- Fill the gaps between Supplements with an epoxy (to be defined during de detailed design phase).
- Repeat all the steps on the other guide rail.

7.2.3 Cleaning and Reparation of dome structure cracks and defects

The lasts crack elongation surveys carried out on the structure during the previous year shows that the existing cracks have not increased, according to the conclusion of the survey the cracks are not propagating and seems to be stacked.

So the recommendation is to maintain an active control check, making the corresponding surveys to verify the length of the cracks. This verification shall be done once per year, monitoring the crack development along time. If any crack propagation is detected, a crack reparation procedure will be necessary to be released and approved by Grantecan.

7.3 PHASE 2

The second assembly phase will not start until May 2015 and during this period of time the following task are going to be executed:

- Bogies and Hydraulic System installation
- Take-up System Installation
- Counterweight System Installation
- Windscreen Actions
- Shutter Drive System Installation

The second integration phase will be divided in three different periods. The first working period will be between May-June 2015 and the replacement of the bogies will be carried out. During these operations the telescope performance will not be interrupted. The rest of the tasks on the upper shutter will be done between July-September 2015. During this time, the upper and lower shutter chain replacement will be carried out, as well as the upper take up. The telescope performance will be interrupted during this time. The third and last working period will be between September-October 2015, during this period of time, the updates corresponding to the lower shutter (windscreen additional structure, counterweight and lower take up installation) will be carried out.

The telescope performance will not be interrupted, as the lower shutter will be locked in the initial position.

Prior to start with any reparation, the personnel shall verify that working conditions are within the GTC quality plan; additionally the following aspects shall be taken into consideration:

- All the necessary material is on-site: a) before starting with any task, make sure that all the parts have been received. b) The necessary welding equipment, including welding material is available. The most suitable welding process will be defined in the detailed design, defining the welding equipment and filler material. All the welding processes and welders must be within the required welding standard and qualifications.
- Verify if the components of any task can be carried up to the final position with two working members. If not a lifting platform or a small crane (1 ton capacity) shall be necessary.
- All the personnel who are going to be working at heights shall fulfill with the Telescope “Working and Security” standards and will be equipped with the required personal protective clothing and equipment.

7.3.1 Bogies and Hydraulic System

Prior to start with the Bogies & Hydraulic System installation, the personnel shall verify that the workings conditions are within the GTC quality plan, so the following aspects shall be taken into consideration:

- All the necessary material is on-site: a) make sure that all the Bogies, Fixing Plates and all the Hydraulic System components are on-site. b) The necessary welding equipment, including welding material is available. The most suitable welding process will be defined in the detailed design, defining the welding equipment and filler material. All the welding processes and welders must be within the required welding standard and qualifications. c) The necessary piping equipment, pipe bender or any other considered instrument will be provided.
- A lifting platform or small crane will be necessary. Additionally for the manipulation of the bogies at the top of the dome, a pulley tackle is recommended.
- After every working day, all the working material and assembly part shall be collected and removed from the dome. Bear in mind that the telescope performance will not be interrupted during this task.

For the installation of the Bogies & Hydraulic System the following workers will be required:

- 2 workers at the top of the dome, for the Bogies & Hydraulic System installation.
- 1 worker on the lifting platform or small crane.

The recommended Bogies & Hydraulic System assembly process:

- Position the Upper Shutter in the operational position.
- Start with Bogie replacement. In the Upper Shutter all the bogies except the extreme ones shall be replaced. However in the Lower Shutter all the bogies will be replaced.
- Starting from the lowest point of the Upper Shutter, remove the bogie from the actual position.
- Take the removed bogie down to the ground level.
- Protect the working zone with some protecting clothing, in order to avoid the falling of waste material to the inner part of the dome.
- Remove the existing fixing frame by means of the disk grinder.
- Clean and remove any rusty parts on the located places (if required), additionally some protection shall be applied (coating or paint).
- For the alternative bogie design, do not carry out the previous three steps.

- Start with the bogie system installation. The assembly will be done by “whiffletree” zones, closing the hydraulic system every three bogie.
- Carry up the Bogie with all the components, except the hydraulic cylinder and the cylinder fixing frame.
- Position the Welded Plate on the correct position, making the alignment by means of the existing marks.
- Fix the plate with some weld spots.
- Make some established verifications to check that the Fixed Plate is in the correct position. If not remove the weld spots and correct the position, otherwise proceed with the welding.
- Fix the Main Shaft to the Welded Plate.
- Install the required shimming for the positioning and alignment of the bogie.
- Assembly the main body on the eccentric shaft and fix it. The hydraulic cylinder will not be connected until all the bogies and the hydraulic system are already installed.
- Simultaneously start with the replacement of the bogie on the other side, this operation will reduce by half the task length.
- Repeat the process with two more bogies.
- Once three bogies are already installed in each side, the hydraulic system can be installed.
- Carry all the necessary piping material up.
- Make the piping preassembly fixing it with some welds spots or commercial locking systems.
- Once the hydraulic system of the first “whiffletree” zone is already installed, make verifications in order to check the lack of leaks.
- Proceed with the installation of the hydraulic cylinders.
- Install the corresponding shimming on the cylinder fixing frame, aligning the cylinder with the bogie.
- Fix the cylinder in both extremes.
- Repeat the process with the rest of the cylinders of the zone, until all of them are installed.
- Connect the flexible piping of each bogie/cylinder to the hydraulic system.
- Make the filling of the cylinders with oil in both sides.
- Set the working pressure on the system.
- Close the valve of the entrance, and set the “whiffletree” configuration.
- Repeat the assembly process on the other “whiffletree” zones.
- Once all the system is already finished, remove the bogies that already are on the extreme positions.
- Finally all the “whiffletree” zones shall be connected between them in order to close the hydraulic system.
- Carry all the necessary piping material up.
- Make the piping preassembly fixing it with some welds spots or commercial locking systems.
- Connect all the systems and set the final working pressure on the system.
- Repeat the same steps on the Lower Shutter.

7.3.2 Shutter Drive System

The Shutter Drive system is composed by chains and motors/gears that give motion to the Shutters. The replacement of all the components shall be completed during the Drive System modification, starting with the removal of the old motors/gears and finalizing it with the chain removal and the installation of the new one.

Prior to start with the tasks, the personnel shall verify that the workings conditions are within the GTC quality plan; additionally the following aspects shall be taken into consideration:

- All the necessary material is on-site: a) make sure that all the chain links, the necessary assembly tools, motors and gears or any other complementary component is on-site. b) The necessary chain fixing equipment and motor fixing material is available. c) The necessary cabling equipment, cabling welding equipment or any other considered

instrument will be provided. d) The required gauges will be provided if required for the alignment of the motor and fixing frame.

- A lifting platform or small crane will be necessary.

For the installation of the motors-gears and chain the following working team will be required:

- 2 workers at the top of the dome, for the Motors-Gears and Chain installation.
- 1 worker on the lifting platform or small crane.

The recommended assembly process starts with the replacement of the motor-gears and finally the replacement of the new chain. The design and procurement of any additional lifting or manipulation tool for the old motor removal operation or the new motor assembly operation, will be defined during the detailed design phase:

- Make all the required preparations of the motor on the ground level.
- Lock the upper and lower Shutter with the existing supports.
- Lose all the nuts from the old motor.
- Install the lifting/manipulation tool, if required and remove the old motor.
- Lay the motor on the corresponding packing.
- Install the lifting/manipulation tool, if required in the new motor-gear and carry it up.
- Assembly the new motor-gear on the corresponding position.
- Make the alignment of the motor by means of the shims if required.
- Repeat the assembly process with the rest of the motors-gears.
- Once all the motors-gears are already replaced, the installation of the new chains shall be done. The detailed design for the chain exchange will be defined and delivered by the manufacturer during the detailed design.
- Position the package of the new chains in a secure position, aligned with the chains, which are already installed on the Shutter and check that they can be easily extracted from the box.

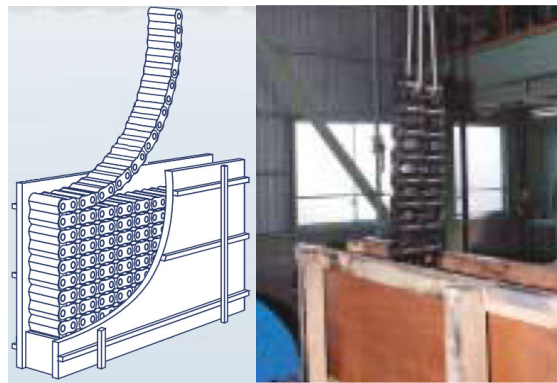


Fig. Chain extracting position from the package box

- Position the package of the old chain (the box where the chain is supposed to be packaged), aligned with the old chains.
- Start with the removal task of the old chain.
- Unlock the last links that are attached to the “Fixed Frame” (on the Shutter) and joint both extreme links together, leaving the chain as a closed circle.
- Unlock again the chain on the links that are at the lowest position.
- Lift the extreme of the new chain to fix it with one of the extremes of the old chain.
- Once both chains are fixed and with smooth movements start moving the motors. This movement will remove the old chain and install the new one in the same position. Ensuring that all gears along the travel will fix with the chain holes.
- While the old chain is being removed, it shall be introduced in the box that previously has been positioned.
- When the new chain is fully installed, unlock it from the old chain and fix with the other new chain extreme.

- Finally the chain shall be unlocked close to the “Fixed Frame” (on the Shutter) and fix extreme links to the frame.
- Package the old chain in the box.
- The chain replacement task is fully completed; repeat the process with the rest of the chains.

7.3.3 Take-up System

Before starting with the installation of the take-up system, the replacement of the new chains shall be finished. Prior to start with the Take-Up System installation, the personnel shall verify that the workings conditions are within the GTC quality plan; additionally the following aspects shall be taken into consideration:

- All the necessary material is on-site: a) make sure that all the parts that comprise the Take-Up System are on-site. b) The necessary assembling equipment, including a manual hydraulic pump is available.

For the installation of the Take-up System the following working team will be required:

- 2 workers at the top of the dome, for the Take-up System installation.

The recommended Take-Up System assembly process:

- Make the pre-assembly of the system on the ground level, except the cylinder. This pre-step will avoid inconvenient processes at the heights and carrying up necessary tools.
- Position the gear in the correct place (depending if the upper or lower Take-Up System is being installed) and assembly the Take-up System to the motor fixing frame.
- Tighten the nuts, checking the preload according to the VDI standard.
- Fix the cylinder to the motor fixing frame.
- Compress the cylinder to the required length by means of the manual hydraulic pump and the additional assembly tool and fix it to the Take-up system.

7.3.4 Counterweight System

Prior to start with the Counterweight System installation, the personnel shall verify that the workings conditions are within the GTC quality plan; additionally the following aspects shall be taken into consideration:

- All the necessary material is on-site: a) make sure that all the parts that comprise the system are on-site. b) The necessary welding equipment, including welding material is available. The most suitable welding process will be defined in the detailed design, defining the welding equipment and filler material. All the welding processes and welders must be within the required welding standard and qualifications.
- A lifting platform and medium size crane (10 ton) will be necessary.

For the installation of the Counterweight System the following workers will be required:

- 2 workers at the top of the dome, for the Counterweight System installation.
- 1 worker for the lifting platform.
- 1 worker for the small crane.

The recommended Counterweight System assembly process:

- Pre-assembly all the subassemblies on the ground level.
- Make the corresponding cleaning jobs on the arc beam, removing any rusty parts where the anchor plates will be installed.
- Carry the anchor plates up.
- Position the plates on the arc beam by means of the measures of the total station.
- Fix the anchor plates by means of clampers and fix them with some welding spots.
- Repeat the process with the rest of the anchor plates.

- Once all the anchor plates are already installed, make a final verification with the total station checking that all parts are where they need to be.
- If any anchor plate is misaligned make the corresponding reparations. If all the anchor plates are correctly installed, proceed with the final welding process.
- Carry up all the subsystems and assembly them on their positions by means of the pulley tackle.
- Move the Upper Shutter to an intermediate position.
- Assembly the counterweight to the Upper Shutter.
- Make the corresponding verifications to check the performance of the system.

7.3.5 Windscreen Actions

For the Windscreen Latching System there are two previewed tasks, the assembly between the Windscreen and the Lower Shutter and the replacement of the wheels of the blade.

In order to allow enough working space on the Windscreen Latching System, the Upper Shutter must be placed at the maximum level, every time the works starts. Prior to start with the Windscreen Latching System installation, the personnel shall verify that the workings conditions are within the GTC quality plan; additionally the following aspects shall be taken into consideration:

- All the necessary material is on-site: a) make sure that all the parts that comprise the Windscreen Latching System are on-site. b) The necessary welding equipment, including welding material is available. The most suitable welding process will be defined in the detailed design, defining the welding equipment and filler material. All the welding processes and welders must be within the required welding standard and qualifications. c) The necessary assembling equipment is available. c) The required assembly ancillaries shall be available if required (this ancillaries will be defined and designed during detailed design phase).
- A lifting platform or small crane will be necessary.

For the installation of the Windscreen Latching System the following working team will be required:

- 2 workers at the blades stow level, for the Windscreen Latching System installation.
- 1 worker on the lifting platform or small crane.

The recommended Windscreen Latching System assembly process:

- Remove the old latching system.
- Clean up the upper blade removing any remaining welding material or rusty parts.
- Weld the additional UPN beams and stiffeners to the upper blade, according to the plane 18242-DWG-05-000.
- If any part of the System is not assembled to the main structure, do it before starting with the assembly process.
- Assembly the new Dragging Structure. This process shall be completed by means of a small crane.

Once the Dragging Structure is fixed to the upper blade and Lower Shutter, the installation of the new guiding wheels can be done. To complete this task the Lower Shutter must be moved step by step in order to change the wheels of all the blades. The recommended process:

- Move the Upper Shutter to the highest level.
- Lock the Dragging Structure to the Lower Shutter.
- Move the Lower Shutter until the first blade is in the air.
- Replace the old wheels with the new ones.
- Move the Lower Shutter until the second blade is in the air.
- Fix the previous blade fixing the ancillary (this will unload the blade from the weight of the blades that are above it).
- Replace the old wheels with the new ones.
- Repeat this process until all the wheels are replaced.