Visible & Infrared Survey Telescope for Astronomy

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# 1 Scope of Document

## 1.1 General

This document defines the basic requirements and provides the technical specifications for the Coating Plant Work Package for the VISTA (Visible and Infrared Survey Telescope for Astronomy) project.

VISTA is a 4m class, wide field telescope, optimised to perform surveys of the southern sky in both visible and infrared wavelengths. The telescope will be located on the NTT peak at the location of the Cerro Paranal Observatory of the European Southern Observatory (ESO) in the desert of Atacama, in northern Chile.

The telescope is equipped with an Alt-Azimuth mount and a Cassegrain focus, the optical configuration is a modified Ritchey-Chrétien. The diameters of the primary (M1) and secondary (M2) mirrors are 4.1m and 1.24m respectively.

The Coating Plant, the subject of this specification, is required to provide the reflective coating for both mirrors.

## 1.2 Coating Plant Concept

The tasks in this work package include the detail design, manufacture, assembly, testing, packing, transport, on-site erection, and commissioning of the Coating Plant and Wash Facility. It also includes test equipment, service equipment, documentation and spares.

The work involves fabricated steel structural components that form the vacuum vessel, mechanical and electrical drive gear, mechanism control systems and various subsidiary and ancillary components together with associated cabling and wiring systems. The work includes the provision of a number of magnetrons, a vacuum pumping system and the leak testing at the manufacturer's premises. It also includes the provision of a mirror washing and stripping facility and spares.

For the principal structural components, as well as for the general arrangement of the plant, drawings indicating the nature, dimensions and extent of the work are provided for information. The Contractor shall prepare all working drawings necessary for manufacture and erection.

*Note:*
*This document primarily specifies requirements at the system and sub-system level. Meeting these requirements is the responsibility of the Contractor. The document also includes some conceptual design details. Sections with such details are clearly marked "conceptual design" and/or "for information only". Conceptual design details are included for guidance only and do <u>not</u> constitute requirements. If these conceptual design details are used by the Contractor, the Contractor shall assume full responsibility for them, including verification, analysis and testing.*

### 1.3 Definitions

The following terms will be used throughout this specification with the meaning herein:

| | |
|---|---|
| Coating Plant Work Package | The complete deliverable object of this specification, including the detail design, manufacture, assembly, testing, packing, transport, on-site erection and commissioning of the Coating Plant and Wash Facility. It shall include test equipment, service equipment, documentation and spares. |
| Coating Plant | The vacuum vessel and all systems necessary for coating the VISTA primary and secondary mirrors. |
| Control System | The system that controls all the Coating Plant functions and hardware, including the pumping system and magnetrons. |
| Auxiliary Building | The building located adjacent to the Enclosure used to house the Coating Plant as well as other plant, maintenance and storage facilities (not part of this contract). |
| Enclosure | The building which houses and protects the Telescope structure as well as providing the infrastructure for its operation (not part of this contract). |
| Contractor | Refers to the Company entrusted with delivering the Coating Plant Work Package. |
| Lower Vessel | Lower section of the vacuum vessel containing the mirror support system and rotation mechanism. |
| M1 Mirror | The polished primary mirror including all components bonded to the mirror but without a reflective coating (not part of this contract). |
| M1 Lifter | The device that is used for safe handling of the M1 Mirror (not part of this contract). |
| M1 Lifter Trolley | The device that is used to remove the M1 Lifter from below the wash stand. |
| M2 Mirror | The polished secondary mirror including all components bonded to the mirror but without a reflective coating (not part of this contract). |

Cryopump — The term Cryopump refers to a vacuum pumping system that utilises cryogenic temperatures to create a high vacuum.

Substrate — The term *Substrate* refers to the mirror surface, when addressed in terms of mechanical characteristics.

Upper Vessel — Upper section of the vacuum vessel containing the magnetrons and cryopumps.

Wash Facility — A pedestal stand for M1 with all the equipment necessary (including drainage facilities) for stripping and cleaning the primary mirror. This includes the M1 Lifter trolley.

Lower Vessel Carriage — The motorised carriage which transports the Lower Vessel on rails between the Auxiliary Building and the Enclosure.

## 1.4 Major Components

A simplified diagram of the components included in (but not limited to) the Coating Plant Work Package is shown in **Figure 1**.

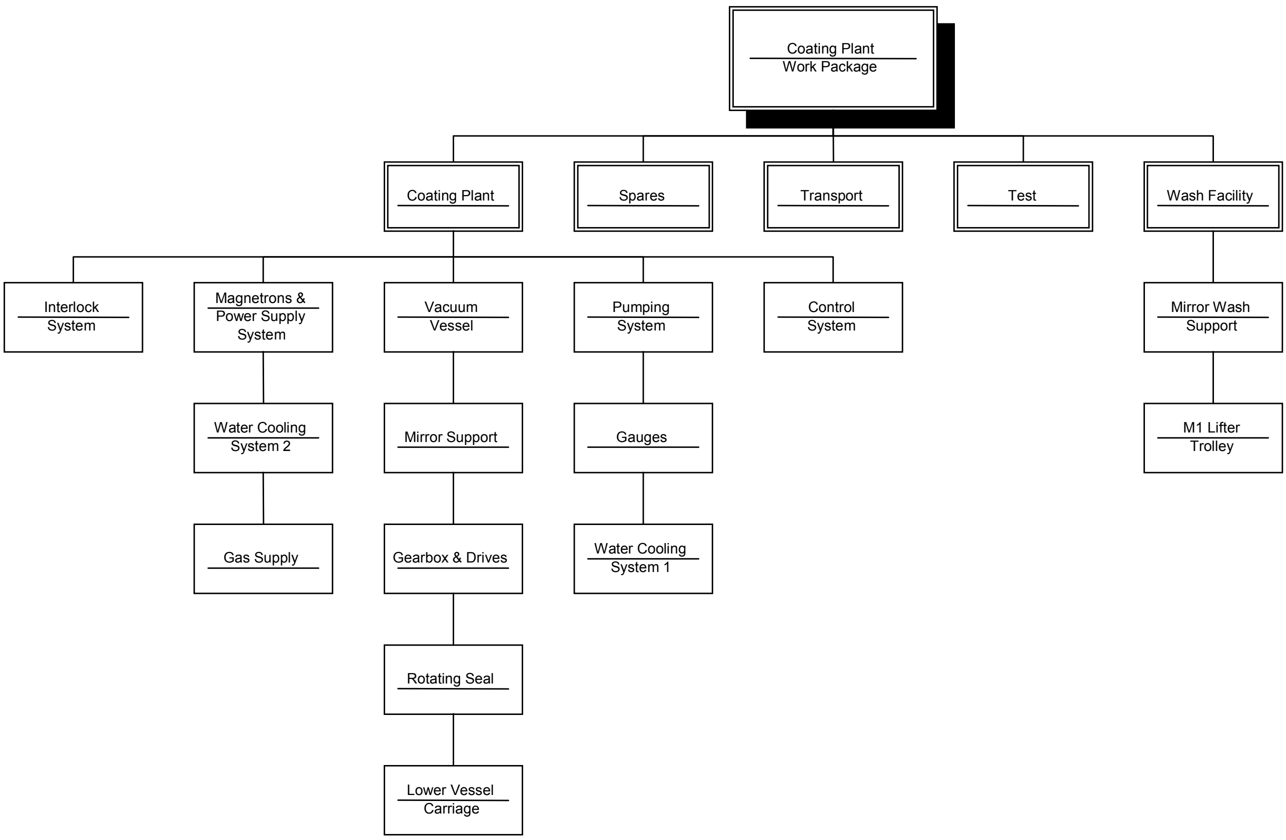


**Figure 1: Component Tree**

## 2 Abbreviations and Acronyms

| | |
|---|---|
| ADXX | Applicable Document number XX |
| Ag | Silver |
| ASME | American Society of Mechanical Engineers |
| ATC | UK Astronomy Technology Centre, Edinburgh |
| ESB | Emergency Stop Button |
| ESO | European Southern Observatory |
| ESS | Emergency Stop System |
| FDR | Final Design Review |
| FE | Finite Element |
| ICD | Interface Control Document |
| M1 | Primary Mirror of VISTA |
| M2 | Secondary Mirror of VISTA |
| MLE | Maximum Likely Earthquake |
| NiCr | Nickel Chromium |
| OBE | Operating Basis Earthquake |
| PDR | Preliminary Design Review |
| PLC | Programmable Logic Control |
| SCP | Service Connection Point |
| SWL | Safe Working Load |
| TN-S | Power system with the main earthing terminal of the installation connected to the earthed point of the source of energy |
| UHV | Ultra High Vacuum |
| VISTA | Visible and Infrared Survey Telescope for Astronomy |
| VLT | Very Large Telescope |
| VPO | Vista Project Office |
| WHT | William Herchel Telescope |
| 4N's | 99.99% Purity |
| 5N's | 99.999% Purity |

Note: *At the present stage a certain number of parameters defining the coating plant must be considered provisional. Such parameters will be fixed before signing the contract for the supply of the Work Package or at a later stage to be mutually agreed between the VPO and the Contractor. The parameters that are still provisional are labelled with TBC or TBD.*

TBC: To be confirmed by the Vista Project Office at the time of Contract Signature or at an agreed date during Contract duration.

TBD: To be decided between the VISTA Project Office and the Contractor in charge of the Coating Plant Work Package at the time of Contract Signature or at an agreed date during Contract duration.

TBR: To Be Reviewed: a requirement specified to meet the VISTA top-level requirements, but which might over-constrain the design. The Contractor shall investigate the requirements labelled TBR during the preliminary design phase. The findings of these investigations shall be used in further development of the requirements.

# 3 Applicable and Reference Documents

The following documents of the exact issue shown constitute part of this technical specification to the extent herein specified. In the event of a conflict between the documents referenced herein and the content of this specification, this specification shall be considered a superseding requirement.

## 3.1 Interface Control Documents

| Reference | Title | Document Number |
|---|---|---|
| AD01 | Coating Plant to M1 Mirror Interface Control Document | VIS-ICD-ATC-12000-02000 Issue 2.0 |
| AD02 | Coating Plant to M2 Mirror Interface Control Document | VIS-ICD-ATC-12000-05010 Issue 1.0 |
| AD03 | Interface Control Document between the Coating Plant and the Enclosure and Auxiliary Buildings Work Package | VIS-ICD-ATC-12000-10000 Issue 2.0 |

AD04 to AD10 left intentionally blank

## 3.2 Applicable Documents

| | | |
|---|---|---|
| AD11 | Service Connection Point Technical Specification | VLT-SPE-ESO-10000-0013 Issue 4.1 |
| AD12 | VLT Environmental Specification | VLT-SPE-ESO-10000-0004 Issue 6.0 |
| AD13 | VLT Electronic Design Specification | VLT-SPE-ESO-10000-0015 Issue5.0 |
| AD14 | VLT CANopen Specifications | VLT-SPE-ESO-10000-2772 Issue 1.0 |
| AD15 | VISTA Project Safety Management Plan | VIS-PLA-ATC-00001-0019 Issue 2.0 |
| AD16 | EMC and Power Quality Specification-Part1 | VLT-SPE-ESO-10000-0002 Issue 2.0 |
| AD17 | EMC and Power Quality Specification-Part 2 | VLT-SPE-ESO-10000-0003 Issue 1.0 |
| AD18 | Acceptance Procedure Electrical Safety and EMC | VLT-VER-ESO-10000-0958 Issue 2.0 |
| AD19 | VLT Requirements for safety analyses | VLT-TRE-ESO-00000-0467 Issue 1.0 |

| | | |
|---|---|---|
| AD20 | Manual of ESO's Policies, Rules and Regulations concerning Safety, Health and Environmental Protection | SAF-POL-ESO-00000-0001 Issue 2.0 |

## 3.3 Applicable Drawings

| | | |
|---|---|---|
| AD21 | Primary Mirror Interface to Handling Equipment | VIS-DWG-ATC-02000-11000 Issue C |
| AD22 | Primary Mirror Interface to Coating Plant | VIS-DWG-ATC-02000-12000 Issue B |
| AD23 | Secondary Mirror Interface to Coating Plant | VIS-DWG-ATC-05010-12000 Issue A |
| AD24 | Enclosure and Auxiliary Building/Ground floor | VIS-DWG-ATC-10010-0003 Issue E |
| AD25 | Enclosure Forbidden Zone for Mirror Washing and Handling | VIS-DWG-ATC-10010-0032 Issue A |

*AD26 to AD32 left intentionally blank*

## 3.4 Standards

The following international standards are specifically referenced in this Technical Specification. The latest editions/revisions thereof and any amendments or supplements thereto in effect on the date of the contract documents shall be taken as valid.

| | | |
|---|---|---|
| AD33 | Eurocode No.8 "Design provisions for earthquake resistance of structures" | European Prestandard ENV 1998-1-1: 1994 E, Parts 1.1 and 1.2. |
| AD34 | General Principles for the Safety Design of Technical Products | DIN 31000 VDE 1000 (1979-03) |
| AD35 | Safety of Machinery - Electrical Equipment of Machines - Part 1: General Requirements | IEC 60204-1 (2000-05) Consolidated Edition 4.1 (incl. amendments) |
| AD36 | Protection against electric shock – Common aspects for installation and equipment | IEC 61140 (2001-10) Edition 3.0 |
| AD37 | Insulation co-ordination for equipment within low-voltage systems - Part 1: Principles, requirements and tests | IEC 60664-1 (2000-04) Consolidated Edition 1.1 (incl. amendments) |
| AD38 | Information technology equipment – Safety – Part 1: General requirements | IEC 60950-1 (2001-10) Edition 1.0 |
| AD39 | Electrical installations of buildings | IEC 60364 (2001-08) Edition 4.0 |
| AD40 | Adhesion tests ISO standard test procedures | ISO/TC172 9211-4 January 1992 |
| AD41 | Electrical Equipment of Industrial Machines | EN 60 204 |

| | | |
|---|---|---|
| AD42 | Electromagnetic compatibility (EMC) | IEC 61000 |
| AD43 | Specification for unfired fusion welded pressure vessels | PD 5500:2000 |

### 3.5 Reference Documents

| | | |
|---|---|---|
| RD01 | VISTA Project Overview | VIS-TRE-ATC-00000-0004 Issue 1, 25/09/01 |
| RD02 | Interface Control Document between the Enclosure Buildings and Facility Handling Equipment | VIS-ICD-ATC-10000-11000 Issue 2.0 |
| RD03 | Primary Mirror Handling Procedure | VIS-TRE-ATC-02040-0001 Issue 2.0 |

*RD02 toRD10 left intentionally blank*

### 3.6 Reference Drawings

| | | |
|---|---|---|
| RD11 | Coating Plant Conceptual Design | VIS-DWG-ATC-12000-0001 Issue A |
| RD12 | Telescope Interface to M1 Handling Equipment | VIS-DWG-ATC-01000-02040 Issue B |
| RD13 | Mirror Support Conceptual Design | VIS-DWG-ATC-12000-0002 Issue A |
| RD14 | Magnetron Shutters Conceptual Design | VIS-DWG-ATC-12000-0003 Issue A |
| RD15 | Wash Stand Conceptual Design | VIS-DWG-ATC-12020-0001 Issue A |
| RD16 | Mirror Rotation Drive System Conceptual Design | VIS-DWG-ATC-12000-0004 Issue A |

# 4 Coating Plant Requirements

## 4.1 Functional Requirements

The Coating Plant vacuum vessel shall be centrally situated in the Auxiliary Building adjacent to the outer wall as shown in **Figure 2**. The vacuum vessel as shown in **Figure 3** consists of two sections designated the Lower Vessel and the Upper Vessel. When closed, the vacuum vessel shall be ~5m in diameter and ~2m in height. The vessel shall have mounted on it all systems necessary for the coating of the primary (M1) and secondary (M2) mirrors. Locations shall be provided in the Auxiliary Building for the control systems including the pumping station, heat exchange, gas supply and magnetron control panel as shown in AD24. The Lower Vessel is mounted on a carriage which is driven between the Auxiliary Building and the Enclosure on a rail system. An area in the Enclosure defined in AD25 shall be kept clear for mirror handling and the positioning of a removable pedestal used for the stripping and cleaning of the M1.

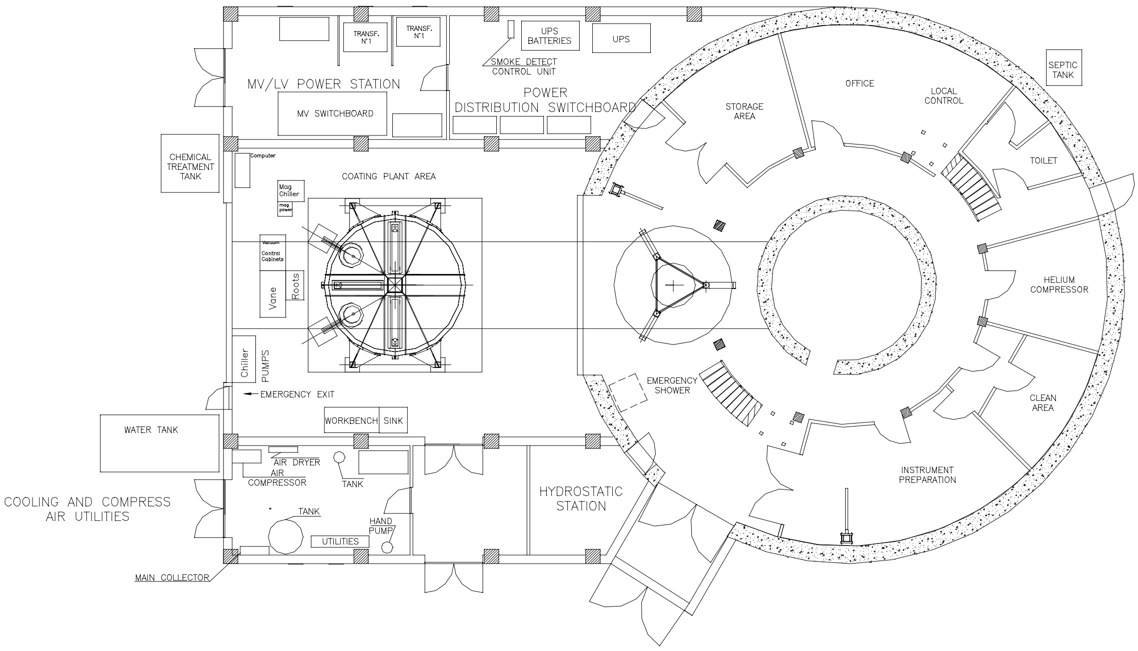


**Figure 2: Enclosure and Auxiliary Building Ground Floor (conceptual layout)**

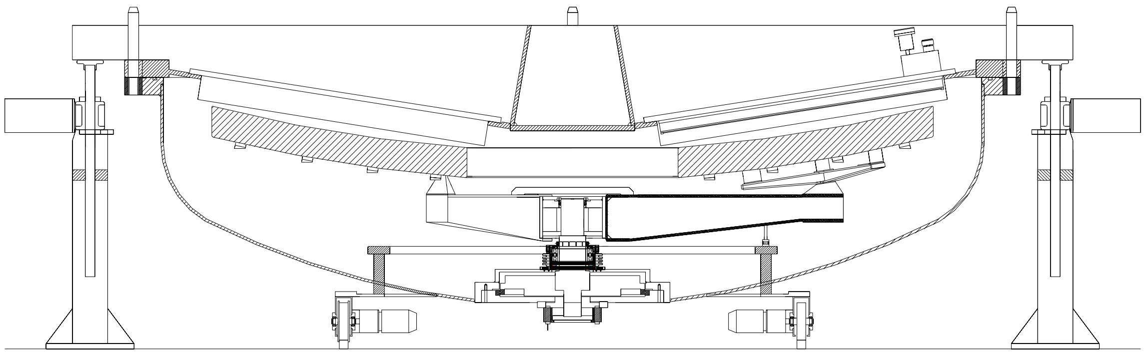

**Figure 3: Vacuum Vessel (conceptual layout)**

## 4.2 Interfaces

### *4.2.1 Interface with the M1 Mirror*

The interfaces with the M1 Mirror are defined in AD01, the mirror will be handled by means of a specialised handling tool which is not part of the supply of the Coating Plant Work Package.

### *4.2.2 Interface with the M2 Mirror*

The interfaces with the M2 Mirror are defined in AD02, the mirror will be handled by means of a specialised handling tool, which is not part of the supply of the Coating Plant Work Package.

### *4.2.3 Interface with Enclosure and Auxiliary Buildings*

The interfaces with the Enclosure and Auxiliary buildings are defined in AD03.

Included in this interface are:

- Power supply system and conduits
- Foundations (Required for the attachment of the rails and the pedestals)
- Locations of vacuum pumping systems, magnetron power supplies, gas supplies and control system
- Wash Facility
- Sink and work benches
- Embedded rails
- Power supply
- Heat Exhaust

The peak power demand for the Coating Plant is estimated to be 60kW (TBR).
Provision shall be made for all stationary free standing plant equipment to be secured to the Auxiliary Building floor.

#### *4.2.3.1 Power Supply*

The VISTA power supply is supplied from the ESO Paranal infrastructure:

- 230V 50Hz single phase
- 400V 50Hz 3 phase.
- UPS

The low voltage electrical installations of the VLT Observatory are designed and erected according to AD39. The grounding system used is TN-S. Earthing of the Upper and Lower vessels to prevent build of static charge is a responsibility of the Contractor.

### *4.2.4 Interface with Handling Equipment*

The interface with the M1 Lifter is defined in AD21, the M1 Lifter will be a specialised handling tool which will be used to locate the M1 in the Coating Plant and Wash Facility (see section 13). The M1 Lifter is not part of the supply of the Coating Plant Work Package.

# 5 Loads and Environmental Conditions

The load combination cases specified in section 14.2.2 shall be used to determine maximum loading conditions. The loads determined must meet the stress verification criteria specified in section 14.2.3.

## 5.1 Environmental Conditions

### *5.1.1 General*

The equipment shall comply with the requirements defined in the VLT Environmental Specification AD12, unless specifically amended by the requirements defined herein. AD12 describes the overall environmental conditions to be expected in operation, maintenance and storage at the Chilean site and transport from the Contractors premises to Paranal.

### *5.1.2 Environmental Temperature*

The temperature range defined for plant operation shall be:

Operational temperature range: 5° to 30°C

This temperature range does not apply during transportation and storage on site where the requirements specified in AD12 apply.

### *5.1.3 Altitude*

The altitude of the NTT peak is 2520m above sea level, the design of the Coating Plant shall take into consideration the effects of operation at this altitude.

### 5.1.4 Earthquakes

Protection for the mirrors against an earthquake occurring during the process of mirror coating or stripping and washing shall be provided for in the design of the vacuum vessel and mirror wash support.

Two design earthquakes are defined in section 4.2.14 of AD12, an Operating Basis Earthquake (OBE) and a Maximum Likely Earthquake (MLE)

OBE: An earthquake of moderate size with a high probability of occurrence during the lifetime of the telescope.

MLE: An earthquake of large magnitude with a lower probability of occurrence.

Earthquake loading shall be considered as a short-term accidental loading. The criteria for acceptable earthquake hazards are described in AD12 in terms of ground acceleration.

## 5.2 Operational Requirements

The system shall be designed to meet the duty cycle as specified in section 17.2.1. The design loads and conditions to be considered are the normal conditions and loads experienced by the Coating Plant during its operational cycle. All mechanisms shall be fully operational under the specified environmental conditions with the exception of the defined earthquake conditions.

### *5.2.1 Pressure*

The system shall be required to operate under an ultimate working pressure of $3 \times 10^{-7}$ mbar.

### *5.2.2 Accidental Loads and Conditions*

This is defined as the accidental loads, which may be experienced by the plant during its operational life. The plant does not have to fulfil its operational performance requirements during the occurrence of these events however it should be able to survive them. The accidental conditions are defined by the individual load cases defined in section 14.2.2.

- OBE earthquake conditions - no physical damage shall be allowed and all systems shall be capable of being automatically reset and reactivated
- MLE earthquake conditions – some physical damage can be allowed, preferentially to components that can be more easily overhauled or exchanged

### *5.2.3 Emergency Braking*

During the coating process the mirror is rotated within the vacuum vessel. Mirror Rotation emergency braking shall be considered as a short-term accidental loading and it shall be possible to put the plant back in operational condition with no maintenance requirements.

# 6 Mirror Coating

## 6.1 General

The Coating Plant shall be capable of depositing a wide range of coating materials, including metallic (Aluminium, Silver) Gold), oxides (Hafnia, Yttria) (TBR), nitrides (Silicon nitride) (TBR), and alloys such as (NiCr) and fluorides (Magnesium fluoride) (TBR).

The coating shall be applied to the mirror with the mirror horizontal. There shall be no heating of the mirror Substrate above 80°C. The coating must be capable of being removed, and the mirror totally prepared for coating within one eight hour shift, without any possible surface damage to the following mirror Substrate materials.

- Zerodur
- Sitall

The coatings must pass the following ISO standard test procedures defined in AD40.

- Moderate adhesion (scotch tape) test
- Moderate abrasion (cheesecloth) test
- Moderate to severe water solubility test
- Chemical durability test
- ISO Salt Mist test (done with atmospheric sulphides)

## 6.2 Optical

The Coating Plant shall deposit bare Aluminium with a reflectivity within 0.4% of the values in **Table 1**, throughout the spectral range from 0.3 microns to 3.3 microns. The coating uniformity requirements are +/- 5%, with a coating thickness of approximately 140nm.

## 6.3 Infrared

The Coating Plant shall deposit a protected Silver layer of 80nm (TBR) with an emissivity no worse than that indicated in **Table 2**, throughout the spectral range from 0.3 microns to 3.3 microns. **Table 2** indicates the emissivity of fresh UHV evaporated silver before any protective coatings are applied and the allowable emittance of the coating after the protective layers are added. The coating will be based on a Silver coating with suitable protection to enable the coating to maintain its emissivity for a period of at least two years in the telescope environment (the atmosphere will contain water vapour and sulphur compounds).

## 6.4 Adhesion Layers and Overcoats

An adhesion layer of NiCr of approximately 40nm thickness and a protective layer of 1nm thickness is required for the protective silver coating (TBR).

### 6.5 Measurements

The method used to measure emissivity and reflectivity of the coated surface shall be agreed with the VPO at the start of the contract. A high quality spectrophotometer suitable for measuring test samples to the required accuracy through the specified spectral range shall be provided by the VPO.

**Table 1: REFLECTANCE VALUES FOR ALUMINIUM**

| $\lambda$ (µm) | R | $\lambda$ (µm) | R |
|---|---|---|---|
| 0.300 | 0.9208 | 2.000 | 0.9779 |
| 0.350 | 0.9205 | 3.000 | 0.9805 |
| 0.400 | 0.9194 | 4.000 | 0.9826 |
| 0.450 | 0.9175 | 5.000 | 0.9843 |
| 0.500 | 0.9162 | 6.000 | 0.9856 |
| 0.550 | 0.9157 | 7.000 | 0.9866 |
| 0.600 | 0.9117 | 8.000 | 0.9872 |
| 0.650 | 0.9057 | 9.000 | 0.9874 |
| 0.700 | 0.8977 | 10.000 | 0.9876 |
| 0.750 | 0.8862 | 11.000 | 0.9879 |
| 0.775 | 0.8773 | 12.000 | 0.9882 |
| 0.800 | 0.8676 | 13.000 | 0.9884 |
| 0.825 | 0.8657 | 14.000 | 0.9886 |
| 0.850 | 0.8677 | 16.000 | 0.9892 |
| 0.875 | 0.8744 | 18.000 | 0.9896 |
| 0.900 | 0.8908 | 20.000 | 0.9902 |
| 0.925 | 0.9075 | 22.000 | 0.9907 |
| 0.950 | 0.9243 | 24.000 | 0.9912 |
| 1.000 | 0.9402 | 26.000 | 0.9918 |
| 1.200 | 0.9637 | 28.000 | 0.9923 |
| 1.500 | 0.9742 | 30.000 | 0.9928 |

UHV Evaporated Aluminium information from:

“IR Reflectance of Aluminium Evaporated in Ultra-High Vacuum”, Bennett et al. Journal of the Optical Society of America, 53: 1089-1100, 1963.

**Table 2**: EMITTANCE VALUES FOR SILVER

| **λ (μm)** | **E** | **λ (μm)** | **E** |
|---|---|---|---|
| 0.300 | | 2.000 | 0.0060 |
| 0.350 | | 3.000 | 0.0058 |
| 0.400 | 0.0436 | 4.000 | 0.0056 |
| 0.450 | 0.0294 | 5.000 | 0.0054 |
| 0.500 | 0.0214 | 6.000 | 0.0052 |
| 0.550 | 0.0169 | 7.000 | 0.0050 |
| 0.600 | 0.0140 | 8.000 | 0.0049 |
| 0.650 | 0.0120 | 9.000 | 0.0048 |
| 0.700 | 0.0106 | 10.000 | 0.0047 |
| 0.750 | | 11.000 | 0.0046 |
| 0.775 | | 12.000 | 0.0046 |
| 0.800 | 0.0084 | 13.000 | 0.0045 |
| 0.825 | | 14.000 | 0.0045 |
| 0.850 | | 16.000 | 0.0044 |
| 0.875 | | 18.000 | 0.0044 |
| 0.900 | 0.0071 | 20.000 | 0.0044 |
| 0.925 | | 22.000 | 0.0044 |
| 0.950 | | 24.000 | 0.0043 |
| 1.000 | 0.0064 | 26.000 | 0.0043 |
| 1.200 | 0.0062 | 28.000 | 0.0042 |
| 1.500 | 0.0061 | 30.000 | 0.0042 |

UHV Evaporated Silver Information from:

"IR Reflectance and Emittance of Silver and Gold in Ultra-High Vacuum", Bennett et al. Applied Optics, 4:221-4, 1965.

Protected Silver coating requirement is to allow a maximum emissivity increase as follows: (TBR)

For λ between 0.30 and 0.38 μm, the goal is to increase by up to 0.30 (30%).
For λ between 0.38 and 0.8 μm, an increase of 0.05 (5%) is allowed.
For λ between 0.8 and 2.0 μm, an increase of 0.01 (1%) is allowed.
For λ between 2.0 to 3.3μm, an increase of 0.001 (0.1%) is allowed.

# 7 Performance

## 7.1 General Capabilities

The coating process shall be carried out inside a vacuum vessel made from stainless steel. Within the tank shall be a wiffle tree to support and rotate the mirror and 3 Magnetrons for applying different coating materials. The magnetrons remain stationary during coating while the mirror is rotated. The magnetron output shall be regulated with actuated shutters associated with each device. A software system shall be required to control the power supply, gas supply, process of mirror rotation at various speeds and to turn the deposition of the coating on and off by control of the shutters (see section 8). A remote interface is also required for issuing commands and for the display of status information.

## 7.2 User Characteristics

The system will be operated by ESO staff in Chile to carry out routine coating of the mirrors. The user interface provided shall automate much of the coating process. For development and maintenance, a lower level of control shall be provided with access to the individual parts of the system.

## 7.3 Coating Process

For a description of the handling procedure of M1 from the telescope to the Coating Plant refer to RD03

The proposed operation for the coating of M1 is as follows:

<u>State at start up</u>

(1) Vacuum vessel closed and left under low vacuum.

(2) M1 Mirror ready, coating removed, washed and dried.

<u>Suggested operation</u>

(3) Using the air admittance valve bring vessel up to atmosphere.

(4) Using a hand held controller activate the mechanism which raises the Upper Vessel.

(5) When the Upper Vessel is clear micro switches shall permit the drive system for the Lower Vessel Carriage to be activated.

(6) The Lower Vessel is driven on rails into the Enclosure where the mirror is installed. A mirror lifter of vacuum quality will be used.

(7) The Lower Vessel is driven back into the Auxiliary Building.

(8) Upper Vessel is lowered onto Lower Vessel.

(9) Some pre-load of the seal will be produced when the Upper Vessel is sitting onto the Lower Vessel flange.

(10) The automatic vacuum pump down sequence is then put into operation.

(11) Once the high vacuum is obtained (3 x $10^{-7}$ mbar) the Cryopump valves are throttled back and the Argon gas (or other gas) is introduced into the magnetrons.

(12) The magnetrons with shutters closed are then energised for a short while to burn off the oxidised layer on the target.

(13) The mirror rotation is then started at a speed determined during the test phase of the plant.

(14) The shutters are opened at a pre-selected rotational position, and the deposition started. See section 8.6.

(15) The approximate time for deposition shall be 15 minutes (Aluminium) using the standard magnetron.

(16) After the coating is complete the magnetron is shut down and the vacuum system is brought up to atmosphere

(17) The opening sequence of the vessel is repeated and the mirror is returned to the telescope.

The Contractor may propose an alternative sequence of operations to those listed above subject to approval by the VPO.

## 7.4 Diagnostic Testing

Aids to testing, fault-finding, and de-bugging shall be built into the design. It shall be possible to run individual mechanisms and sub-systems from a password protected engineering interface.

## 7.5 Interlocks

Interlocks independent of software control shall be implemented to prevent hazardous situations from occurring, which may endanger personnel or cause damage to the mirrors or equipment.

Interlocks shall be provided, as a minimum, for the following:

- Vacuum vessel from being opened when under vacuum.
- Lower Vessel from being moved until the Upper Vessel has been raised and clear of the location dowels.
- Upper Vessel from being lowered until the Lower Vessel is in position.

It shall not be possible to power the magnetrons if:

- The mirror stops rotating during a coating cycle.
- The vacuum tank is open (interlocked to pumping system).
- Cooling water supply to the magnetrons fails.
- Gas supply to the magnetrons fails.
- Vacuum is not maintained in the vessel.

The above are not intended to be exhaustive lists of interlocks. It is a requirement of AD15, that a hazard analysis shall be carried out by the Contractor, should safety critical scenarios be identified, suitable implementation of interlocks shall be provided by the Contractor. A list of interlocks to be provided shall be agreed between the VPO and the Contractor at PDR.

### 7.6 Motion Alarms

Visual and audible indicators shall be provided which are activated when the Upper Vessel is being raised or lowered and when Lower Vessel is in motion.

### 7.7 Emergency Stop

An Emergency stop system (ESS) shall be provided to put the system into a safe condition in the event of an emergency. Provision for a minimum of 3 Emergency stop buttons (ESB) shall be made. The ESB shall be bilingual with labels according to AD11, the locations of each ESB to be agreed between the VPO and the Contractor at PDR. A method shall be proposed by the Contractor to bring the mirror to a stop quickly in the event of an emergency. The distance taken to stop from maximum speed shall be <1/4 revolution.

### 7.8 Loss of Power

In the event of a sudden loss and restoration of the main power supply, the system must be designed to recover to a safe state without damage to any part of the system. This requires that after such a loss of power the system is automatically closed down and restarted under controlled start conditions. Detail to be agreed between the VPO and Contractor.

#### *7.8.1 Shutdown*

For a controlled restart of the system due to power failure it shall be a requirement that the system status information at shutdown be retained.

## 8 Control

A Control System shall be used to control the coating process from a control console. The pumping sequence shall have both automatic and manual control. In the manual (or Engineering) mode the sequence shall be controlled by the operator and therefore individual control facilities for pumps and valves shall be provided, all components referred to in this specification shall be compatible with these requirements. The control console shall be located as near as practical to the vacuum vessel, this shall facilitate the use of short connecting leads to all equipment on or in the vacuum vessel.

### 8.1 Control System

The Coating Plant shall be operated via a PLC based Control System.

The PLC used shall be one of the following:

- Siemens LOGO micro PLC
- Siemens Simatic S7 series

The Siemens S7 may be connected to an external controller, in which the communications shall use the CP341 interface with RK512 based on 3964R protocol. CANbus devices may be used as specified in AD14.

A control System utilising an industrial PC and suitable software (eg.Labview) may be used for system set-up, monitoring and the user interface with agreement from the VPO. If such a system is adopted all process control shall be by the PLC.

## 8.2 Control Console

The control console shall be free standing in a fixed position such that the operator at the console has an uninterrupted view of the plant. The console shall comprise of a standard 19 inch rack. Access to equipment installed in the console shall be from the rear and any doors shall be lockable. Bottom cable entry is preferable for the mains power supply.

### *8.2.1 Mimic Panel*

A visual, stylised display of the vacuum system shall be provided by means of mimic panel. The panel shall incorporate pump and valve controls as 'on/off' or 'open/closed' illuminated push buttons, showing green for 'on' and 'open' and red for 'off' and 'closed'. Representations of pumps, etc. shall be suitably labelled.

## 8.3 Controls

The following separate control facilities shall be provided (but not limited to):

- Power
- Pumping cycle (low and high vacuum)
- Coating cycle (from start to finish including multiple coatings)

The coating cycle parameters must be adjustable for optimum coating quality.

### *8.3.1 Sub-System Controllable Functions*

The Control System shall provide an interface that, as a minimum, allows the following functions to be automatically controlled and allow setting of variable parameters in each sub-system:

- Select Magnetron (1 – 3)
- Cooling ON
- Magnetron ON/OFF
- Set Magnetron power or current
- Set mirror speed (speed rpm)
- Start mirror rotation
- Open Shutter
- Close Shutter
- Stop Magnetron
- Stop mirror rotation.

- Sputter gas (Ar) flow
- Chamber pressure during monitoring

To meet the coating requirements each function shall be able to be individually tested through an engineering interface.

#### *8.3.2 Status Display*

The Control System shall provide via the user interface, as a minimum, the following status information:

- Magnetron cooling water flow
- Magnetron gas flow
- Magnetron power input
- Arc count
- Selected Magnetron
- Position of Magnetron shutters
- Position of mirror
- Mirror rotation activity
- Coating cycle progress
- Vessel Pressure
- Rough pumps cooling flow

#### *8.3.3 Control Cycle Interrupt*

It shall be possible for the cycle to be interrupted in a slow controlled manner, causing no damage. The system shall be automatically reset to a safe condition. It shall be possible for a coating cycle to be interrupted either by activation of the ESS or by a power failure, in such circumstances the conditions of section 7.8 shall apply.

### 8.4 Mirror Rotation

The mirror shall be supported and rotated on a wiffle tree arrangement attached to the main shaft. An on axis encoder fixed to the main shaft shall be used to monitor the angular position of the mirror. The angular position shall be monitored for controlling the magnetron shutters while coating and also to position the mirror support for installing and removing the mirror.

#### *8.4.1 Speed Control*

The mirror shall be capable of revolving at any speeds defined by the user, between 1rpm and 0.016rpm as follows:

| | |
|---|---|
| Deposition of the overcoat layer | 0.06 to 1rpm +/- 5% |
| Deposition of Aluminium or Silver | 0.016 to 0.06rpm +/- 2% |
| Deposition of other coatings plus position control | Up to 0.016rpm (no accuracy requirement) |

The acceleration time from rest to 1rpm shall be <2 minutes and the time to stop from 1rpm shall be <1 minute. For safety the mirror control shall have a separate speed detector, which shuts off the power if the mirror rotation speed gets too high (50% over speed).

## 8.5 Mirror Positioning

When the vacuum vessel is open, control must be maintained to the servo drive in the lower half so that the mirror wiffle tree support can be moved (if necessary) to the correct position to accept the mirror.

### *8.5.1 Position Control*

Installation and removal of the mirror from the vessel requires that the support mechanism be stopped in the correct user defined position to engage with the M1 Lifter.

This position shall be achieved with an accuracy of +/-2mm on the M1 circumference.

## 8.6 Magnetron Control

During operation the magnetron shutters control the deposition process. The method used to operate the shutters will determine the control requirements. The two positions of the shutters shall be encoded so that the Control System can read the open or closed status of the shutters. The magnetrons shall have their own dedicated power supply provided with a system of interlocks (section 7.5) to prevent power being applied in the event of loss of cooling to the magnetrons or loss of vacuum in the tank. One power supply may serve all the magnetrons (sequentially) with a software-driven switch to determine which one is to receive power. The power supply shall be capable of being controlled and interrogated for status remotely.

### *8.6.1 Positioning*

The Control System shall provide a signal to automatically open and close the magnetron shutters at user defined points during the rotation of the mirror.
The accuracy of this operation shall be +/-0.2mm on the M1 circumference)

## 8.7 Upper Vessel Jacking and Lower Vessel Carriage Drive

The motor driven mechanisms for raising the Upper Vessel and moving the Lower Vessel shall have limit and home switches, so that the range of motion can be limited and a home datum can be established. In addition provision shall be made in the mechanical design for encoders to be fitted to give indication of their position.

## 8.8 Cooling Water

Operation of the plant shall not be possible in the event of a cooling water supply failure. A flow detector and a temperature monitor with appropriate switches shall be included in the cooling water return line.

### 8.9 Pneumatic Control

If pneumatic control is implemented a dedicated compressor shall be supplied. Operation of the plant shall not be possible in the event of inadequate air pressure being available.

### 8.10 Electronics

All the electronics shall he contained within a suitable cabinet(s), which along with the control console shall be located close to the vacuum vessel. The supplied system shall conform to AD13. The equipment shall the capable of working at an altitude of approximately 2520m above sea level. If required de-rating of electronics shall be in accordance with AD13.

## 9 Major Component Characteristics

### 9.1 Conceptual Design

*RD11 illustrates a conceptual design of the Coating Plant provided for information only. The VPO takes no responsibility for the performance of this design.*

*The conceptual design presented and much of the descriptive specification is based on Upper Vessel jacking to separate the two halves. An alternative strategy of jacking the Lower Vessel would be acceptable subject to meeting the requirements.*

### 9.2 Vacuum Vessel

As a minimum the following requirements shall be provided:

- The vessel shall be cylindrical with a lower and upper vessel section designed to adequately sustain an internal vacuum.
- The lower section shall be detachable and form part of the vacuum vessel carriage that supports the mirror during the coating process.
- The upper section shall be supported from the concrete floor on four pedestals and shall contain the magnetrons and mounting ports for the vacuum pumps.
- The upper and lower vessel sections shall locate together by the means of pins through their respective flanges.
- The inside of the vessel shall be designed to facilitate easy cleaning.
- The vessel shall be fabricated in stainless steel of a suitable grade to be agreed with the VPO.

The method of construction shall include the following:

- The inner construction of the vessel shall avoid ‘dirt traps’ and ‘volume traps’.
- The outer construction of the vessel shall be designed so as to facilitate ease of cleaning.
- All gas captivating construction aids, such as pins, bolts, etc. shall be provided with vent holes to avoid virtual leaks.

- Only continuous welds shall be used on the inside of the vacuum vessel as well as on all ports, pipes, etc. exposed to vacuum.
- Intermittent welds may be used on outside surfaces.
- All materials used on areas exposed to vacuum shall be selected for low vapour pressure.

## 9.3 Lower Vessel

The lower section of the vacuum vessel shall contain all the mounting surfaces to install a rotating turntable and its drive system. The turntable supports the mirror during the coating operation and requires accurate rotational and axial location. A rotary motion feed-through port shall also be provided through the vessel shell for the turntable drive. The flange at the top of the lower section shall house a sealing ring that will mate with the flange of the upper portion of the vessel.

### 9.3.1 Lower Vessel Carriage

The Lower Vessel Carriage shall be made of a heavy duty, all welded, steel construction, completely sandblasted and painted a high visibility safety yellow. It shall include a drive platform supporting a control cabinet on the rear of the Lower Vessel Carriage. The Lower Vessel drive system shall allow access to the drive mechanisms and encoders. It shall be powered by an AC powered drive package. The voltage and current requirements shall be rated appropriately for the specified altitude and environmental conditions.

It shall also include the following:

- Walk-along pendant control
- Positioning sensors (number and location to be agreed at PDR)
- Cable chain (or equivalent) for all Lower Vessel systems

Power to the Lower Vessel Carriage shall be activated only when the Upper Vessel is clear of the location pins, each pin shall be interlocked to prevent accidental motion of the Lower Vessel. When the Lower Vessel Carriage is active the lifting screw jacks shall be automatically de-activated.

### 9.3.2 *Wheel Assembly*

This shall consist of two stub-axle idler wheel assemblies, one side to be double flange, the other to be a flange-less flat wheel. A continuous through axle wheel assembly is preferred so as to require only one drive motor for the motion.

### *9.3.3 Safety Requirements Lower Vessel Rails*

During installation, the Coating Plant Contractor shall be responsible for positioning and attaching end stops to the rails supplied by the building contractor. These are required to prevent any over drive when returning the Lower Vessel to its parked position and to prevent any possible damage to the vacuum system, positioned at the rear of the plant.

### *9.3.4 Rotation System*

The rotation system which includes the following (but not limited to) shall be installed and tested during factory assembly and test:

- Bearing
- Gearbox
- Drive motor
- On axis encoder
- Feed-through seal

In order to obtain a clean vacuum, reduce the levels of out gassing and overcome the problems associated with the above working within an UHV it is preferred that they shall be located outside the vacuum vessel. The use of a magnetic liquid feed-through seal (ie Ferrofluidic or equivalent) between the main drive shaft and the vessel is therefore preferred.

Drawing RD16 shows the conceptual design outline of the seal, vacuum vessel and the rotating shaft.

#### 9.3.4.1 Vacuum Pressures (seal)

- The seal shall be required to seal a pressure of $3 \times 10^{-7}$ mbar against atmosphere.
- The leak rate of the seal shall be less than $10^{-9}$ mbar l/s.

#### 9.3.4.2 Rotational Speeds

The rotational speeds as specified in section 8.4.1 are as follows:

- The maximum rotational speed of the shaft shall be one revolution per minute.
- The minimum rotational speed of the shaft shall be one revolution per hour.

#### 9.3.4.3 Usage

- The seal shall meet the duty cycle requirements specified in section 17.2.1.
- The seal shall be designed for non-operational periods when the vessel shall be left under a rough vacuum ($2.7 \times 10^{-2}$ mbar).

### *9.3.5 Earthquake Protection for Mirrors*

The design must be able to satisfy the conditions of an OBE as defined in section 5.1.4

### *9.3.6 M1 Mirror*

Drawing RD13 shows a cross-section through the conceptual design of the Lower Vessel with M1 in-situ during coating. The Contractor shall provide suitable earthquake protection for M1.

### *9.3.7 M2 Mirror*

Drawing AD23 shows the same cross-section with M2 in-situ during coating. The secondary mirror may either be:

- Held in place on a mount, attached to one of the primary mirror wiffle tree, support arms.
- Held in place by a support arm bolted onto the central spigot (between the wiffle tree arms).

A counterbalance weight shall be attached to the central spigot in both cases.

### *9.3.8 Test Samples*

Provision for the coating of test samples shall be required. This shall be by means of a removable mount, which positions the test samples in the Coating Plant at the height of the polished surface of M1 and allows testing along the length of the magnetron.

### *9.3.9 Wiffle tree*

M1 shall be supported in the vacuum vessel on a wiffle tree arrangement, where the load of the mirror is supported on nine areas of contact. The load of the mirror shall be equally distributed between each of the nine supports. The material used shall be stainless steel, bead blasted and all components shall be of vacuum quality. The interface of the wiffle tree support to the back of M1 is described in AD22, elastomer pads suitable for vacuum shall be used between the mirror and the supports. Accurate location in the vessel is required, as the wiffle tree support system has to avoid the pads on the rear surface of the mirror.

Stresses induced in the mirrors due to the support shall never exceed the values specified below:

- 5 MPa under any circumstances
- 3 MPa for any period > 24 hours

Under the term *stress* it is here intended the *maximum principal tensile stress* in the M1 and M2 Mirrors.

## 9.4 Upper Vessel

The upper section of the vacuum vessel shall be supported from the concrete floor of the Auxiliary Building on four pedestals bolted to the floor. The Contractor shall ensure adequate spreading of the load through the pedestals to the floor.

- 100kN/$m^2$ for each pedestal pad of interface area 750mm x 750mm

The Upper Vessel shall contain four apertures for the mounting of the external magnetrons, these apertures must have cover plates of stainless steel for use during vacuum testing of the vessel without the magnetrons in place. The magnetrons and cover plates shall contain the vacuum seals, vacuum sealing quality surfaces are therefore required around the apertures. Ports shall be provided in the upper section of the vacuum vessel to allow for all sealed connections to vacuum pumps, magnetrons, mechanisms, gauges and services. Viewing ports for monitoring the coating process shall also be positioned in the Upper Vessel.

### *9.4.1 Lifting System*

The design of the Upper Vessel lifting system shall be based on a commercially available screw jack. The jack must be chosen for stability during earthquake. All motors shall require synchronous control so that the jacks operate together.

### *9.4.2 Cryopumps*

Two Cryopumps shall be mounted on the Upper Vessel. Flexible lines shall be used to connect the two Cryopumps to the compressor units on the Auxiliary Building floor. The Cryopump flanges shall be of standard ISO design.

### 9.4.3 View Ports

Four view ports shall be required in the vacuum vessel. These shall be situated near the magnetrons in the Upper Vessel. The ports shall not require internal masks.

## 9.5 Upper and Lower Vessel Flanges

The Upper Vessel flange shall be machined with a good quality flat surface suitable for a vacuum. The Lower Vessel flange shall contain sealing requirements suitable for UHV. Location pins or similar feature shall be provided on the flanges for accurate and repeatable positioning of the Upper and Lower Vessels.

## 9.6 Electric Motors

All pump motors, valve motors (if used) and variable transformer motors shall be fitted with full overload protection switches. All motors must have single phasing protection.

## 9.7 Lights

A minimum of six vacuum quality lights shall be placed in strategic positions within the chamber, with manual operation from outside the vessel.

## 9.8 M1 Lifter (not part of this contract)

The M1 lifter is to be left in the vacuum vessel during mirror coating, therefore it shall be designed for vacuum operation.

# 10 Vacuum Pumping System

The Contractor shall design the vacuum pumping system for the Coating Plant based upon this section. AD24 shows a layout of the conceptual pumping system.

## 10.1 General Information

The pumping system shall be attached to the movable Upper Vessel with suitable connections for the pumps.

## 10.2 Pressure and Pumping Times

The system is required to reach its working pressure within 2 hours, under normal site operating conditions. The working pressure shall be determined by the Contractor, subject to achieving the required mirror coating performance, as specified in this document.

The following are typical values based on the conceptual design and are provided as a guide:

- The volume of the conceptual design for the vacuum vessel is $<22m^3$ with an inner surface area of $<50m^2$.
- Ultimate working pressure of $3 \times 10^{-7}$ mbar attained in the dry vacuum vessel starting from ambient air conditions and using a Cryopump system.
- Partial pressure of water vapour in the vessel to be better than $2.0 \times 10^{-7}$ mbar.

The VPO accepts no responsibility for the accuracy of the figures quoted above. The Contractor will be required to revise these numbers at PDR and FDR based on their proposed design.

## 10.3 Leak Rate

Individual leaks greater than $1 \times 10^{-7}$ mbar l/sec shall be detected and eliminated by the Contractor. Refer to performance testing in Section 12. The Contractor shall show that the total pressure rise in the vacuum vessel does not exceed $3 \times 10^{-3}$ mbar/hour with pumps valved off after pump down to $2.7 \times 10^{-2}$ mbar.

### *10.3.1 Leak Detection*

The detection of leaks during the vessel construction and during on-site installation shall be the responsibility of the Contractor. The Contractor is not asked to supply a leak detector, but shall supply the connection between the detector and the vacuum plant. An automatic direct reading Helium leak detector with a helium bottle will be available at the site (TBC).

## 10.4 Vacuum Pumps

### *10.4.1 Mechanical Pumps*

The mechanical pumps shall not be mounted on anti-vibration pads, but shall be secured to a metal plinth and bolted to the concrete floor. They shall have automatically operated air vent valves as a safety device, to prevent back streaming of oil when the pumps are switched off or in the case of power failure and shall incorporate an automatic lubrication system. The mechanical pumps alone shall be capable of maintaining a pressure of 2.7 x $10^{-2}$ mbar. The exhaust from the rotary pumps shall be through oil mist filters and vented to outside the building.

### *10.4.2 Roughing Pump*

This mechanical pump shall be used to reduce the pressure in the vessel from atmospheric to a pressure adequate for the operation of the booster pump(s). The roughing pump shall discharge to atmospheric pressure via the exhaust duct situated on the Auxiliary Building wall.

### *10.4.3 Booster Pump*

One mechanical booster pump (Roots or similar) shall be used to reduce the initial pump down time prior to the Cryopumps coming into operation in the pumping cycle.

#### *10.4.3.1 Cold Trap*

If required the Contractor shall provide a cold trap between the booster pump and the vessel to prevent any oil vapours from entering the chamber during roughing.

### *10.4.4 Cryogenic Pumps*

The Cryopumps shall be used to obtain the ultimate pressure required by this specification and to reduce the partial pressure of water vapour to better than 2.0 x $10^{-7}$ mbar.

## 10.5 Valves

All the vacuum valves shall be fail safe in the event of power failure or loss of control. After normal conditions have been restored the automatic cycle shall be resumed, however if the system is being pumped in a manual mode the valves shall require manual resetting. Air vent valves on the mechanical pump shall be exempt from this requirement.

### *10.5.1 High Vacuum Valves*

High vacuum valves shall be installed between the Cryopumps and the vessel to isolate the Cryopumps during roughing and loading/unloading of the vessel. The valves shall be dimensioned to suit the pumping system design. The valve shall be controllable so that the pumping speed can be throttled back when using the magnetrons. The Contractor shall ensure that the valve aperture can be adjusted and set for optimum conditions for the film deposition.

### *10.5.2 Air Admittance Valve*

A solenoid actuated and pneumatically operated valve shall be fitted to admit air into the vessel in order to break the vacuum, the valve shall be fitted with a 5 micron air filter. Control of the valve shall be from the control console.

#### *10.5.3 Gas Admittance Valve*

Valves with a manual micrometer adjustment shall be fitted to the vessel for the controlled admittance of the plasma gas, the valves shall be backed by solenoid operated shut-off valves, which may be remotely controlled from the console. The gas required for the magnetron system shall be separate from this and have its own control. See section 11.2

#### *10.5.4 Other Valves*

Valves in the roughing line entering the vessel, the fore lines, the holding lines of the pumps and other valves required for the operation of the pumping system shall be pneumatically operated and installed for remote control from the control console. It is important that the valves operate from a supply that is not liable to be interrupted or fluctuate in pressure value.

## 10.6 Gauges General

High and low vacuum pressures shall be monitored at convenient points in the system but away from regions of influence of the Cryopumps and the vacuum piping. Any gauges not able to withstand pressures outside their specific range of operation shall be interlocked with pressure switches to avoid damage to the monitoring element. All gauges shall be monitored by the Control System.

### 10.6.1 Low Vacuum Gauges

A thermocouple gauge (Pirani or similar) shall be fitted to the low vacuum side of the system, the gauge shall be monitored through a meter. The meter scale shall be clearly graduated and show a range from atmosphere to zero.

### *10.6.2 High Vacuum Gauges*

The Contractor shall be required to provide two high vacuum gauges, these are defined in the following two sections.

#### 10.6.2.1 Cold-Cathode Gauge

A Cold-Cathode gauge (Penning or similar) shall be fitted to the high vacuum side of the system. Separate indicating meters shall be provided for the gauge. The meter scale shall show a range from $10^{-3}$ to $10^{-9}$ mbar.

#### 10.6.2.2 Hot-Cathode Gauge (Ionisation)

A gauge of this type shall be fitted to the high vacuum side of the system for accurate indication at the lower pressure values.

### 10.6.3 Partial Pressure

It is a requirement that the partial pressures of the residual gases in the vacuum vessel shall be analysed. Therefore a mass spectrometer unit shall be supplied as part of this contract. The control unit for the mass spectrometer shall be mounted in a control cabinet with its sensing head positioned at a suitable port in the Upper Vessel. A display screen shall be incorporated into the overall Control System.

### *10.6.4 Additional Gauges*

A simple direct reading gauge of low accuracy shall be fitted to the side of the vacuum vessel, to be used for monitoring of the vacuum in the vessel when the plant is not in use.

### 10.7 Pipes

All pipes connecting vacuum system components shall be dimensioned for the optimum transfer of gas. Bellows or similar couplings shall be provided where necessary to isolate sources of vibration and accommodate raising of the Upper Vessel. Any pipes containing liquid nitrogen or other cooling fluids shall be supported on fixings designed to minimise heat transfer to the pipes and prevent excessive icing and condensation.

### 10.8 Cooling System

A stand alone water Chiller unit shall be used for the cooling of the vacuum pumping system, the size and position of which shall be determined by the Contractor.

## 11 Magnetrons

### 11.1 General Information

The prime purpose of the Coating Plant is for the coating of the M1 and M2 VISTA mirrors. The method of coating the mirrors shall be by DC magnetron fitted with high purity targets of 5N's Aluminium, Silver and NiCr. The mirror to be coated shall lie in a horizontal position with the surface to be coated facing upward. The mirror shall be supported axially on a turntable within the lower section of the vacuum vessel. The magnetrons shall be supported on the upper section of the vessel and shall deposit in a downward direction. This part of the specification covers the provision of the three identical magnetron sources and six targets plus one Aluminium for testing. It also includes the supply of the gas admittance system, cooling system, the power supplies and controllers.

### 11.2 Magnetron Requirements

The Contractor shall include the supply of three DC planar magnetrons, suitable power supplies and all cables, coolant pipes and feed throughs. The gas dosing valve shall be of the automatic control type with automatic control of gas flow. The magnetrons shall each be fitted with a mask and shutter assembly to help control film purity, gas distribution and uniformity of film thickness. The assemblies shall be mounted inside the vacuum vessel and positioned above the mirror surface. It is well known that at each end of a magnetron there will be an area of film non-uniformity as shown schematically on **Figure 4.**

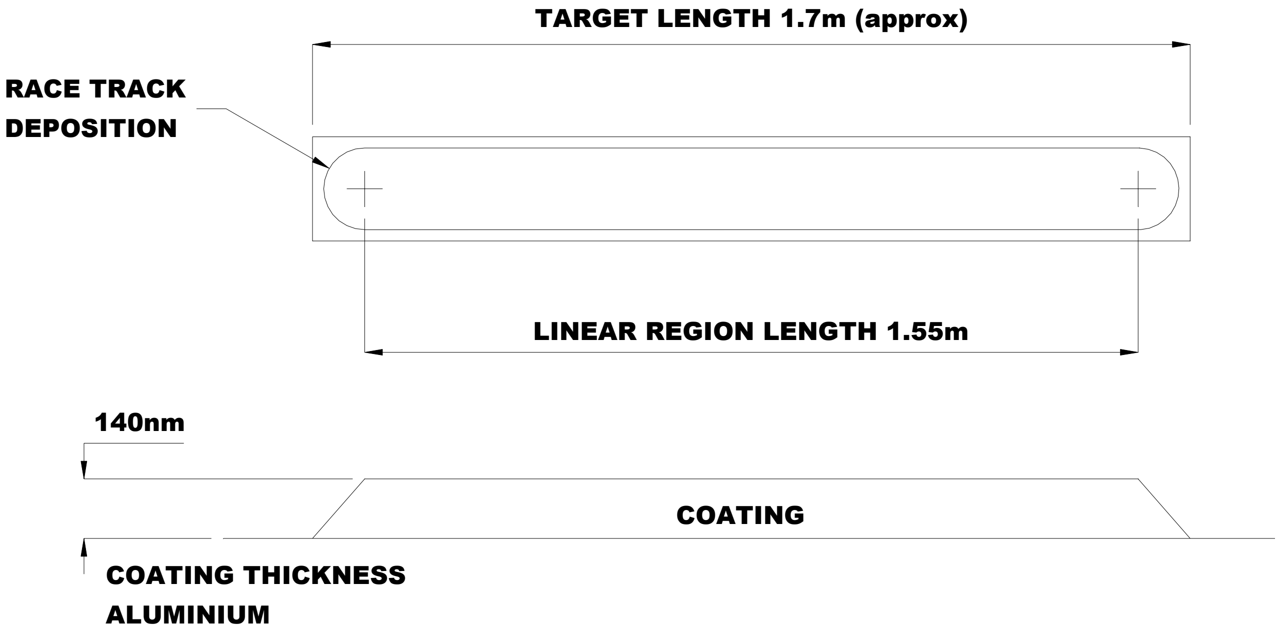


**Figure 4: Magnetron Coverage**

The uniformity requirement for a length as described by the linear region in **Figure 4** is 1.55m with a film uniformity of thickness nominally 140nm +/- 5%.

### 11.3 Magnetron Shielding

Each magnetron shall be shielded against unwanted plasma for the following conditions:

1. Shutter closed, <1% of target atom leaks to the vessel.
2. Shutter open, 99% of target atoms shall pass through the mask.

### 11.4 Magnetron Mask

Each magnetron shall be fitted with a static mask to ensure even coating thickness across the radius of the mirror. This mask shall be manually adjustable to optimise the coating process. The mask shall be designed to withstand the heat generated from the magnetron without risk to the operation of the magnetron or primary mirror. The use of liquid coolant is permissible.

### 11.5 Magnetron Shutter

Each magnetron shall be fitted with a shutter. The shutter shall be automatically controlled as defined in section 8.6. In the closed position the shutter shall completely shield the mirror from the target atoms. In the open position, the magnetron shall allow a free path for the target atoms, limited only by the mask. During operation, the shutter shall not reduce the gap between the mirror surface and the magnetron. The shutter shall be designed to withstand the heat generated from the magnetron without risk to the operation of the magnetron or primary mirror. The use of liquid coolant is permissible.

### 11.6 Targets

The targets supplied shall be:

- 3 of the High-purity Aluminium (5N's) type (1 for initial testing)
- 2 of the Silver (4N's) type
- 2 of the NiCr (4N's) type

The targets shall be supplied with a certification of material purity, they shall be of the indirect cooled type and shall be 1.7m (TBR) in length and sized to fit the magnetrons.

### 11.7 Deposition Rates

The magnetron design must be consistent with the requirement to produce a very high quality optical film of Aluminium with the highest possible reflectivity. A maximum deposition rate of at least 12000 Å/min from an indirectly cooled target shall be achievable and the power supply must be capable of achieving the power density necessary for this deposition rate on an Aluminium target (TBR). A deposition rate reproducibility of better than +/- 1% shall be attainable consistently.

### 11.8 Power Supply

Requirements for the magnetron power supply are as follows:

- The power supply shall be power or current stabilised on demand and shall be fully arc-suppressed at the sputtering source with appropriate safety devices conforming to the EEC standards of electrical safety.
- The power supply shall be able to control sequentially up to three separate magnetrons.
- The power supply shall be able to change the plate voltage on demand.
- The power supply shall be fully safety interlocked against water flow failure, cabinet door opening, chamber opening, vacuum failure and non-demanded wiffle tree rotation. It is the responsibility of the Contractor to recommend and supply appropriate safety interlock switches to the vessel.
- The power supply shall be fully controllable from the Control System as defined in section 8.
- The Control System shall display the current, voltage and arc count from the power supply.

### 11.9 Cooling System

A re-circulating closed cooling system shall be supplied for the magnetrons, the size and position of which shall be determined by the Contractor. The magnetron cooling fluid has special requirements of purity and conductivity therefore de-ionised water shall be used. The cooling system shall be drained during periods of plant shutdown, the Contractor shall provide for the drainage of trapped liquid.

## 12 Performance Tests

### 12.1 Tests of the Pumping System

The complete pumping system, water-cooling and Control System shall be assembled with the Cryopumps blanked off. The tests shall confirm that the design parameters quoted in this specification have been attained.

#### *12.1.1 Initial Performance Tests of the Vacuum Vessel*

The Contractor shall provide the necessary equipment to pump the vacuum vessel down to $2.7 \times 10^{-2}$ mbar, then carry out tests to determine the leak rate and the rate of pressure rise as defined in section 10.3.

### 12.2 Tests at the Contractors Works

The Contractor shall assemble the complete vacuum vessel, magnetrons and pumping system in order to test its performance. The layout of equipment and cabinets must mirror the site layout and all cables, pipes, etc. terminated to size.

The performance tests shall include (but not be limited to):

- Pump down of the clean, dry and empty vessel to the ultimate pressure in the specified design time. Should the vessel have been pumped down prior to this test the access door shall remain open for at least one hour before carrying out the performance test.
- Leak test to determine the leak rate achieved, using a mass spectrometer and helium as a search gas.
- Establish the time taken to let up the vessel to atmospheric pressure with the air admittance valve and filter.
- Test the Control System.
- Test the safety devices.
- Test the mechanical equipment of the vacuum vessel

## 12.3 Magnetron Tests

### *12.3.1 Testing Schedule*

It is highly desirable that all magnetron tests are performed in the vacuum vessel. It is realised that the magnetron schedule and vacuum vessel may not facilitate this therefore a subset of tests may be performed with a magnetron in a test vessel by agreement with the VPO, (section 12.3.3) and may be combined with a reduced full system test.

### *12.3.2 Preliminary Acceptance Magnetron Tests*

As a minimum the following tests must be completed before shipping the coating plant to Chile:

1. Optimisation of the coating parameters: gas flow, pumping rate and magnetron current (could be a stand-alone test).
2. Duration testing, simulating an equivalent duty cycle for coating the M1 (could be a stand-alone test).
3. Uniformity testing of both thickness and reflectivity, under simulated mirror coating conditions (Al).
4. Overlap region testing of both thickness and reflectivity, under simulated mirror coating conditions (Al).

### *12.3.3 Stand Alone Tests*

The following standalone tests shall be performed to allow a reduced full system test schedule:

1. Optimisation of the coating parameters: gas flow, pumping rate and magnetron current.
2. Duration testing, simulating an equivalent duty cycle for coating the M1.

#### *12.3.4 Provisional Acceptance Magnetron Tests*

The following tests must be repeated on site after installation:

1. Uniformity testing of both thickness and reflectivity, under simulated mirror coating conditions (Al).
2. Overlap region testing of both thickness and reflectivity, under simulated mirror coating conditions (Al).

# 13 Wash Facility Requirements

During the lifetime of the telescope the mirrors will require periodic re-coating, this therefore means that the mirrors will be removed from the telescope approximately every 18 months, washed, stripped, re-coated then returned to the telescope.

The Wash Facility shall consist of the following:

- Mirror wash stand.
- Trolley for the M1 Lifter.
- Storage tank for de-ionised water.
- Pump(s), hoses and equipment necessary for applying the cleaning fluids to the mirror.
- Provision for drainage of waste fluids to cast in channels in the Enclosure basement floor.

The Contractor shall develop procedures for removing from the mirror substrate the anticipated coatings specified in section 6.1.

## 13.1 Washing and Stripping

Refer to Appendix for a description of a typical mirror washing and stripping process.

The washing and stripping operations shall be carried out in the Enclosure basement, in the area defined in AD25. The mirror on the M1 Lifter shall be lowered into this area using the enclosure crane and positioned on to the mirror wash stand as defined in RD03, once the mirror is secured on the wash stand the M1 Lifter is removed using the M1 Lifter trolley. The mirror is then hand washed by ESO personnel wearing suitable protective clothing. De-ionised water will be required which shall be supplied from a storage tank, with gravity feed to the point of use. A sink and workbench shall be required for the mixing and preparation of the cleaning fluids. The cleaning fluids shall be drained to a waste storage tank, through cast channels in the floor, provided by the Enclosure and Buildings Work Package contractor, the location of the drain is to be agreed at PDR. A facility for collecting the waste fluids from the mirror surface and for channels to the drain shall be the responsibility of the Coating Plant Contractor, to be designed as part of the wash stand.

After the mirror washing and stripping has been completed, the M1 Lifter is returned to the wash stand on the trolley, the mirror is lifted and the wash stand removed. The Lower Vessel of the Coating Plant is then driven into position under the mirror, ready for the mirror to be installed

### 13.2 Mirror Wash Stand

A conceptual design for the wash stand is described in RD15. The mirror wash stand shall consist of three pedestals, which support the M1 such that the mirror surface is positioned at a suitable height for manual cleaning. At the top of each pedestal a large pad covered by a chemical resist elastomer shall be used to support the mirror, each pad shall be supported on a spherical bearing with limited tilt movement. The pads must be able to co-align to the rear surface of the mirror, however the tilt must be restricted so that the pads do not interfere with any of the M1 support pads on the rear surface of the mirror (see AD22). The mirror wash stand shall provide earthquake protection for the mirror. The structure may utilise the rails in the Enclosure floor or additional floor mounts may be used to bolt it to the concrete floor. Located in the upper part of each pedestal shall be a removable location bracket designed so that the M1 Lifter locates in only one orientation. When the mirror is in place, the location brackets can be removed and the M1 Lifter lowered onto the M1 Lifter trolley and removed from under the mirror. The pedestals must be capable of being removed manually with no personnel working below M1 when it is suspended on the crane. Accurate location on the wash stand is required, as the supports have to avoid the pads on the rear surface of the mirror.

#### *13.2.1 Materials*

The materials to be used shall be compatible with the chemicals used in the coating stripping process, typically HCI @15% and KOH @ 5% concentration. Stainless steel shall be the preferred material for the Wash Facility.

### 13.3 M1 Lifter Trolley

The M1 Lifter trolley is used to transport the MI Lifter from beneath the mirror after it has been detached from the mirror and lowered using the crane onto the trolley.
The M1 Lifter trolley shall be designed by the Coating Plant Contractor and supplied as part of this contract. The trolley shall be designed such that it can be easily manoeuvrable with the M1 Lifter in-situ, between the mirror wash stand support pedestals.

## 14 Requirements for Design and Construction

### 14.1 Vacuum Vessel

The vacuum vessel for the Coating Plant shall be designed, built, tested and certified according to AD43 or equivalent recognised standards, subject to approval by the VPO. All materials used shall be suitable for use in UHV and where required at high temperature.

## 14.2 Structural Analyses

All FE analyses necessary for the verification of the design and the performance of the Coating Plant and Wash Facility including support structures shall be performed with a numerical code agreed with the VPO. Mass and inertial effects of M1 must be included in all analyses.

### *14.2.1 General*

The structural model shall be sufficiently detailed to provide an accurate description of the quantities under study (stiffness, stresses, displacement, etc.).

The accuracy level required for the verification of compliance with this specification is:

- Accuracy of static analysis 5%

The following FE analyses shall be performed as a minimum:

- Gravity and pressure
- Thermal stress and thermal deflection for bulk temperature variation
- Stress analyses for load combinations defined in section 14.2.2

### *14.2.2 Load Combination for Stress Analyses*

As a minimum the load combination cases to be verified are:

**Operational loading**

a) Gravity + Pressure + Thermal (functional)

**Short-term accidental loading**

b) Gravity + Thermal (functional) + Emergency braking + Pressure

c) Gravity +Thermal (functional) + Earthquake (OBE) + Pressure

**Survival loading**

d) Gravity + Earthquake (MLE) + Pressure

### 14.2.3 Stress Verification Criteria and Limits

The stress criteria shall be verified, the corresponding allowable limits are given in **Table 3**

| Case | Criteria | Allowable stress |
|---|---|---|
| Operational loading | Mechanical stress in vessel | As per pressure vessel codes |
| | Mechanical stress in wiffle tree or pedestals | 0.2% Proof stress /4 (metallic parts) |

| | | |
|---|---|---|
| Short term accidental loading | Mechanical stress in Vessel | As per pressure vessel codes |
| | Mechanical stress in wiffle tree or pedestals | 0.2% Proof stress /1.5 (metallic parts) |
| Survival loading | Mechanical stress in vessel | As per pressure vessel codes |
| | Mechanical stress in wiffle tree or pedestals | 0.2% Proof stress/1.2 (metallic parts) |

**Table 3: Criteria and limits for stress analysis**

### *14.2.4 Acceptable Earthquake Hazards*

The acceptable hazards in the event of an earthquake under load case combinations (c) and (d) are defined in **Table 4**.

| Earthquake Type | Acceptable Hazard | Not Acceptable Hazard |
|---|---|---|
| OBE | None | Minor system damage<br>Major system damage<br>Damage to M1 or M2<br>System Unrecoverable<br>Severe injury or death |
| MLE | Minor system damage<br>Major system damage | System Unrecoverable<br>Damage to M1 or M2<br>Severe injury or death |

**Table 4: Acceptable Earthquake Hazards**

Definitions:

1. Minor System Damage: defined as any damage that can be repaired by site personnel without any support from industry and/or the system is up to three weeks out of operation.
2. Major system Damage: defined as a system that can be recovered but extensive industrial support is necessary and/or the system is out of operation for more than three weeks.
3. System Unrecoverable: defined as permanent damage affecting the performance of the system.
4. Severe Injury: defined as partial/permanent disability of human beings.

## 14.3 Material Parts and Processes

Metric units shall be used for all equipment, design calculations and documentation unless otherwise specified by the VPO. Where necessary the materials used shall be suitable for use in UHV and at temperatures consistent with magnetron operation.

### *14.3.1 Outgassing*

All components exposed to the high vacuum shall be manufactured from low outgassing materials compatible with pressures of less than $10^{-7}$ mbar.

### *14.3.2 Stress Relieving*

A stress relief treatment shall be performed to all critical mechanical components with the aim to reduce internal stresses and to increase long-term stability. This applies to the Lower Vessel Carriage, M1 Lifter trolley, wiffle tree, rotation system, drives and support pedestals. It need not apply to the main vacuum vessel.

### *14.3.3 Surface Treatment*

- Unpainted carbon steel surfaces shall be treated against corrosion.
- Stainless steel surfaces other than vacuum flanges shall be bead blasted.

### *14.3.4 Nameplate and Product Marking*

As a general rule the main component parts of the Coating Plant shall be identified with nameplates, visible after installation of the parts, with the following information:

- The part name
- The drawing number and revision
- The serial number
- The manufacturing date and manufacturer

The list of nameplates shall be agreed in advance with the VPO.

### *14.3.5 Workmanship*

Only components and techniques with proven reliability in service should be used in the design, manufacture and testing of the Coating Plant.

## 14.4 Electromagnetic Compatibility

### *14.4.1 Intra-system Electromagnetic Compatibility*

The Coating Plant shall exhibit complete electromagnetic compatibility among the parts, components, devices, apparatus and equipment of which it is composed (intra-system electromagnetic compatibility).

No malfunction, degradation of performance or deviation from specified parameters is admitted because of lack of intra-system electromagnetic compatibility.

### *14.4.2 Inter-system Electromagnetic Compatibility*

Minimisation of the electromagnetic interference between the Coating Plant Work Package and its environment shall be considered in the design and manufacture. In order to achieve inter-system electromagnetic compatibility, the Coating Plant Work Package shall comply with the EMC requirements set by the applicable documents AD16 and AD17.

The following sections 14.4.3 to 14.4.5 are highlighted as a reminder of the requirements and not as a waiver to the EMC requirements of AD16 and AD17.

#### *14.4.3 Electromagnetic Environment*

The Coating Plant Work Package will be installed, operated and located within the electromagnetic environment specified by AD16 and therefore, shall comply with the requirements imposed by AD16. For the purpose of this Specification, the requirements applicable to the Telescope Area of the VLT Observatory are to be intended as fully applicable to the Coating Plant. As a minimum this entails the following requirements (the following list is simply to be intended as a reminder of such requirements and not a waiver To AD16).

Earthing and equipotential bonding shall comply with requirements.

The electrical power interface shall be protected against overvoltages.

The VLT power system is expected to provide electric power with the quality specified by Chapter 4. “PERFORMANCE REQUIREMENTS” of AD16.

#### *14.4.4 Emission*

Note. In the present subsection and in the following one 14.4.5, the term “port” is used according to the definition given by the European Standards CENELEC EN 50 081-1:1992 and EN 50 082-1:1992, viz.,
“port”: particular interface of the specified apparatus with the external electromagnetic environment.
The Coating Plant Work Package shall comply with the emission limits specified by AD17. As a minimum this entails the following requirements (the following list is simply to be intended as a reminder of such requirements and not a waiver to AD17).
Radiated emission ref. subsection 4.1.2 and 4.1.3.
Conducted emission (disturbance voltages) ref. subsection 4.1.2 & 4.1.3.
Conducted emission (harmonic currents) ref. subsection 4.1.5.
Conducted emission (voltage fluctuations) ref. subsection 4.1.5.

#### *14.4.5 Immunity*

The Coating Plant Work Package shall comply with the applicable immunity limits specified by AD17. As a minimum this entails the following requirements (the following list is simply to be intended as a reminder of such requirements and not a waiver to AD17).

- Input (and output, if any) AC power ports ref. section 4.2.
- Control, signal ports ref. section 4.2.
- Enclosure port ref. section 4.2.
- Input and output DC power ports (if any) ref. Section 4.2.

### 14.5 Requirements for Technical Documentation

The technical documentation relating to VISTA shall meet the following general requirements:

- Documentation relating to the manufacturing of the plant and of any other deliverable item within the scope of supply governed by this technical specification shall be delivered.
- Documentation relating to manufacturing equipment and manufacturing processes is not part of the supply.
- All documentation shall be written in English.
- The units used shall be as per those used within this specification or otherwise agreed by the VPO.
- Operation manuals and instructions, where applicable shall be delivered.
- A logbook of the operations performed by the Contractor during the manufacturing and testing of the plant shall be kept by the Contractor for the purpose of traceability of possible problems. An extract of the logbook, agreed with the VPO, shall be delivered.
- Finite Element models and analyses shall be delivered on an electronic media. The format of the media shall be agreed with the VPO.
- Drawings, constituting part of the delivery shall be delivered on paper and on an electronic media. The format of the media shall be agreed with the VPO.
- Layouts for electronic circuits shall be delivered on an electronic media.

# 15 Safety Requirements

The requirements with respect to safety for the VISTA project are contained in AD15.

## 15.1 Hazard Risk Acceptance Criteria

The Contractor shall perform a hazard analysis in accordance with that required in AD15.

## 15.2 General Safety

The principles of safety design of technical products defined in AD34 shall be applied.

All mechanical design shall meet the requirements as defined in section 14.2.2. Furthermore the Contractor shall during all manufacturing phases and during testing, assume all precautions necessary to guarantee the safety of the deliverable items of this technical specification.

## 15.3 Mechanical Safety

A minimum safety margin consistent with Table 3 or 1.5 with respect to sigma 0.2% (which-ever margin is higher) shall be used in the design of all those mechanical components, which in case of failure lead to an unacceptable or undesirable hazard risk.

## 15.4 Handling, Transport and Storage Safety

The design of the Coating Plant Work Package shall incorporate all means necessary to preclude or minimise hazards to personnel and equipment during assembly, disassembly, test, transport, transport on site and during storage.

Transport, lifting, hoisting and similar equipment shall be approved by an officially recognised independent verification agency.

### 15.5 Cooling System Safety

The Cooling systems shall be designed in accordance with AD34.

### 15.6 Pneumatic Safety

Any compressed air piping, including connections of compressed air systems shall be designed in accordance with AD34.

### 15.7 Software Safety

Any computer software failure or failures shall not lead to an unacceptable or undesirable hazard risk. Information technology equipment shall be compliant with AD38.

### 15.8 Electrical Safety

In order to achieve protection against electric shocks and other hazards, the Contractor shall comply with AD35 and AD36 in the design, supply and erection of the Coating Plant Work Package.

### 15.9 Operational Safety

None of the following cases shall lead to an unacceptable or undesirable hazard risk

- Independent operator error
- One operator error plus one hardware failure
- One or two independent hardware failures
- One or two independent software failures
- Power failure
- Emergency braking
- OBE or MLE earthquakes

## 16 Installation

Installation of the Coating Plant into the Auxiliary Building shall be through a removable section in the rear wall of the building.

Two possible solutions for the installation are:

1. The vessel may be set on a system of roller/skates and pulled into position.
2. The Upper and Lower Vessel may be assembled outside the Auxiliary Building, on an extension to the rails (TBR), allowing the vessel to be moved into position. The Lower Vessel Carriage shall be designed to be able to carry out this operation if required.

### 16.1 Overhead Gantry Crane

An overhead gantry crane with a SWL of 1.5 tonne will be available in the Auxiliary Building this can be used by the Contractor for the installation of the Coating Plant Work Package.

# 17 Product Assurance Requirements

## 17.1 General Considerations

At the time of Provisional Acceptance the following shall occur:

- Inspection of the Test Set-up for verification of the vacuum system.
- Checking of the correctness and completeness against the technical documentation.
- Testing, inspection, and/or checking of any other deliverable as applicable, according to the procedures delivered by the Contractor and agreed by the VPO.

### 17.2 Lifetime and Reliability

The Coating Plant including interface connections shall be designed and manufactured for a minimum lifetime of 25 years.

#### *17.2.1 Duty Cycle*

A duty cycle shall be defined as one complete mirror coating process.

| | |
|---|---|
| Years 0 – 2 | 30 cycles |
| Years 2-25 | 5 cycles per year |

## 18 Performance Verification Matrix

In addition to the inspections performed according to the Quality Assurance requirements applying to the execution of the contract for the *Design and Manufacturing of the Coating Plant),* the verification of the compliance of the delivered items with the requirements of this specification shall be done according to a verification matrix listing all the relevant requirements and the methods used to perform the verification.

The possible methods of verification are[1]:

| | |
|---|---|
| Verification by design check | The performance shall be reviewed at the level of the design by means of the documentation that will be submitted by the Contractor to the VPO during the design phase. |
| Verification by analysis | The fulfilment of the specified performance shall be demonstrated by appropriate analysis (example Finite Element Analysis). The analysis will be submitted to the VPO for review and check. |
| Verification by inspection | The compliance of the item with the performance requirement is checked by manufacturing data and end inspection. |
| Verification by test | The compliance of the item with the performance requirement is checked on a test specimen, or by direct testing |

The verification methods to be used for Acceptance Testing are summarised in **Table 5**. All verification activities shall be properly planned, performed, and documented. In all instances verification by test shall be made, unless agreed by the VPO.

[1] Use of any design or analysis data supplied by the VPO does not relieve the Contractor from the fulfilment of the requirements of the present Technical Specification.

| Performance Requirement | Reference | Verification Method | | | |
|---|---|---|---|---|---|
| | | Design | Analysis | Inspection | Test |
| ***Interfaces*** | | | | | |
| Interface with M1 | AD01 | x | | x | |
| Interface with M2 | AD02 | x | | x | |
| Interface with buildings | AD03 | x | | | x |
| Interface with handling equipment | 4.2.4 | x | | x | |
| ***Environmental Requirements*** | AD12 | | | | |
| General | 5.1.1 | x | | | |
| Temperature | 5.1.2 | x | x | | |
| Altitude | 5.1.3 | x | | | |
| Earthquakes | 5.1.4 | x | x | | |
| ***Operational Requirements*** | | | | | |
| Pressure | 5.2.1 | x | x | | x |
| Accidental loads | 5.2.2 | | x | | |
| Emergency braking | 5.2.3 | | x | | x |
| ***Mirror Coating*** | | | | | |
| General | 6.1 | x | | | x |
| Optical | 6.2 | | | x | x |
| Infrared | 6.3 | | | x | x |
| Adhesion layers and overcoats | 6.4 | | | x | x |
| Measurements | 6.5 | | | x | x |
| ***Performance*** | | | | | |
| Coating process | 7.3 | x | | | x |
| Diagnostic testing | 7.4 | x | | | x |
| Interlocks | 7.5 | x | x | | x |
| Motion alarms | 7.6 | x | | | x |
| Emergency stop | 7.7 | x | | | x |
| Power loss | 7.8 | x | x | | x |
| ***Control*** | | | | | |
| Control system | 8.1 | x | x | | x |
| Speed control | 8.4.1 | x | | | x |
| Position control | 8.5.1 | x | | | x |
| Magnetron control | 8.6 | x | | | x |
| Positioning | 8.6.1 | x | | | x |
| Vessel Jacking & Lower Vessel Carriage Drive | 8.7 | x | x | x | x |
| Cooling | 8.8 | x | x | | x |
| Electronics | 8.10 | x | | | |
| ***Major Components*** | | | | | |
| Lower Vessel | 9.3 | x | | x | |
| Lower Vessel Carriage | 9.3.1 | x | | | x |
| Rotation system | 9.3.4 | x | | | |
| Earthquake protection | 9.3.5 | x | x | | |
| Wiffle tree | 9.3.9 | x | | x | |
| Upper vessel | 9.4 | x | | x | |
| Lifting system | 9.4.1 | x | | | x |
| Mirror wash facility | 13.2 | x | | x | |
| M1 lifter trolley | 13.3.1 | x | | x | |
| ***Vacuum pumping system*** | | | | | |
| Pressure & pumping times | 10.2 | | x | | x |

| | | | | | |
|---|---|---|---|---|---|
| Leak rate | 10.3 | | x | | x |
| Vacuum pumps | 10.4 | | x | x | x |
| Valves | 10.5 | | | x | x |
| Gauges | 10.6 | | | x | x |
| Cooling system | 10.8 | x | x | | |
| ***Magnetrons*** | | | | | |
| General | 11.1 | x | x | | |
| Requirements | 11.2 | x | | | x |
| Deposition rates | 11.7 | x | x | | x |
| Power supply | 11.8 | x | x | | x |
| Cooling system | 11.9 | x | x | | x |
| ***Performance tests*** | | | | | |
| Pumping system | 12.1 | | | | x |
| Vacuum vessel | 12.1.1 | | | | x |
| Tests at Contractors works | 12.2 | | | | x |
| Magnetron tests | 12.3 | | | | x |
| ***Design & Construction*** | | | | | |
| Structural analyses | 14.1.1 | x | x | | |
| Load combination for stress analyses | 14.1.2 | x | x | | |
| Stress verification criteria and limits | 14.1.3 | x | x | | |
| Acceptable earthquake hazards | 14.1.4 | x | x | | |
| ***Material Parts & Processes*** | | | | | |
| Outgassing | 14.2.1 | | x | | x |
| Stress relieving | 14.2.2 | x | | | |
| Surface treatment | 14.2.2 | x | | x | |
| Nameplate & product marking | 14.2.3 | x | | x | |
| Technical documentation requirements | 14.4 | | | x | |
| ***Electromagnetic Compatibility*** | 14.3 | | | | |
| Intra-system EMC | 14.3.1 | x | x | | |
| Inter-system EMC | 14.3.2 | x | x | | |
| EMC environment | 14.3.3 | x | x | | |
| Emission | 14.3.4 | x | x | | |
| Immunity | 14.3.5 | x | x | | |
| ***Safety*** | | | | | |
| Hazard risk acceptance criteria | AD15 | x | | | |
| General | 15.2 | x | | | |
| Mechanical | 15.3 | x | x | | |
| Handling transport & storage | 15.4 | x | | | |
| Cooling system | 15.5 | x | | | |
| Pneumatic | 15.6 | x | | | |
| Software | 15.7 | | | x | |
| Electrical | 15.8 | x | | | |
| Operational | 15.9 | x | | | x |
| ***Product Assurance Requirements*** | | | | | |
| General | 17.1 | | | x | |
| Lifetime & reliability | 17.2 | x | x | | |
| Duty cycle | 17.2.1 | | x | | |

**Table 5: Performance Verification Matrix**

# 19 Summary of Items TBC, TBD and TBR

The following items are designated either TBC, TBD or TBR

| Item | Section | Designation |
|---|---|---|
| Peak power demand | 4.2.3 | TBR |
| Deposition of oxides, nitrides and fluorides | 6.1 | TBR |
| Thickness of protected silver layer | 6.3 | TBR |
| Adhesion layers and overcoats | 6.4 | TBR |
| Emissivity increase of protected Silver coating | Table 2 | TBR |
| Length of magnetron | 11.6 | TBR |
| Power density for deposition rates | 11.7 | TBR |
| Provision of extension to rails for Installation | 16 | TBR |
| Availability on site of Helium leak detector | 10.3.1 | TBC |

# Appendix

The following appendix, included for information, is an abbreviated description of the procedure for washing and stripping the Aluminium coating from the WHT primary mirror.

1. The first stage in washing the mirror is to rid the mirror surface of any particles of solid matter, which may be present. To avoid scratching the mirror surface this is done by hosing down the surface with water, to remove any contamination introduced by the hosing down the mirror is then thoroughly rinsed with de-ionised water.

2. The next step is to strip the old coating from the mirror. This requires that a solution of Caustic Soda (NaOH) made by adding 10-15% by volume of NaOH pellets to de-ionised water until fully dissolved, be applied to the mirror surface, this is done using pure cotton wool or soft paper soaked in the solution. The surface is gently swabbed continuously until there is no trace of the coating left on the mirror surface, when all the coating has been removed the surface is hosed again and rinsed with de-ionised water.

3. It occasionally happens that an Aluminium coat is slow to disappear using the alkali solution, in which case an acid solution of Hydrochloric acid (HCl), de-ionised water and Copper Sulphate ($CuO_4S$) is used.

4. The next step is to dry the mirror, this is done by progressively replacing the water on the mirror surface with IS0-propyl alcohol and spreading the alcohol around until it evaporates, wiping the surface gently with pads of high quality absorbent paper.

5. Final cleaning continues using a linen cloth with a small amount of Balzers® substrate cleaner No.2 on it.

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