Figure 3: *The first series of azimuth axial pads ready to undergo final machining at the factory of Riva Hydroart in Milan.*

Figure 4: *The telescope foundations in the test hall of Ansaldo in Milan.*

At the end of this programme the results have reasonably proved that the system as designed can fulfil the requirements, and especially has shown a fairly large flexibility in mounting tolerances, which is very much appreciated in the case of fitting on large diameters such as for the VLT.

Foundations in Milan

Since November last year in Ansaldo premises in Milan, AES has been preparing the test facilities for the main structure.

The foundations have been dug out and the concrete walls which simulate the concrete pier on which the telescope will be mounted on Paranal has been built (Fig. 4).

The next operation will be to place the interfaces with the azimuth tracks and to align them within 0.5 mm planarity. This will be a very interesting task which ESO will follow carefully because of the information which can be gained for the same operation to be performed on Paranal.

Next Steps

The redesign needed to meet the dynamic specification has caused a delay in the activities planned to deliver the first telescope on Paranal in April 1996.

AES has prepared a series of recovery actions which will allow the delivery of the first telescope in July 1996.

The first telescope will be ready for ESO testing in Milan starting from August 1995.

Before getting to the final act of declaring the telescope fully compliant with the requirements, we are sure we will encounter many problems which we will have to solve.

Nevertheless, the results of the final design assure us that all the provisions are there to provide the astronomical community with an instrument at the limit of the technology which is allowable today, and which has the potential to provide performance as required.

A New Approach for the In-Situ Cleaning of VLT Mirrors: The Peel-Off Technique

P. GIORDANO, ESO

1. Introduction

This paper describes the second approach[1] selected by the VLT Telescope Group for the *in-situ* cleaning of VLT mirrors.

The use of a strippable adhesive coating to remove dust and other organic contamination is a somewhat unconventional cleaning procedure but has proved to be effective in removing even small particles and providing a perfectly clean surface.

To apply the material onto the optical surface, it is preferable to use a soft brush or a non-contact technique. After a drying phase, the duration of which depends on the ambient conditions, the cured film is removed from the surface by attaching adhesive tape to the edge of the film. During the removal phase, known as the "peel-off process", all the contaminants, including sub-micron particles trapped by the material, are removed from the optical surface.

Various market products mainly dedicated to the cleaning of small optical components were tested and discussed by J. Bennett [1]. Their scaling-up to large optical mirrors was only possible at great cost and without any guarantee for the film removal on large areas.

For the reasons mentioned above, the VLT Telescope Group decided to carry out its own research programme.

2. Requirements

The selection of a suitable cleaning product was based on the following criteria.

Cleaning efficiency: This parameter could be expressed as the possibility to

[1] The first approach is the CO_2 snow-flake technique currently in use at La Silla. See next article.

restore reflectivity and micro-roughness of the mirror by approaching the values of a freshly coated Aluminium (Al) mirror by at least 95 %.

Removal capability: For large optical surfaces, the dried film shall be removed in one piece, with no risk of breakage. The peel-off of a 2-m diameter mirror is the first challenge. The final goal would be to treat a mirror as large as the 8.2-m VLT M1 mirror.

Applicability: The fragility of the Al coating, as well as the mirror glass substrate, compels us to concentrate our attention on the application of the cleaning product by non-contact techniques.

Safety aspects: This last requirement concerns the purity of the product and also the absence of chemical solvents. Additional contamination by organic components of the optical surface shall not be tolerated. The application on large surfaces shall be made with a maximum of safety for the personnel and the environment.

3. Selected Product

The first run of investigations started with the German chemical company Bayer AG in Leverkusen and has proved useful. Mr. Zöllner rapidly understood the ESO cleaning requirements, and a good professional interaction was established. After three or four working runs the ideal product corresponding to ESO's criteria of cleaning efficiency, removability and safety, was established.

The second part of the investigation was carried out with the collaboration of two other companies. The IRSA company, a producer of high-tech varnishes, modified the selected Bayer product in such a way that it could be used with the mirror in vertical position, without any deterioration of the good cleaning properties of the product. The firm Jahnke GmbH, a representative of the company Wagner, advised us in the selection of the spray-gun unit, the "Fine Coat", which is particularly suitable for application of thixotropic material.

4. Experiments

Intensive tests were conducted in the optical laboratory in Garching using the various IRSA formulations and achieving a uniform spraying on optical surfaces. Proof of the suitability of the product was obtained at La Silla Observatory during the technical time allocated for the installation of the CO_2 cleaning device on the NTT (28 September – 10 October 1993).

4.1 Cleaning efficiency evaluation

Dust contamination of the optical surfaces is currently evaluated at ESO-Garching by using the µScan scatterometer [2]. It is a portable instrument, purchased from T.M.A. Technology (USA), designed to measure the quantity of light scattered by surface irregularities (Bi-directional Reflectance Distribution Function or B.R.D.F.) regardless of whether they are surface micro-defects or dust contamination. Another parameter provided by this instrument is the surface reflectivity at the wavelength of 670 nm. From the scattered light measurements an equivalent micro-roughness value of the optical surface (RMS) has been computed.

The regular use of the µScan, both in the laboratory and *in-situ* on telescopes, confirms the high sensitivity of this equipment and its suitability for the evaluation of dust contamination on optical surfaces and in the selection of cleaning products and techniques.

4.2 Removal test: (see photo)

Several removal tests have been performed on the "1.6-m test plate" stored in the metalization plant of the 1.52-m telescope building. The experiment has been carried out in better conditions than in Garching, mainly due to the extremely low air humidity, typically 15 %. Several layers of product were applied to the vertical surface, without any running of the material. An optimally dried film with a thickness of about 100 micrometres allowed us to savely remove the film, that is without breakage. Difficulties still remain with regard to starting the removal process, but when the first centimetres at the edge are free, the film removal can be performed with two hands.

4.3 Cleaning the "Chilimap"

The 40-cm telescope (Chilimap) stored in the previous metalization plant had been out of service for at least 15 years and its main mirror was never recoated. The *in-situ* cleaning was carried out successfully. No measurements of reflectivity or micro-roughness were performed before cleaning, but values

TABLE 1.

	BRDF[1] [0,0][2]	BRDF [50,180]	Reflectivity %	RMS Å
1st cleaning	9.224E-04	1.465E-04	86.8	27
2nd cleaning	5.908E-04	1.008E-04	87.0	21.4
NTT M3 mirror (freshly coated)	8.909E-04	1.274E-04	89.6	29.1

[1] Bi-directional Reflectance Distribution Function measured as scattered power normalized by the incident power and the cosine of the polar angle.
[2] [0,0] and [50,180] are the locations of the two scatter detectors.

obtained after two consecutive cleaning processes are excellent and may be compared with the values of a freshly coated mirror (see Table 1).

4.4 Comparative study

A comparative cleaning study has been conducted taking as reference the product Opti-Clean, the stripping material giving the best cleaning results [1] and which has been regularly used at ESO for the cleaning of small Al coated mirrors. The advantages of the "XL Clean 5" coating are shown in Table 2.

TABLE 2.

	Opti-Clean	XLClean 5
Organic solvent	90 %	none
Solid resin	10 %	approx.37 %
Cost	high	low

A flat mirror (diameter = 158 mm) with a protected reflective layer was exposed for 5 years to the dust contamination of our laboratory. Half of the mirror has been cleaned using the Opti-Clean and the other half with the product selected by ESO, known as XL Clean 5. The results are shown in Table 3.

TABLE 3.

	BRDF (0,0)	BRDF (50,180)	Reflectivity %	RMS Å
Dusty mirror (full surface)	1.555E-02	1.429E-02	78.6	93.5
XL Clean 5 process (1/2 part)	3.327E-04	5.840E-05	87.3	15.6
Opti-Clean process (1/2 part)	5.641E-04	8.335E-05	87.6	29.1
XL Clean 5 on complete surface	2.720E-04	3.920E-05	87.3	15.4

5. Technical Data

Name: XL Clean 5

Based on a polyurethane emulsion produced by Bayer AG. Easy application with a spray-gun. Multilayer application recommended to obtain a final dried film of 100 micrometres. Drying time about 2.5 hr largely depending on the relative humidity of the air. No special safety regulations to be applied during the application of the product. Possibility of removing any product remains during washing of the mirror surface before the coating operation. Consumption: 500 g/m^2

6. Conclusion

The product selected by ESO fulfils our requirements for the *in-situ* cleaning of large mirrors and has been successfully tested for mirrors up to diameter 1.6 m.

A normal precaution before using such a new product in the cleaning of astronomical mirrors is to perform a first test on a small area of the mirror or better still on a sample plate. This precautionary measure is recommended to evaluate the adhesion quality of the Aluminium coating over the glass surface.

Another advantage of this peel-off product is that it provides protection during packing and trans-oceanic transportation of expensive and delicate optical pieces. A long-term ageing test of the XL Clean 5 product has been initiated at ESO.

References

[1] Jean M. Bennett, Lars Mattson, Michael P. Keane, and Leif Karlsson. "Test of strip coating materials for protecting optics." *Applied Optics*, Vol. **28**, No. 5, 1 March 1989, page 1018.

[2] T.M.A. Technologies, Inc. P.O. Box 3118 BOZEMAN, MT 59715.

In-Situ Cleaning of the NTT Main Mirror by CO_2 Snow-Flake Sweeping

P. GIORDANO, ESO-Garching, and A. TORREJON, ESO-La Silla

1. Introduction

Since the beginning of 1992 most telescope mirrors on La Silla have been cleaned regularly using the CO_2 snow-flake technique. Although this manual operation could be considered an easy one for some telescopes on La Silla, it has sometimes required mountaineering skills on the part of the operator. In fact, this preventive cleaning operation has become a very delicate and risky undertaking.

The CO_2 cleaning method, preselected for the optical maintenance of VLT mirrors, should be an improvement on the conventional manual methods and should be tried out on existing telescopes before its implementation on the VLT.

A telescope such as the NTT working in a well-ventilated dome is more exposed to dust contamination than an older telescope. A prototype CO_2 snow-flake cleaning project was therefore proposed at the beginning of 1991 for the NTT. This selection was also guided by the idea to finalize the original concept of the NTT. It should be remembered that a cleaning system, based on a wet process, was foreseen earlier and that part of it was already included in the M1 cell design, but never completed.

Experience gained during the installation phase of the NTT on La Silla was of paramount importance for the development of the ESO concept of CO_2 cleaning.

2. Realization

A contract was awarded at the end of September 1992 to the company ICMP for the final design, manufacturing, assembly, testing and transportation to Chile of the cleaning device.

ICMP is a small engineering/mechanical company located in France close to Grenoble. The engineering staff of this company were involved, directly or indirectly, in the construction of various mechanical sub-systems early on in the