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 snowflake 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 snowflake 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

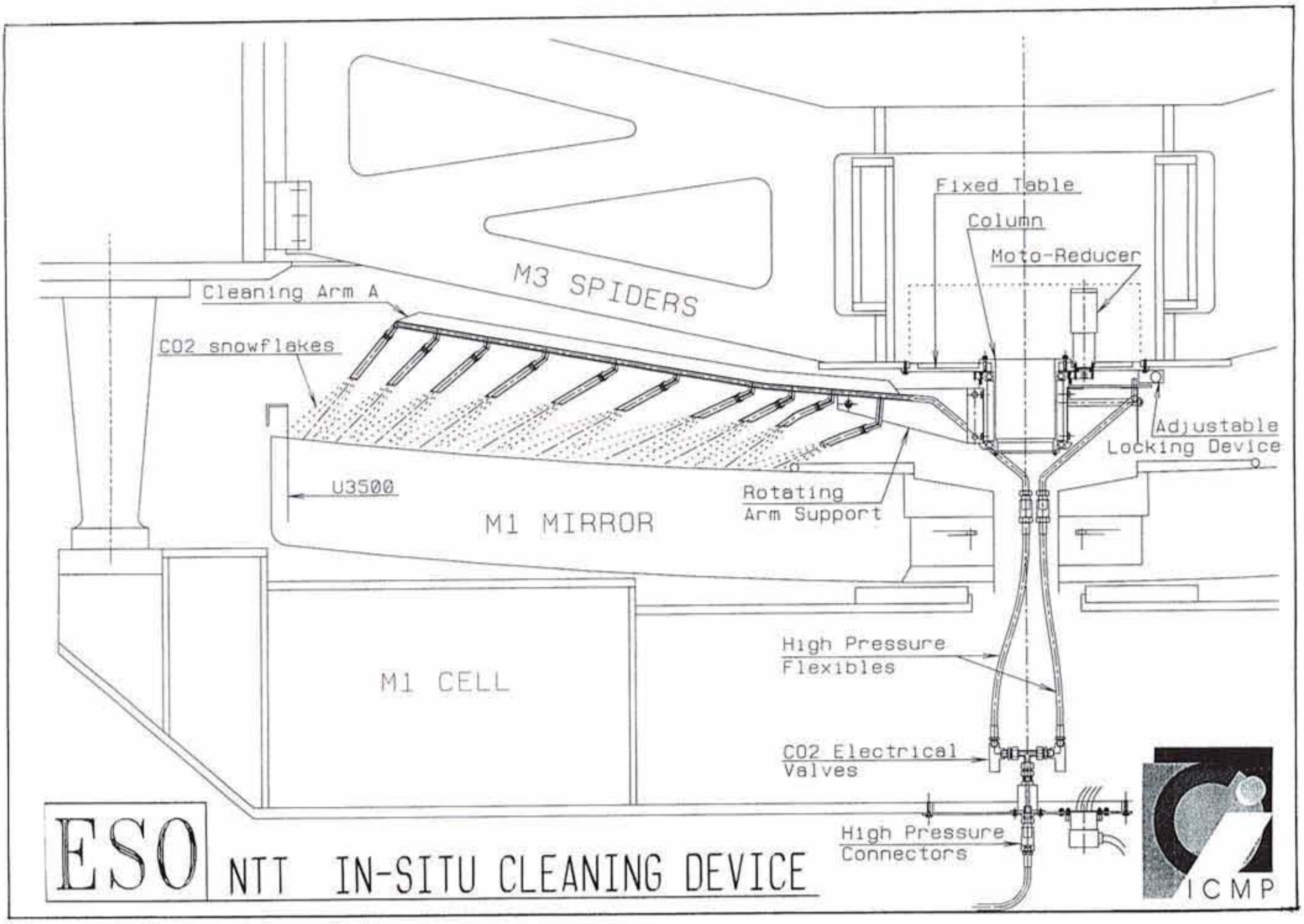

Figure 1.

3.6-m telescope project and more recently in the NTT. The NTT M1 mirror handling tool and altitude axis lock-pin were constructed by them.

After tests on an internal prototype, the company solved a great many problems connected with the critical use of cryogenic products. The main goal was to obtain a final pre-adjusted product, easy and safe to operate. Figure 1 illustrates the final concept.

3. Description of the CO_2 Cleaning Device

Two arms with a series of 10 injectors are connected to a turntable fixed under the M3 unit of the telescope. In the rest position they are totally in the shadow of the M3 spiders.

For the cleaning operation, during day time, the telescope is inclined to at least 70 degrees. Connection is made to two electrical and one CO_2 pipe connectors. The electrical control cabinet and the CO_2 cylinders are permanently installed in the dome. The operator, facing the M1 mirror and using a portable handset, can start and control the cleaning operation. The cleaning device is removed from its parking position. The arm rotation and the ejection of liquid CO_2 are accomplished simultaneously for the left side of the mirror which receives a high quantity of CO_2 snowflakes. (See Figure 2.)

On reaching the lowest point of the M1 the liquid CO_2 distribution is stopped and transferred to the right-hand arm which is now at the top position of the M1.

The rotation motion is maintained until the lower point of the M1 is cleaned again. The pipes are now purged with CO_2 gas and the CO_2 cleaning device is

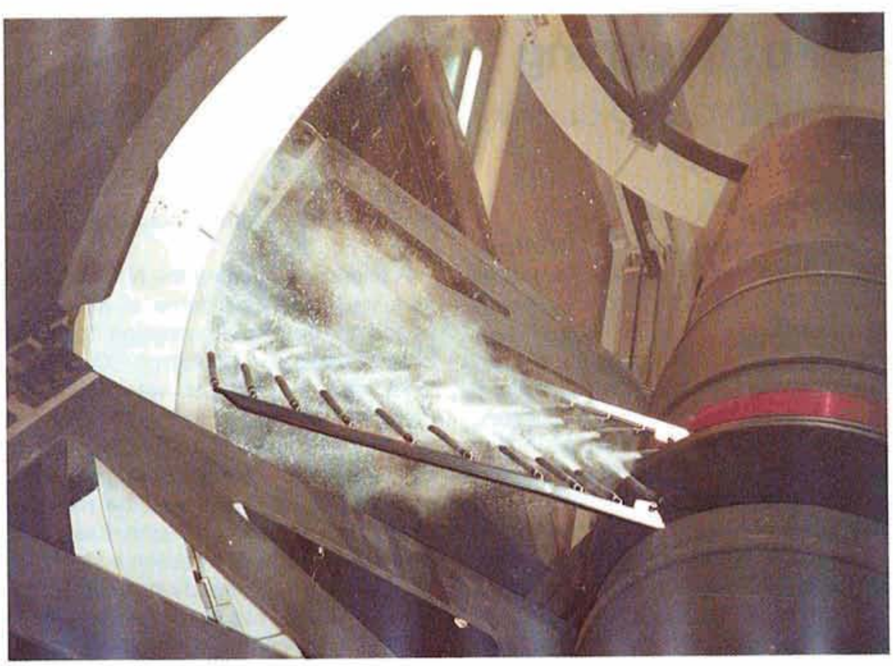

Figure 2.

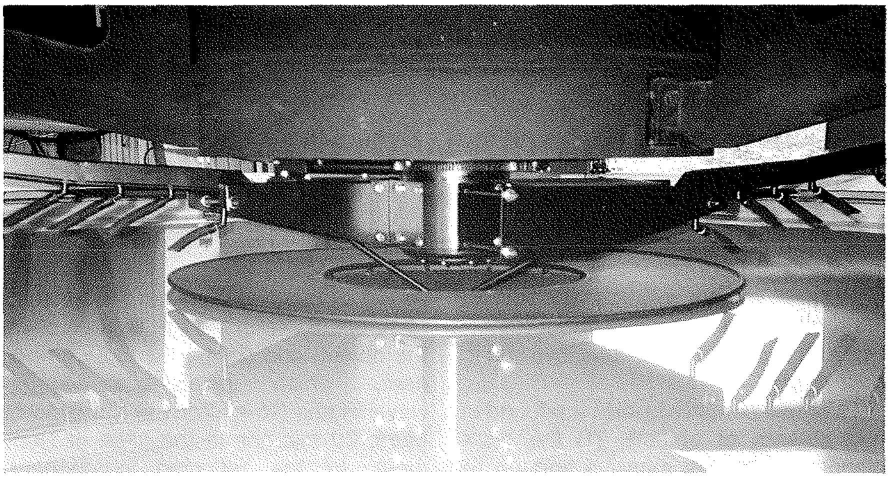

Figure 3: *View of the turn-table*

then parked under the M3 spiders. The cleaning process duration (the only adjustable parameter) was optimized to twice 45 seconds!

4. First Installation and Tests

A period of five days was reserved at the NTT at the end of September 1993, for the installation, testing and staff training for the CO_2 snow-flake cleaning device. It has been installed in the free space between the main mirror and the M3 Unit.

The supply pipes (liquid and gas CO_2, electricity) pass through the central hole of the main mirror and its cell. A plate at the back of the M1 cell will receive the various connectors. Flexible pipes will ensure interfacing between this plate and the CO_2 cylinders resting on the telescope floor.

After adjustment of the two arms in the shadow of the M3 spiders, several tests were performed to check:
- the rotation of the arms
- the parking position (stability, reproducibility, efficiency)
- the transfer of CO_2 liquid and gas
- the safety functions (electro-valves, emergency button, etc.) and the cleaning of the pipes using clean CO_2 products.

Three cleaning processes were performed to evaluate the efficiency of the system and to train staff from the Optical Group on La Silla.

5. Results and Comments

Measurements of mirror reflectivity at 670 nm as well as part of the light scattered by dust contamination were carried out, using the portable Uscan scatterometer.

The cleaning evaluation was performed on quite a dusty mirror, coated one year before, but cleaned regularly manually with the same CO_2 snow-flake technique except during the last two months previous to this installation.

After three successive cleaning operations, several circular zones appeared on the mirror surface corresponding to the direct impact of the CO_2 jets.

Measurements at an ambient temperature of 10 degrees with the Uscan scatterometer are listed in Table 1.

The limitations of this technique are well known and are illustrated by the present test. Extremely fine particles settling for a long time on the optical surface and suffering humidity variations and/or electrostatic charge need extremely high forces for their removal. However, it is important to remember that this cleaning technique was proposed and investigated with the objective of regularly removing dust contamination deposited over a *clean* mirror.

We will know more about the efficiency of this technique after the re-coating of M1 (next year) and the regular weekly cleaning of its surface, with monitoring of reflectivity and light scattering.

6. Conclusion

The CO_2 cleaning prototype installed on the NTT seems user-friendly and easy to operate, important parameters to justify weekly utilization. With this cleaning periodicity, which has already been adopted, only a limited additional contamination is expected.

TABLE 1.

	BRDF[1] (0,0)	BRDF[1] (50,180)	REFLECT. %	ABS[2] R %	RMS Angst.
Dusty mirror	1.325E-02	6.474E-03	79.1	82.7	86.9
After 1st cleaning	1.100E-02	4.004E-03	80.6	84.2	80.3
After 2nd cleaning	1.051E-02	3.581E-03	80.8	84.4	79.0

[1] Bidirectional Reflectance Distribution Function.
[2] Absolute reflectivity measurements computed with reference to a dielectric mirror.