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Smithsonian Institution &
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MMT Primary Mirror Wash Results of May 11, 2004

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Abstract

Results of the most recent primary mirror wash are given. A high-pressure spray proves considerably more effective at removing contamination than the low-pressure spray previously used, with no apparent increased risk to the aluminum film. It has no effect on the poorly understood, high-scatter residual layer that still requires burnishing to minimize scatter. An attempt to modify this layer with high-pressure isopropanol has no effect. Final reflectance is within 1.5% of pristine and as a result, mirror recoating will be deferred. Recommendations for CO_2 and washing schedules are given.

Introduction

On May 11, 2004, the MMT 6.5m primary mirror was cleaned with a pressure washer using detergent solution, to determine whether it met the MMTO Council's reflectance (***R***) criterion, ***R*** to be within 3% of pristine, for realuminizing the following August. This provided an opportunity for further experimentation with washing techniques, specifically: (1) increasing the rigor of the spray wash; and (2) trying different solvents to remove the residual high-scatter film.

Washing Techniques

As our initial pressure-washing experiment, the wash of 8/03 (see MMTO ITM **03-6**) was extremely conservative, the low-pressure setting of the sprayer being the rough equivalent of a thumbed garden hose. It was surmised that a well-adhering film should withstand a vigorous spray cleaning, but in the interest of safety not much experimentation with high-pressure spray was attempted. There were no indications of film delamination or other problems but a film, noticeable under the right lighting, remained that didn't respond to further spray washing.

For this iteration two changes to the sprayer system were made. Instead of feeding the sprayer with pressurized building water, water/solution was siphoned from a bucket. In addition, a 30' extension was added to the high-pressure line. Both had the effect of reducing somewhat the overall throughput and output pressure; the combined effect is a high-pressure spray that appears to be just about right. The jet fans out 4-6 inches at one foot. Some method of quantifying pressure and flow will be developed in the future. A new wand with continuously variable pressure has been purchased but it cannot be used with the existing pump, which is of molded composite construction and has no interchangeable fittings.

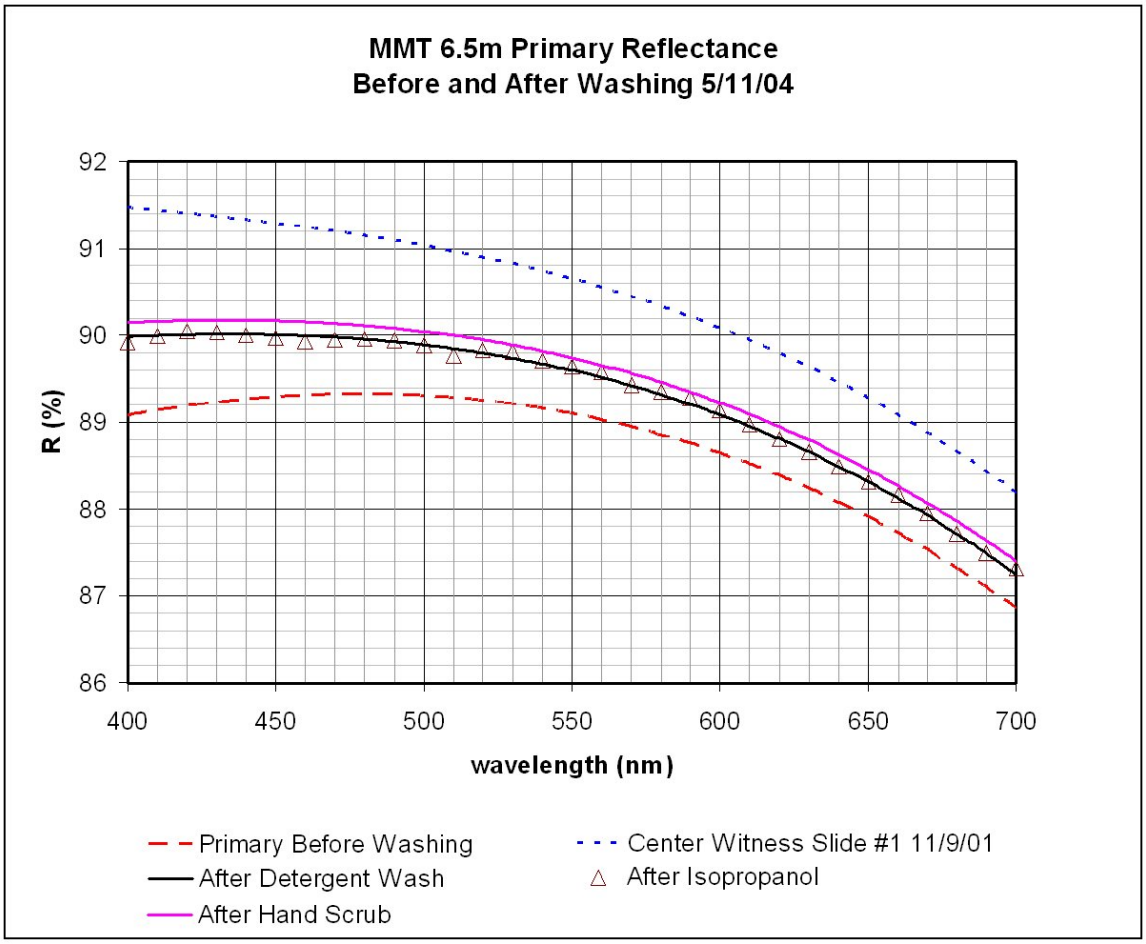

Figure 1

A portion of the outermost zone of the mirror was washed with this jet at all angles of attack and for various durations. This and the innermost zone of the mirror should be most susceptible to damage owing to proximity of an exposed metal/glass interface. No combination of incidence angle, distance of nozzle to surface, and duration produced any indications of film damage. This was true even in areas of poor adhesion near the edge of the glass where Scotch® tape had lifted some aluminum in pre-wash testing. Perhaps some boundary effects are acting to protect the exposed interfaces of the 900**Å** film. With these results bolstering our fortitude, we proceeded to similarly wash the entire surface, again with no indications of film distress.

The second experiment was to follow the detergent wash with that of another solvent. Isopropanol was on hand and lacked serious toxicity. The hope was to affect the remaining high-scatter film whose nature was not understood. After the detergent wash of 8/03, this film accounted for as much as 3% ***R*** and almost one-third of the diffusely reflected light.

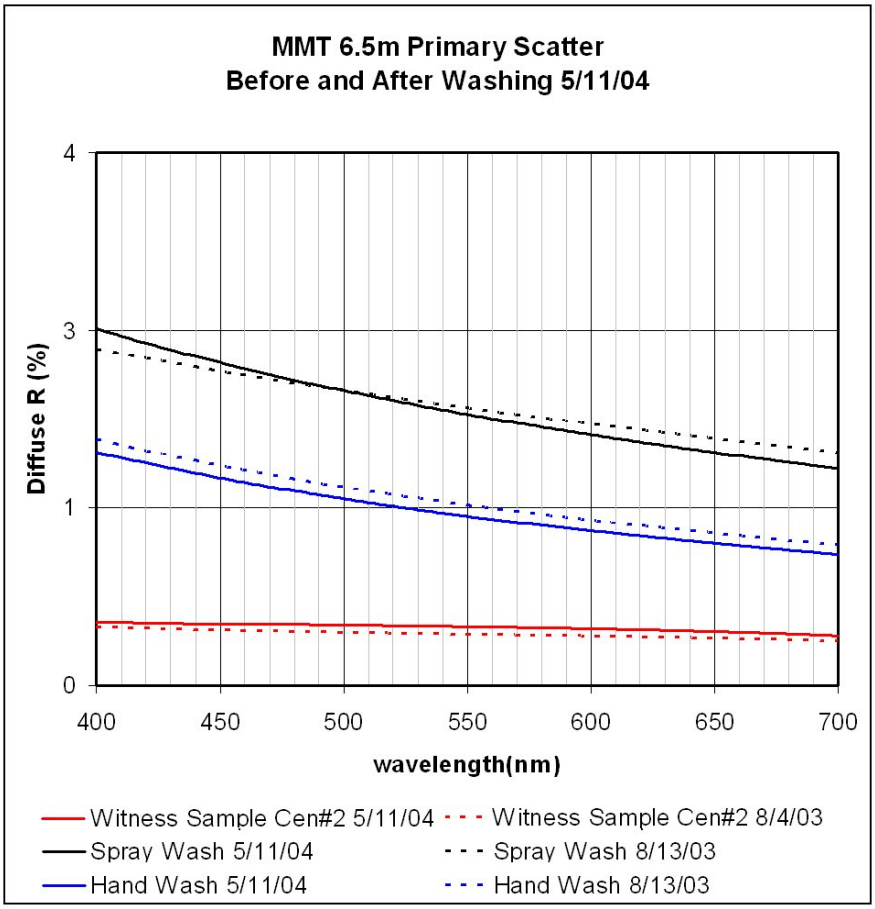

Figure 2

Results and Discussion

Figure 1 shows ***R*** of the primary mirror at each stage of the process compared to that of a protected witness sample from 11/01 (all measurements Minolta CM-2002). Each curve represents the arithmetic mean of twenty measurements over a small area (≈1 ft^2) with no attempt to avoid water spots or bug deposits. Note first that ***R*** since the washing of 8/03 (where initial ***R*** was 86%) has held up very well in spite of the mirror having been rained on at least twice—starting condition of the mirror was much better this iteration.

The most significant result is the negligible difference (<0.2%) between ***R*** after vigorous high-pressure spray washing and further hand scrubbing (again, compare results from 8/03 where ΔR was up to 3%). This is very encouraging because one of our objectives has been to find a way to eliminate any contact processes and their inherent risks to the aluminum so we can increase washing frequency. The higher-pressure spray evidently does a much better job of cleaning as might be expected. On the downside, while much more effective in terms of ***R***, the vigorous spray wash does not measurably reduce scatter (***S*** – see Figure 2) as compared to the mild wash; hand scrubbing is still needed to

produce the best results. Scattering results are within measurement noise of being identical to those of 8/03. Some effort to understand the nature of this residual contamination is needed in order to find any possible noncontact methods for effecting its removal.

Whether or not such a method can be found, the spray wash is here to stay. What makes hand scrubbing such a delicate and risky endeavor is the likelihood of incorporating particulates not removed during the preparatory wash that will sleek the film. Avoiding damage in this manner requires great care and expertise. With virtually all such particulates removed, hand scrubbing is much safer and more likely to be without consequence in inexperienced hands.

The lower left quadrant (facing the horizon-pointing primary) of the mirror was given an additional vigorous spray wash with a 33% isopropanol solution. As seen in Figure 1, it had no measurable effect on ***R*** (or ***S***, not shown). This suggests to us that the scattering layer remaining after non-contact washing is more in the nature of an inert mineral deposit than, say, a hydrocarbon film.

The previous wash of 8/03 restored ***R*** of the 22-month-old film to pristine values. Identical treatment this time, with the previously discussed exceptions, brought ***R*** to within 1.5% of pristine. There is probably measurement uncertainty involved in the difference but the suggestion is of some nonlinear or delayed-onset aging process that we should make an effort to understand.

Conclusion

The wash of 5/11/04 restored ***R*** of the MMT primary mirror to within 1.5% of pristine across the visible spectrum. This being well within the criterion of 3%, realuminizing will be deferred until 2005. A much more vigorous (higher pressure) spray wash (unquantified parameters) proved considerably more effective than the previous low-pressure attempts, although hand scrubbing with absorbent cotton remains necessary to remove the residual high-scatter film. An experimental isopropanol spray had no effect on the film and further work is needed to determine if there exists any means, other than mechanical, for removing or mitigating it.

On the basis of these and previous results, we conclude the following:

1) A well-adhering aluminum film can withstand a very energetic, high-pressure spray wash with little risk of delamination or other damage
2) Such a spray wash is exceptionally effective at removing contamination excepting a thin scattering layer of undetermined nature that, so far, has responded only to mechanical cleaning

3) As the mirror ages, CO_2 cleaning effectiveness decreases relative to that of washing; high frequency snow cleanings are more efficacious in the early life of the mirror and perhaps can delay onset of the more irremediable aging processes

4) A triannual washing schedule should be implemented, before and after the cold season and sometime in-between, as well as regular and timely CO_2 cleanings no less frequent than the current biweekly schedule

5) With an adequate snow and washing schedule, ***R*** within 3% of pristine should be attainable for at least three years

6) Pardon the cliché but an ounce of prevention is worth more than a pound of cure. Once the aluminum film is damaged it cannot be repaired nor will it heal itself. If we want to make triennial coating a fact, snowing, washing, and related items, e.g., a precipitation detector/alarm, must be assigned a high priority and resources made available. Consider the amount of effort we are spared by not having to aluminize this year. A fraction of that level of effort will give us three-year mirrors.

References

W. Kindred, "Effects of CO_2 Cleaning and Detergent Washing on the Specular and Diffuse Reflectance of the MMT 6.5m Primary Mirror," MMT Observatory Internal Technical Memorandum **02-1** (2002).

W. Kindred, "Effects of CO_2 Cleaning and Detergent Washing on the Specular and Diffuse Reflectance of the MMT 6.5m Primary Mirror, An Addendum to MMTO ITM **02-1**," MMT Observatory Internal Technical Memorandum **03-6** (2003).