



## MULTIPLE MIRROR TELESCOPE OBSERVATORY

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### MMT Internal Technical Memorandum 88-3

Mirror Coating at the Sunnyside Facility - An Operational Guide  
(Revised and updated version of MMT Internal Technical Memorandum 87-2)

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## I. INTRODUCTION

The following is a revised version of a previous memo (87-2) that summarized the operation of coating the MMT mirrors at the Sunnyside coating facility. Most of the procedures described here were related to me by Bill Kindred and J.T. Williams as we coated the mirrors. These procedures evolved from painstaking, frustrating, and time consuming trial and error, and their presentation here is meant to save someone else a lot of time and effort. This summary might also be used as a refresher by someone with experience, just to get back in the mirror coating mode.

The viewpoint presented here is entirely operational. Some information pertains specifically to Sunnyside and some to mirror coating in general. Much of the new material evolved from mirror coating adventures with A. Bauer. Chiefly, it concerns filament loading, the pumping and electrical systems, and new techniques that have arisen in response to problems. Some further information and references can be found in Columbus Project Technical Memorandum UA-88-06.

The procedures for doing the MMT primary mirrors are given step-by-step, whereas less effort is made to order the steps elsewhere.

Any additions or corrections to this report are welcome.

## II. PRIMARY MIRROR COATING

The primary mirror coating process generally takes 3 days, although it can be done in less. Three days is preferable because the mirror should spend the night after stripping in the clean room drying out and the next night in the chamber pumping out.

### A. Uncrating

Be sure to have planned where to put the mirror crate once it's off the truck and where to put the top of the crate. Also, the handling ring has to go on so the crate should be centered with respect to the hoist. Leave room for the mirror cart to roll inside the building and to the washing area (see Figure 1).

There are two crates--one with pins through the bottom ends of the side bolts and one with nuts. The one with pins requires the pin puller. The one with nuts requires the bolt puller and a lever arm (2 x 4 works fine), as the bolts fit tightly.

The crate with pins has steel bars through the bottom with holes to mount the clevises when lifting. The crate with nuts requires additional steel bars to lift from the bottom (none are mounted). For safety's sake, never lift from any other place on the crate.

The sides of both crates detach, leaving the crate bottom with a raised cushioned portion to accommodate the mirror. The mirror should be centered on the raised portion for the crate with pins but not for the other crate. One should mark the mirror location on the crate with nuts before lifting it off, as the raised portion is a bit off center in at least one crate.

### B. Handling Ring

The metal parts of the handling ring should be cleaned with acetone if the ring has not been in use for a long time. However, the rubber pads should

not be cleaned (the acetone can outgas from the pads during coating). If portions of the pads have to be cleaned due to contamination with opticoat or other materials, it should be done well in advance of a shot. In addition, the pads should be touched only with gloved hands and their general cleanliness ensured. Try not to get any opticoat on the ring (use paper or plastic skirts). It would be a good idea to put the handling ring assembly in the chamber (rough vacuum) overnight (before doing any coating) to "pump it out" if the pads had to be cleaned.

The sides of the handling ring are numbered and should be assembled in a consistent fashion. If the turnbuckles have about 1/2" of thread through the nuts it is generally easy to slip the handling ring over the mirror. It is easiest to mount the handling ring on the mirror when it is suspended from the handling bar and the hoist. One section will always have the turnbuckles tightening in the opposite sense as the others.

The bolts for the handling bar should have two washers between the bolt head and the handling bar and one washer between the bar and the ring. There are 2 orientations in which the bar can be mounted on the ring (4 holes, 90° apart). One set of holes is "no good" and is marked as such. It is convenient to put a pipe through the handling bar at 90° to the "yoke" (there is a place for it). Then, ropes or nylon clothesline can be tied from the ring to the pipe to pull up the sagging portions of the ring to a level position. The ropes are tied to two long bolts which are screwed in the "no good" set of holes in the ring.

Try to tighten the turnbuckles of the ring section in unison so that the holding pressures are as uniform as possible. When resistance is met but the ring can still be pulled into position, make sure that the mirror top and bottom fit inside the ridges on the rubber pads. Then work with the bottom first (tightening it uniformly), then the top, and finally have one person do the final tightening, ensuring evenness and that the ring is neither too loose nor too tight.

Get the mirror cart into position and lower the three pads (but not all the way). To avoid shocking the mirror one should not lower the mirror onto the cart but, rather, lower the mirror close to the cart and then crank up the pads to the mirror until the weight is off the handling bar and the hoist. Make sure the mirror is centered to a half an inch on the cart. Now remove the handling ring by loosening the turnbuckles evenly until there is 1/2 inch of thread left, carefully raise the ring using the hoist, and pull it out of the way. After moving the mirror out of the way, the handling ring can be picked off the hoist by the forklift (lifting the bar). This is convenient since the hoist will be needed for other things.

### C. Preparation for Stripping

Now that the mirror is on the mirror cart it can be rolled to the stripping or washing area. The mirror should be opticoated--if it isn't, watch out for the sun! The washing area is covered but the east and the south sides are open. Morning is the best time to strip because of afternoon winds and/or rains; however, it might be necessary to erect some shade to keep out the morning sun (black plastic will do). Not only does the shade make life more bearable but it also decreases the chances of sweating on the mirror, keeps the mirror from drying too fast, and stops the danger of starting a fire through the reflected sun on the rafters.

Remove the opticoat. If it is too thin in some places to peel off without excessive use of Scotch tape, one might try spraying more opticoat on the offending areas and peeling it off when dry. At this point the mirror can be

assumed to be covered with grit so don't do any rubbing on the surface.

Next, clean the remaining opticoat with acetone. This includes the beveled mirror edge, the sides of the concave surface, and the central (tertiary mount) area, but not the mirror surface (except where opticoat is embedded in small holes or bubbles--toothpicks and cotton swabs can be used to remove it). Be careful of grit--change paper towels often and don't drag it around. If, for some reason, this is done inside, the organic vapor mask should be worn. The sides of the honeycomb can also be cleaned with acetone if they are dirty (for the sake of good vacuum). Don't clean off any fiducial or alignment markings and don't get any acetone into the holes.

It is essential to keep water out of the honeycomb as it will take forever to dry and might mess up the coating process. This is done by plugging up the five center holes with #12 rubber stoppers (the center hole is larger than the others and requires a stopper with a long screw or one used upside down so that it can be removed) and by putting a skirt of sheet plastic around the mirror. The skirt requires a long plastic sheet with a fairly straight edge. Put the edge of the plastic sheet about halfway up the side of the concave slab. Seal it on with the brown, Mylar 3-M packing tape (2" wide).

This is a two man job--stretching the plastic and keeping the tape from kinking. It is important to do as good a job as possible and even then it may leak slightly.

The mirror should be tilted on the mirror cart to allow fluids to run off. Acid will react with the steel center fixture given enough time. Raise two of the pads and lower one such that the water just runs off (a little puddling is better than risking the mirror sliding off the cart). Arrange so that the lowered end points south. The mirror is ready to be stripped.

#### D. Stripping

Below are the recipes for the cleaning agents used. The amounts should be sufficient for at least 3 primaries. Where H<sub>2</sub>O is required use purified H<sub>2</sub>O only.

Liqui-nox Soap - Put about a tablespoon into a liter bottle and fill with purified water. The amount is not critical but too much soap would be a pain. (Liqui-nox is a phosphate-free laboratory and hospital detergent made by Alconox Inc.)

Aluminum Stripper - 6 lbs. (about 1 gal.) of 37% HCL  
1/2 lb. CuSO<sub>4</sub> (Cupric Sulfate powder)  
H<sub>2</sub>O to 5 gallons.

Potassium Hydroxide - 2 cups KOH (powder)  
H<sub>2</sub>O to 5 gallons.

Nitric Acid - 6 lbs. HNO<sub>3</sub> (70%)  
H<sub>2</sub>O to 5 gallons or a little stronger. 4:1 water

Calcium Carbonate - 3 or 4 jars (500 gms) of CaCO<sub>3</sub> powder

All of these chemicals are available at Stores lab and medical supply.

The mirror should be ready to strip after cleaning with acetone, attaching the skirt, and tilting the mirror. The persons doing the stripping (2 is ok, 3 is easiest, 4 is too many) should wear bouffants, poly gloves, masks, chemical aprons, and rubber boots. Gloves should be changed when the

chemical is changed and occasionally more often. It is not unusual to get acid drops on the wrists or arms and on the knees (between the apron and boots). Wash the acid off the skin immediately and change gloves. It is wise to wear shorts during stripping since the acids and caustics have a more permanent effect on pants than they do on skin.

Bring out only the chemicals to be immediately used, thus preventing the use of the wrong chemical. Have ample paper towels and poly gloves in the area, as they get used fast. Never use a paper towel that has fallen to the ground or touched the side of the mirror. Drop it and use a new one. Use only purified water to rinse and watch that the hose doesn't touch the mirror surface. The steps are:

1. Hose the mirror off well.
2. Washing with Liquinox (do 3 times). Crumple up 6 or 7 double paper towels and put them at various points on the mirror. Pour Liquinox solution on each paper towel and all over the mirror surface. Swirl the wet paper towels around, applying no pressure on the first washing and only gentle pressure on the next two. Pay particular attention to the central area and the edges on the first and second washings. Don't use any of the paper towels that were used in these areas on the rest of the mirror surface. Rinse well after each washing.
3. Stripping the Coat (2 or 3 times). Again crumple 6 or 7 double paper towels and locate on the mirror surface. Pour the HCL and  $\text{CuSO}_4$  solution over the paper towels and all over the mirror surface. Rub the towels around without much pressure. Treat the central and edge regions the same as during washing. Work slowly so that the acid has time to work. Rinse well and repeat. Most of the coat should be gone after 2 applications. Do the third application to be sure.

An alternate, more thorough method is to lay out paper towels over the surface of the mirror in sections and saturate with stripper. Pat down the bubbles and add stripper as needed to keep the surface wet for 10 minutes or so. Rub the surface when picking up the wet paper towels.

4. Calcium Carbonate and Potassium Hydroxide Wash (do 3 times). All but the faintest traces of the previous aluminum coat should be gone. After the mirror is rinsed well, sprinkle  $\text{CaCO}_3$  all over the mirror surface, put down the 6 or 7 crumpled double paper towels, and pour KOH over the towels and mirror surface. Rub in a swirling motion, applying more pressure with each application. Treat the central and edge areas as before (doing a good job on the first two applications and leaving the areas alone on the third). Rinse well after each application, occasionally putting your finger over the hose for a strong spray. Make sure there is no trace of the aluminum on the mirror surface. Also, on the third rinse you might try to get some of the  $\text{CaCO}_3$  off the skirt.
5. Nitric Acid (twice). The nitric acid is necessary not only to remove anything that may have been missed on the mirror surface but also to remove the remaining KOH and  $\text{CaCO}_3$  (which are there

regardless of rinse). One might see the water bead up differently after the nitric acid application and the surface should feel squeaky clean. Again, crumple 6 or 7 double paper towels, place them on the mirror surface, and pour the nitric acid solution over the towels and the surface. Rub around and rinse. The alternate method of laying out paper towels can be employed in this step as well.

6. Final Rinse. Rinse very, very well (15 minutes), spraying from time to time.
7. Drying. Using lots of paper towels (preferably the lint-free variety), dry the mirror surface. This has to be done fast and it is helpful to have 3 people. You want the mirror surface to dry under the paper towels while rubbing and not while exposed between rubs. This prevents streaking. It is best to dry the skirt to some extent first, then do the central area, the edges, and finally the mirror surface. Inspect the surface carefully for streaks or splotches. If there are any, remove with a wet paper towel and dry immediately.
8. Move to the Clean Room. Roll the mirror to the clean room and remove boots and apron before doing any more.
9. Removing the Rubber Stoppers. Remove the rubber stoppers, taking great care not to get any water droplets on the mirror surface. Carefully clean the screw holes in the center puck using Q-tips or cotton swabs to get the water out.
10. Removing the Skirt. The skirt could take forever to dry out and inhibit the evaporation of any water in or on the mirror. So, the skirt should be removed as soon as possible, and it takes a certain amount of care to prevent splattering water (plus whatever chemicals) up onto the mirror surface. After drying the outside of the skirt with paper towels (that part near the mirror surface), two people should have paper towels (pressed from the top at the mirror's edge) centered about the portion of taped plastic being peeled back. As you peel around, go around with the paper towels pushing them slowly over the edge. Stop and get new paper towels and continue the process until done. Check the mirror surface and if anything is splattered on it, remove it with a paper towel wetted with purified water and immediately dry. The brown 3-M packing tape is easily removed from the heavy plastic skirt without destroying the plastic. This should be done after removing the skirt and well away from the mirror.
11. Final Cleaning - 2-Ethoxyethanol (at least 3 times--preferably more). The mirror should be left overnight to dry. Water has run out of the mirror onto the surface when turned upside down. Water in the vacuum will lead to adherence problems as well.

The final cleaning should be done right before the handling ring is put back on to put the mirror in the chamber. It is all right to leave the mirror overnight between steps 10 and 11 but once step #11 is done, the mirror should go into the chamber as soon as possible. The final cleaning is done with

"good" 2-ethoxyethanol and lots of paper towels. "Good" is explained in the miscellaneous section entitled "2-ethoxyethanol." Wear the organic vapormask, bouffant, poly gloves, and long sheets of paper or plastic wrapped around your torso to keep your shirt from touching the mirror. The syringe should be thoroughly washed with 2-ethoxyethanol before filling for use on the mirror. The cleaning is best done with 3 people for a primary mirror and it is best to use paper towels that leave the smallest amount of lint. Squirt a moderate amount of 2-ethoxyethanol over the mirror surface and rub around with a handful of paper towels. Turn the paper towels over and keep rubbing. Have another handful of towels ready, then jump in with them. The object is to dry the 2-ethoxyethanol under the paper towels while rubbing and not while exposed between rubs. This should be done in the "clean room" with any fans turned off to prevent the 2-ethoxyethanol from drying too quickly. When "good" 2-ethoxyethanol dries under the towel while rubbing, the surface tension is terrific (this is a sign of a good cleaning although one shouldn't worry about it on the first application). It is probably best to do the central region first and by itself a couple of times, then leave it alone. Change towels often since particles might be dragged out of the central area to the mirror surface. It is also wise to do the edge (including bevel) by itself and then not go quite to the bevel during the surface cleanings. After 3 cleanings try the "blackbreath test"--looking for streaks in the fogged patch and for evenness as the fogged patch disappears. Blackbreath doesn't work if the room and mirror are too warm, i.e. when the air conditioning is not working. The mask should be worn at all times except when breathing on the mirror for the blackbreath test. Blackbreath should be done with care since any drops of spit will probably screw up the mirror coat there. For the same reason, never talk around the mirror without wearing a mask. If the mirror repeatedly fails the blackbreath test after numerous cleanings with 2-ethoxyethanol then something is wrong. The most likely problem is "bad" 2-ethoxyethanol. If this is not the case then something may have been wrong in the stripping process. If all else fails and the mirror needs to be recleaned (there should be no trace of aluminum) then start the stripping procedure again at the potassium hydroxide-calcium carbonate step.

When the final cleaning is done, turn on the overhead fan unit in the clean room while preparing the handling ring. This unit is supposed to help alleviate static charge on the mirror surface that builds up during the final cleaning.

#### E. Mounting the Handling Ring for the Shot

Although great care should be taken in mounting the handling ring in all cases, even greater care should be taken in this step. The mirror is turned upside down so that the risk to the mirror is greater, as well as introducing some human risk. If the handling bar has been disassembled, one should check that the two vertical bars are mounted correctly. The inside of the bars (near the boltholes with bearings) should angle out from the ring slightly when mounted. If they are reversed, the mirror will not turn over. Trying to force it is unwise since the force is directed to pushing the bolts outward.

When the handling ring is placed over the mirror and is still loose, aluminum foil should be placed between the mirror sides and the rubber pads. This is done by simply tearing off a piece of aluminum foil that is long enough to cover the inside of the ring with some overlap on top and bottom to pull over and scrunch into place after the mirror is tightened. Leave some bare metal of the outside of the handling ring showing so that the vacuum is not excessively retarded. The strips of foil should overlap 3-4 inches.