

**Scanning Electron
Microscope
Examination of
Airxchange
Enthalpy Exchange
Surface**

**Report to
Airxchange, Inc.
Rockland, MA**

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Introduction

Arthur D. Little, Inc. was requested by Airxchange, Inc. to examine samples of the silica gel coated polymer film used for enthalpy exchange in Airxchange Energy Recovery Wheels. The purpose of this examination was to determine the extent to which the silica gel desiccant material will be retained on the surface of the polymer substrate after washing and after extended service. Desiccant particles are attached to the polymer film material through a solvent bonding process, whereby a portion of the polymer film is used as the bonding agent.

Durability Test Method

The basic approach is to compare the silica gel particle density on the as manufactured silica gel coated polymer film enthalpy exchange material with the particle density on material that has been vigorously washed and with material that has been in service under demanding conditions for an extended period of time.

The size range of the silica gel particles -- 4 to 8 microns -- and configuration -- a surface coating on an opaque substrate -- is difficult to observe with optical microscopes but is readily observed with a scanning electron microscope (SEM). To create an SEM image, an electrically conductive surface is required. Because both the polymer film and the silica gel powder are nonconductors, a gold flash must be applied to each sample.

The gold flash is applied by physical vapor deposition and is approximately 60 angstroms (several atomic diameters) thick. This thickness is 3 orders of magnitude less than the silica gel particle size, and thus does not affect the image significantly. The gold flash does not bond the silica gel particles to the substrate.

The procedure followed for all samples was straight forward:

- Wash the sample by scrubbing with a toothbrush using Ivory soap and tap water^{*} rinse with tap water and warm air dry (for examining production material in the as received condition, this step is skipped)
- Gold flash the sample as described
- Mount the sample in the SEM and adjust position, angle, and magnification

^{*}Note that the mechanical forces applied to the enthalpy exchange material by this scrubbing are far in excess of the forces normally applied to the material when cleaning wheel segments in the field.

- Photograph the image.

Scanning Electron Microscope Examination of Production Samples, Before and After Washing

A strip of silica gel impregnated polymer film from a normal production run at Airxchange (on February 27, 1998) was examined by a scanning electron microscope in both the as received condition and after washing with a toothbrush using soap and water.

Figures 1, 2 and 3 are SEM photographs of the as received material. Figures 1 and 2 are images of the surface of the material, at an angle to display the depth as well as the plan area of the individual silica gel particles, at approximately 2000 times magnification. Figure 3 shows the film on edge, the edge having been produced by bending and breaking the film (as opposed to cutting, which smears the silica gel and polymer substrate), at approximately 240 times magnification.

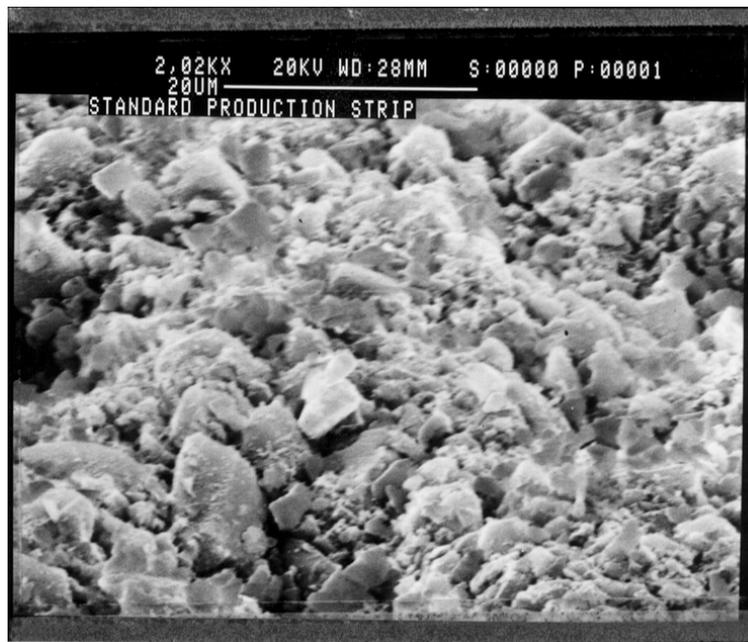


Figure 1: Production Material, as Received, Surface Viewed at an Angle

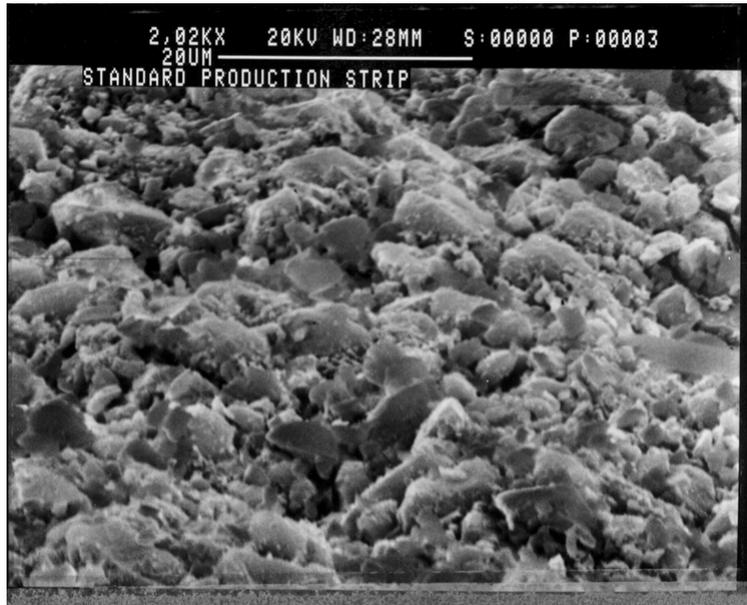


Figure 2: Production Material, as Received, Surface Viewed at an Angle

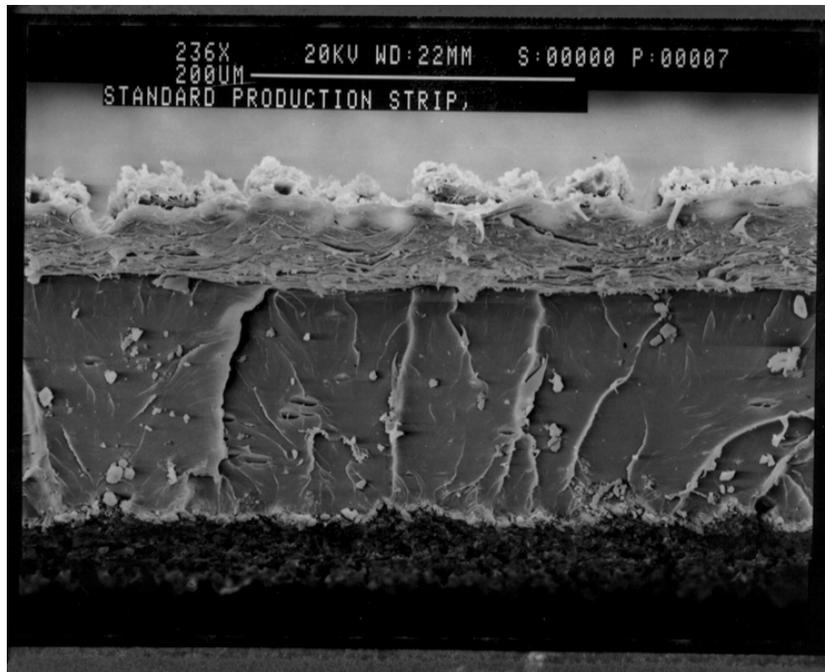


Figure 3: Production Material, as Received, Viewed on Edge

Figures 4 and 5 are the analogues of Figures 1 and 2, respectively, for a strip of the same production film that was scrubbed by a toothbrush in soap and water, then dried and prepared for SEM examination. Comparing the two pairs of figures shows that the washing process removed some finer sized silica gel particles and rounded off some of the sharper corners of the larger particles, but that the bulk of the silica gel remains attached to the substrate. Based on the visual comparison we estimate that more than 90% of the silica gel initially attached to the polymer substrate is retained after the vigorous washing that was performed.

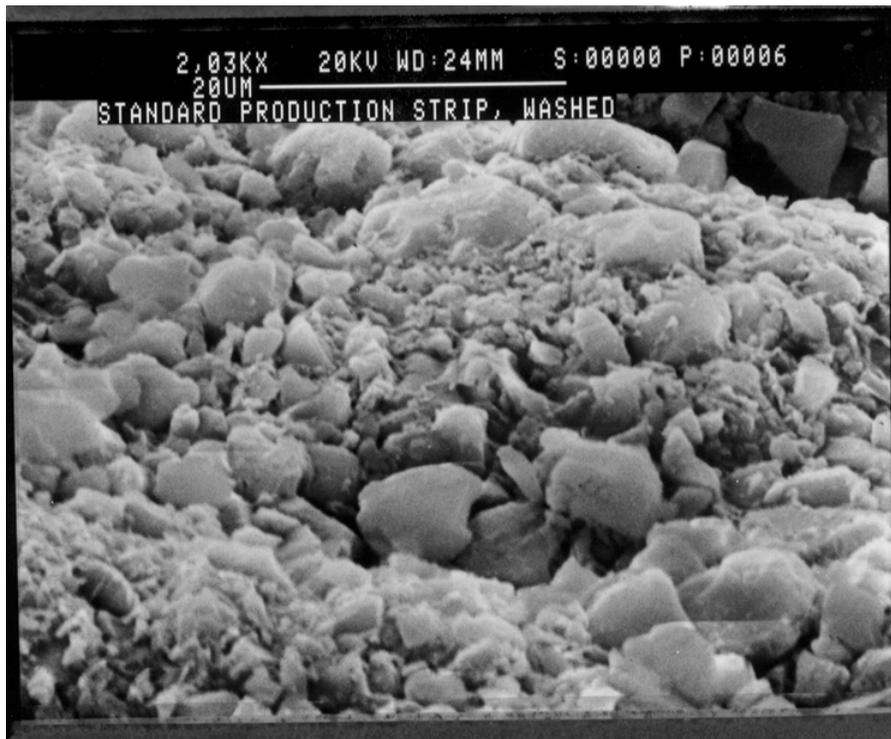


Figure 4: Production Material, After Washing, Surface Viewed at an Angle

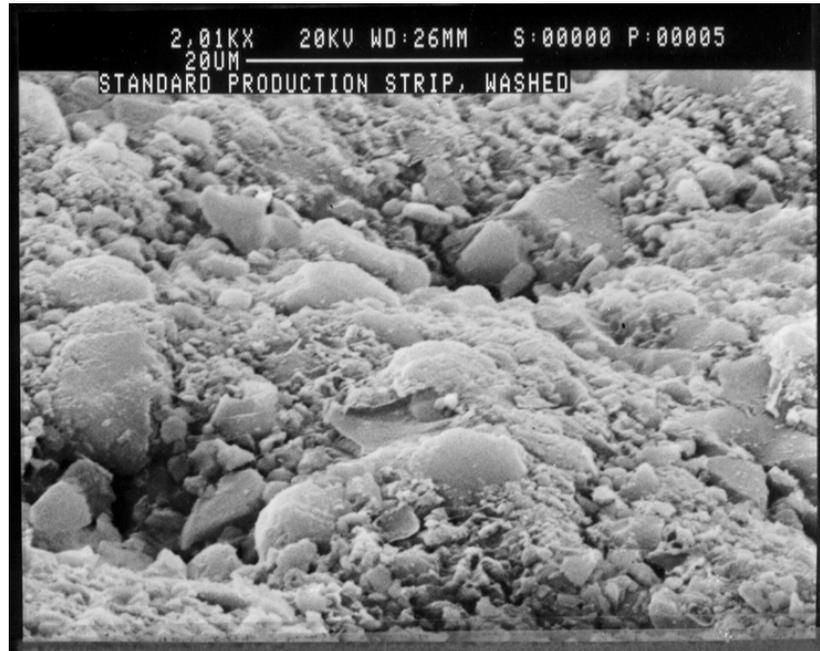


Figure 5: Production Material, After Washing, Surface Viewed at an Angle

SEM Examination of Field Sample

An Airxchange Energy Recovery Ventilation system has been in service for the past three years at a downtown Boston night club. The exhaust air contains a high concentration of tobacco smoke. During this time period, the wheel segments have been removed and cleaned at approximately 3 month intervals. Two sets of segments have been used: every three months, the segments in the ventilation system are replaced with the other set, which have been cleaned during their 3 month off period. Thus each set of segments, to date, has been cleaned 6 times. One of these sets of segments has been recovered from the night club for examination and for performance testing.

Note that Airxchange has separately measured and documented the actual sensible and latent heat transfer effectiveness of the used segments, before and after cleaning.

A length of the polymer film was removed from one of the used night club segments, cleaned vigorously by scrubbing with a toothbrush, using soap and water, and prepared for SEM examination. Figures 6, 7, and 8 are images of this sample that are analogous to Figures 1 and 2 (2000 times magnification, viewing the surface at an angle). It is readily apparent that a large fraction of the original silica gel coating has been retained.

¹Note that the periodic cleanings of the segments in the field consisted of soaking in a detergent solution. In preparing the sample for SEM examination, the brush applied a mechanical force far in excess of force normally used to clean segments in the field.

As is the case with the washed production sample, some silica gel fines have been lost and sharp corners of the larger particles appear to have been rounded off, but the bulk of the silica gel particles have been retained.

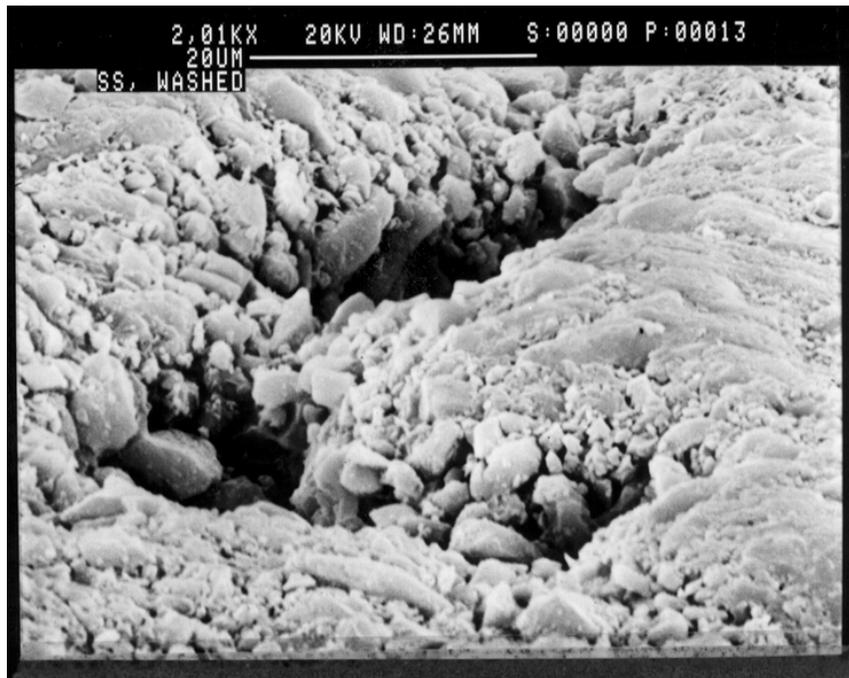


Figure 6: Washed Sample From the Night Club, Surface Viewed at an Angle

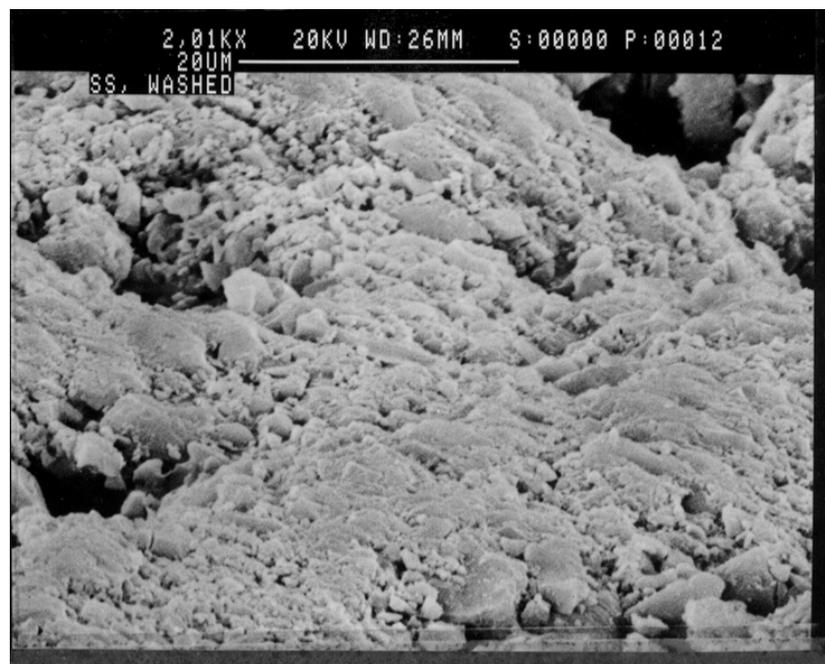


Figure 7: Washed Sample from the Night Club, Surface Viewed at an Angle

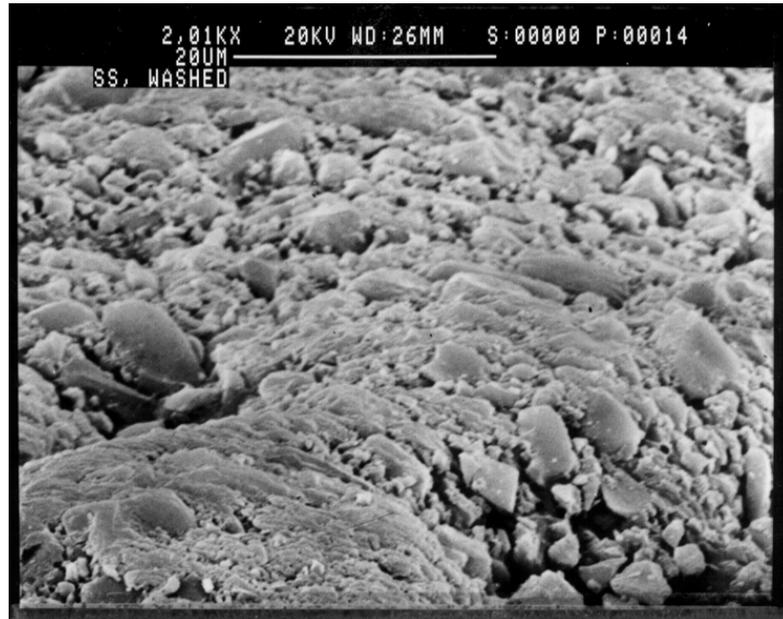


Figure 8: Washed Sample from the Night Club, Surface Viewed at an Angle

Figure 9 shows the sample on edge, analogous to Figure 3. Again, it is readily apparent in Figure 9 that in the field sample, silica gel has been retained to both a depth and density that is similar to as received production material (Figure 3).

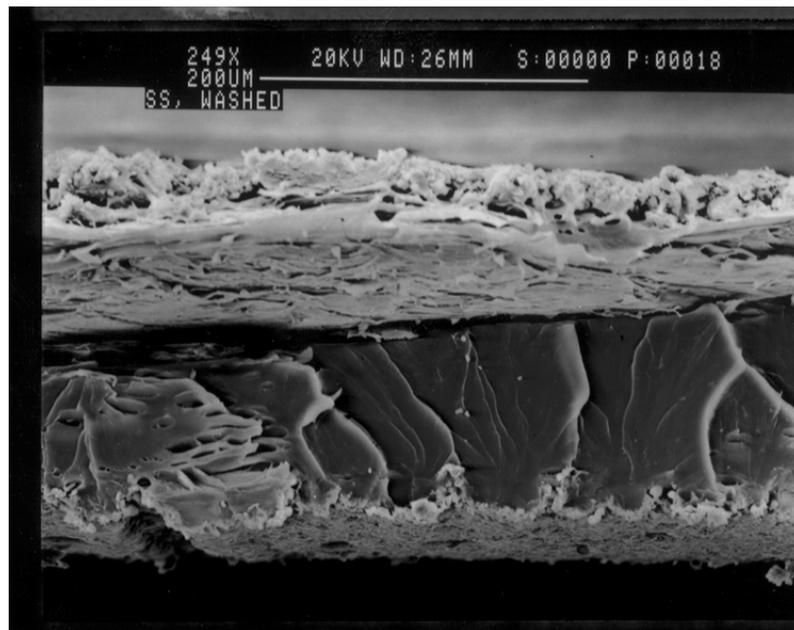


Figure 9: Washed Sample from the Night Club, Viewed on Edge

Conclusions

Based on visual comparison of SEM photographs of samples before and after cleaning, it appears that a substantial fraction (on the order of 90%) of the original silica gel coating on the normal production enthalpy exchange surface is retained after vigorous scrubbing with soap and water.

A substantial fraction (on the order of 90%) of the original silica gel coating remains on a sample of the Airxchange enthalpy exchange surface recovered after 3 years of service at a Boston night club. This material was exposed heavily to tobacco smoke and had been cleaned 6 times during this 3 year service period.

In both cases, there is a strong similarity between the appearance in SEM photographs of the as received production material sample and the appearance in SEM photographs of the washed production material sample and the sample recovered from the field.