CHARACTERIZATION OF MIRROR REFLECTIVITY LOSSES CAUSED BY DUST DEPOSITED UNDER VARIOUS METEOROLOGICAL CONDITIONS

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A critical factor for the economics of high-temperature solar-thermal technologies and of certain kinds of concentrator photovoltaic systems is the problem of keeping the reflector surfaces clean. Receivers that depend only on the global insolation (e.g. solar ponds or non-concentrator photovoltaics) are relatively insensitive to the extent to which dust particles may diffuse some of the incoming beam radiation, but for concentrator technologies dust - and its removal - can be responsible for serious loss of income. The 80 MW parabolic trough systems that Luz constructed in California require about 300 m^3 of water to clean the mirrors. In certain desert areas cleaning may be necessary every few days and it doubtful that such quantities of water would be available.

For these reasons we have undertaken a research program which aims at identifying possible *dry-cleaning* methods for overcoming the problem of dust on mirror surfaces. In order to approach this problem we have started from the well-known result that *particle size* is the dominant parameter for understanding the movement of any particles in a fluid medium (e.g. dust in air). We study particle size distributions of dust deposited on mirror surfaces, using a computerized microscope with CCD camera and appropriate image processing software that we have developed. Details of the system were discussed in [1]. A number of interesting results have already come out of this research and these we report upon here.

First, we have developed a technique that enables our computerized microscope to provide a direct measurement of the degradation in reflectivity caused by a given sample of dust on a mirror surface. To understand how this technique works it is necessary to realize that the scattering of light off particles with a size much larger than the wavelength (i.e. with $l \geq 1$ mm) is a purely reflective process. Furthermore, because of the irregular shape of the dust particles they may be expected to destroy the specular reflectivity of that area of the surface they cover. The fractional loss in mirror reflectivity may accordingly be expressed in the form $q \cdot s_{12}$ where s_{12} is the fraction of surface area covered by particles with sizes between d_1 and d_2 and q is a coefficient which can be shown to take the value 1 for a first surface reflector and 2 for a second surface reflector. We compared the integrated values of $q \cdot s_{12}$, obtained by summing the particle size distribution plots produced by our software, with direct measurements from a standard specular reflectometer. These comparisons were made for many samples of dust deposited both under natural meteorological conditions typical of the Sede Boqer region and artificially. In all cases the two loss-of-reflectivity measurements agreed with one another to within the accuracy of the reflectometer.

Second, we have classified, for convenience, the meteorological conditions under which dust may be deposited, into four principal scenarios: (i) that known in aerosol science as *dry deposition*; (ii) an extreme case of the former, in which particle densities are so high that particle-particle interactions become important, is *dust storm deposition*; (iii) so-called *wet deposition*; and (iv) an extreme case of this which we refer to as *dirty rain deposition*.

Dry deposition occurs during summer days and is the dominant deposition process at Sede Boqer from April through October - the period when solar insolation levels are at their highest. From measurements made with our computerized microscope during the summer of 1993 we found that the particle size distribution on mirror surfaces is a unimodal curve having its maximum in the size range 15-20 mm. We found this shape to be very stable (except, possibly, during so-called *hamsin* conditions, when the peak appears slightly shifted towards smaller particle sizes). The dominant cause of reflectivity loss under such conditions was revealed to be loess particles of size 10 mm and larger.

A typical dust storm event occurred, at Sede Boqer, on March 2, 1993. During this event freshly washed mirrors on the Paz solar-thermal system were subjected to several hours of high intensity dust deposition. Reflectometer measurements indicated that specular reflectivity dropped from 93.5 ± 0.5 % to 80.0 ± 0.5 %.

A dirty rain event occurred, at Sede Boqer, during March 6-7, 1993. Such rain scavenges dust from the atmosphere and can cause severe loss in reflectivity during a small period of time. The effect is particularly dramatic after a dust storm. For the event in question the specular reflectivity of these same mirrors was reduced to 20.0 ± 5.0 %.

The more general case of wet deposition is under further investigation as is the occasional situation in which organic surface contaminants are deposited. For all cases wc assess the effect on specular reflectivity and perform a parallel study of the physics of the situation. This is necessary in order to identify the kind of forces that will be necessary to clean the surface so as to ensure maximum energy collection at minimum cost.

Reference

[1] S. Biryukov and A. Goldfeld, "An investigation into the possibility of suppressing the deposition of dust on the collectors of solar power stations: A computerized system for surface studies", in Proceedings of the Fifth Sede Boqer Symposium on Solar Electricity Production, 15-17 February 1993, ed. D. Faiman (Blaustein Inst. pubn. # CEEP-93/15).