and resistant. The only zone where something useful happens is where there is a marked difference in temperature between the air and the rocks.

This is perhaps somewhat too specialized a discussion of a not very serious problem in heat storage, but one answer that would eliminate the unnecessary friction is interesting to consider.

A storage bin with the air entering at the top could have by-passes (open passage ways) with little friction - the air would follow these to a depth where the rocks became cold and then seep out through the cold rocks where it could lose bouyancy and easily descend.

## SURFACE AREA IN A CUBIC YARD OF ROCK

If we assume that rocks are round and join each other in a checkboard grid we find that a cubic yard of rocks of diameter----- has the following surface area:

| DIAMETER | No. of ROCKS | SURFACE/ROCK | TOTAL SURFACE |
|---|---|---|---|
| 1'' = | $36^3$ = 46656 | $4\pi(½'')^2$ = 3.142 sq.'' | 113 sq. yds. |
| 2'' = | $18^3$ = 5832 | $4\pi(1'')^2$ = 12.5664 sq.'' | 56 sq. yds |
| 3'' = | $12^3$ = 1728 | $4\pi(1½'')^2$ = 28.27 sq.'' | 37.7 sq. yds. |
| 4'' = | $9^3$ = 729 | $4\pi(2)^2$ = 50.256 sq.'' | 28.3 sq. yds. |
| 6'' = | $6^3$ = 216 | $4\pi(3)^2$ = 113.09 sq.'' | 18.85 sq. yds. |
| 9'' = | $4^3$ = 64 | $4\pi(4.5)^2$ = 254.5 sq.'' | 12.56 sq. yds. |

These enormous surface areas account for the rapid transfer of heat from the air stream to the rocks.

What flow channel exists through the rocks? This depends on the percentage of void that is left between the rocks. You can easily tell by filling a 5 gallon can with a sample of the rocks and then seeing how much water can be poured in among the rocks. The more nearly uniform in size the rocks are the greater the void space. When the rocks are big and small the small rocks fit in the voids between the big rocks and, although the small rocks in turn have voids between themselves as they pack the larger voids, they have already largely occupied the possible void space. If spherical rocks remained in a checkerboard pattern, each touching only six neighbors, they would occupy $\frac{\frac{4}{3}\pi R^3}{(2R)^3} = .5236$ of the volume.

This is not the case - the rocks shift to a closer packing which can be seen in any pile of oranges in a market and the void space shrinks to about 26%. Then everywhere that we slice through our rock storage bin we are going to find somewhere in the neighborhood of 25% of the area of the cut to be void, and thus a passageway for air. All of the passageways interconnect and although some become pinched at places, the general flow of air is not badly discouraged by constrictions.

We never want to ask the air to flow rapidly through the rocks. This would require considerable pressure and means installing fans or having a very fine collecting site with a long steep south slope for a solar chimney. What do we mean by fast? In a solar chimney it is easy to get the air to flow over 100 ft/min which comes out to be a little over 1 mph. In one long chimney I built I frequently got air speeds above 400 ft/min.

It's very exciting to build a solar chimney in the wintertime and stick your face at the exit and feel the warm air blowing out. The mechanism, consisting only of black insulation and clear plastic or glass and the air inside and the sun seems magic in its ability to create both warmth and a breeze.