QUALITY

CASE STUDIES

Energy Project Relies On DOE

Low-conductivity material can be used in place of more expensive high conductivity aluminum in manufacturing operations.

The 3-year study by the National Renewable Energy Laboratory (NREL, Golden, CO) relied on design of experiments (DOE) software to plan the experiments. With the aid of this powerful statistical tool, the researchers worked to find the most cost-effective materials for solar air heaters and the information gained in this study may enable manufacturers to produce more cost-effective systems using solar air heaters.

Researchers used transpired air collectors to absorb solar energy on dark metal surfaces, and a fan to pull ambient air through holes in the heated metal. Typically the metal is aluminum, an excellent heat conductor. What the study revealed was that the effect of conductivity on the metal is minimal, therefore, a low conductivity material such as galvanized steel could be used in place of aluminum. Aluminum has high conductivity and is expensive.

Keith Gawlik, Ph.D., senior engineer at NREL, wanted to test different variables at two levels using a standard test plan. Design-Expert, from Stat-Ease, Inc. (Minneapolis) seemed to be the best DOE software program for NREL. The five factors that interested Dr. Gawlik were pitch, the center-to-center distance between holes in the perforated collector; diameter of each individual hole; thickness of the collector plate; mass flux, the mass flow rate of the suctioned air per unit area of the collector surface; and material thermal conductivity. High and low extremes of each factor were entered in the two-level, factorial-design builder program. According to Dr. Gawlik, DOE analysis predicted that variation in conductivity created negligible differences in performance, but did in fact, reveal that the greatest effect came from mass flux.

To validate the software's predicted results, Dr. Gawlik performed confirmatory experiments with perforated flat plates of aluminum that had a known conductivity of 216 watts per meter Kelvin, and styrene with a conductivity of 0.16 watts per meter Kelvin. Each plate measured 1 by 1.5 feet by 0.063 inch thick, with hole diameter and pitch corresponding to the optimal values predicted by the DOE. The plates were subjected to the same conditions used in an earlier test—a computational fluid dynamics program simulation. Thermal conductivity did not significantly affect solar air heater efficiency. The lab tests confirmed both DOE analysis and the computational fluid dynamics runs.

At a typical mass flux of 0.02 kilograms per second per square meter and one common geometry, the high conductivity plate had a 72% efficiency. The low conductivity plate's efficiency was 70%. This is a difference of only 2%, considering the change in conductivity was more than 1,000 times. According to Dr. Gawlik, conductivity was not an issue until extremely low conductivity was approached—as for materials that would be considered insulators, not heat conductors.

High and low extremes for each factor are entered in the two-level, factorial-design builder program.
Photo: Stat-Ease, Inc.

"The use of the factorial analysis was important because I was able to examine a number of different conductivities and configurations. The effect of going to a low-conductivity plate is very exciting," says Dr. Gawlik. Knowledge gained from this study will encourage manufacturers to use solar air heaters more when trying to produce cost effective systems.

BENEFITS

- Multiple factors could be tested simultaneously, saving experimentation time.
- Factors can be entered into the two-level factorial design builder program for high- and low-extreme results.
- Different configurations and conductivities could be examined.

Reprinted from **QUALITY** October 2000