A Review of Experimental Study of Thermal Performance of a Solar Air Heater

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Abstract- This study experimentally investigates a device for inserting an absorbing plate made of aluminum can into the double-pass channel in a flat-plate solar air heater (SAH). This method substantially improves the collector efficiency by increasing the fluid velocity and enhancing the heat-transfer coefficient between the absorber plate and air. These types of collectors had been designed as a proposal to use aluminum materials to build absorber plates of SAHs at a suitable cost

Key Word- Aluminum cans, Thermal efficiency, Experimental process

Introduction-

Numerous SAH devices have been developed and used experimentally. A glass or plastic cover is fixed above the absorber plate and the system is insulated thermally from the back and from the sides. SAHs are simple in design and maintenance. Corrosion and leakage problems are less severe compared with liquid heater solar systems. The main drawback of an SAH is that the heat-transfer coefficient between the absorber plate and the air stream is low, which results in a lower thermal efficiency of the heater. However, different modifications are suggested and applied to improve the heat-transfer coefficient between the absorber plate and air. There are different factors affecting the SAH efficiency, e.g. collector length, collector depth, type of absorber plate, glass cover plate, wind speed, etc.

Increasing the absorber plate shape area will increase the heat transfer to the flowing air, but on the other hand, will increase the pressure drop in the collector; this increases the required power consumption to pump the air flow crossing the collector. A solar heating panel is not just a box with a glass front, a black interior, and a pair of openings in the back. Any fool can build such a box – and many have, but very few have managed to heat an entire building with the result.

You already knew that, of course, or you wouldn’t be reading this. I mention it only because you may not have known that you knew, and because I think it’s an important starting point for our discussion.

2-Requirements for a successful design:

- Passive operation
  The panel must operate efficiently using only the thermal energy it captures – independent of all other energy sources.
- Diurnal operation
  The panel must deliver heat efficiently during the day, and not lose more than an absolute minimum of heat when there is insufficient sunshine to provide any deliverable heat.
- Season-dependent heating
  The panel must deliver maximum heat during winter, and a minimum in summer.
- Maximum reliability
  The panel must have no moving parts to wear out or fail, and must operate dependably in untended situations.
- Long service life
  The panel should last at least as long as the structure it heats.
- Minimum maintenance
  The panel should operate at full efficiency for extended periods of time without needing servicing.
- Low-cost
  The panel must provide the fastest payback when compared to all other heating systems.
methods, and must incur no expense after purchase and installation.

My attitude was that I would take as long as needed to get the job done – and that it would cost whatever it cost. There was the possibility that I might run out of resources without achieving recognizable success, but the possible benefits of success seemed to far outweigh the risk of failure.

It took eight years of full-time effort to satisfy all seven of my original requirements – I’m delighted that the final result far exceeds my original expectations and, in retrospect, I’m surprised by how much I was obliged to learn about things that I hadn’t known would have any bearing on the task.

One of my preconceptions was that, for a conventional structure, I would only be able to reduce the loading on a conventional heating system. The conventionally-built structure in the photo above is heated only with a pair of passive solar panels and its indoor temperature has remained above 65°F/18°C since construction was completed in early 2007. I believe (but can’t prove) that if the overhead door in the demonstration building were kept closed, the indoor temperature in winter would never drop below 80°F/27°C.

One of the things I learned is that a “no-brainer” attitude almost guarantees a poor result. My intention here is to provide basic information you’ll need, but you will need to make the effort to arrive at your own understanding of this information so you can put it to use.

If you learn what I learned, then you should be able to do as good a job as I was able to do – but if you can use this as a starting point for additional knowledge and understanding, then you’re invited to do an even better job and to share what you learn so that everyone benefits from our efforts.

Now, what we have to work with is sunshine, air, and the materials we use to build our panel – so it would seem a good idea to understand them as well as we can...

3-Air Properties

Air has four properties that are of particular interest in our context:

- When air is warmed it becomes less dense (expands), and so it rises above cooler, more dense, air.
- There is friction between moving air and any surface which will act to impede the flow near the surface. This is called the laminar flow effect.
- Also when air is warmed it becomes more viscous (“sticky/gooey”), rather than less – a behavior that is exactly the opposite of most familiar materials.
- When air is in contact with a hot surface, these properties act together to produce a layer of viscous low-density air that “sticks” to the surface. This is called the boundary layer effect, and its thickness depends on the temperature at the surface/air interface.

The first of these properties, the buoyancy of heated air, makes a passive solar heating panel possible, so we want to take advantage of it as much as possible – but all the other properties act to inhibit airflow and rob the panel of efficiency, so we want to do everything we can to minimize their effects.

At first glance this seems contradictory, because the buoyancy that produces the airflow and the properties that work against it all result from warming the air. What I learned is that it’s possible to keep the buoyancy while minimizing the inhibiting effects. Before I can discuss that, though, we’ll need to take a look at what else is going on inside the panel.

4-Sunshine

A photon consists of the smallest possible amount of energy (less than a whole photon would be zero and more than a photon would be multiple photons), and can be thought of as being so small that it doesn’t have physical dimensions.

When a photon impinges on an object, it can either be reflected – or it can be absorbed, by which I mean that its energy remains within the object. In every instance, some photons are reflected and some are absorbed.

In our passive solar heating panel context, of course, we care very much about absorption and reflection.

The object on which photon impinges is made up of atoms – has mass, and we need to take a brief look at the interaction between photons and the mass.
5-Energy and Mass

It’s very important to distinguish between heat (which is energy) and temperature (which is a ratio of energy per unit of mass). To illustrate, imagine holding a sewing pin with a pair of pliers and heating it until it glows red hot (about 100°F/550°C) – then dropping the red hot pin into a teacup filled with cold water. All of the heat concentrated in the small mass of the pin went into the water, but that heat was not enough to make the much larger mass of water noticeably warmer to the touch.

Every object absorbs energy from its environment and every object whose temperature is above absolute zero gives off (radiates) energy to its environment at a rate determined by its temperature – the hotter the object, the faster energy is emitted.

If the object is warmer than the environment, it will emit more energy than it absorbs, and if it is cooler than its environment it will absorb more energy than it emits. In a closed system, energy will be exchanged between object and environment until an equilibrium is reached in which the amount of energy emitted by the object will equal the amount of energy absorbed.

6- Literature-

The double-flowtype SAHs have been introduced for increasing the heat-transfer area, leading to improved thermal performance. The increases of thermal energy between the absorber plate and the air, which clearly improves the thermal performances of the solar collectors with obstacles arranged into the air channel duct. Ghoneim investigated the effects of gap thickness on the performance of compound honeycomb using the solar collector. Sadasuke et al. are made on the performance of a collector with a flow in the upper channel on the absorber plate as well as in the lower channel.

Njomo examined the unsteady state heat exchanges governing the functioning of an unglazed one-pass SAH utilizing a non-porous selective absorber. The mathematical model developed is then used to predict the thermal performances of such a collector. Karim and Hawlader investigated both experimentally and theoretically in an effort to improve the performance of conventional air heaters using finned and v-corrugated air heaters. Ramadan et al. examined experimentally and theoretically thermal performance of a double-gllass double-pass SAH with a packed bed above the heater absorber plate.

This paper presents an analysis of efficiency evaluation of a new double-flow SAH. Three different absorbing plates have been used in this study. This SAH with an absorber plate made of aluminum cans, the thermal performance evaluation and a comparison of its thermal efficiency against the efficiencies of other collectors with different absorber plate designs reported in the literature.

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