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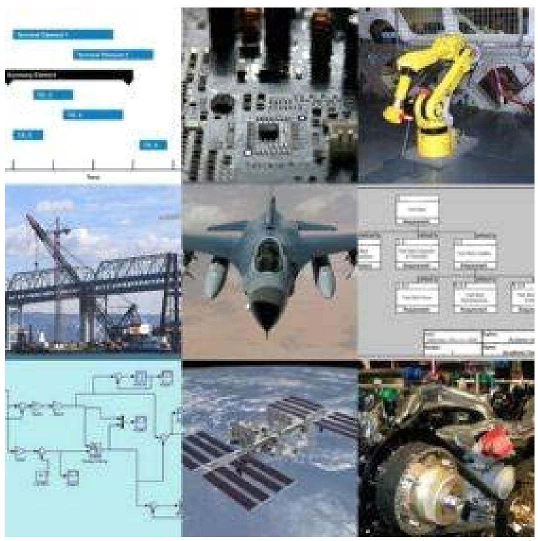

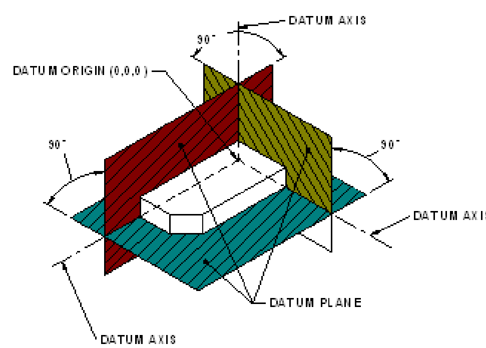

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An Introduction to Solar Energy System Fundamentals

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1. INTRODUCTION. A solar thermal energy collection system (or "solar system" for short) is defined as a set of equipment that intercepts incident solar radiation and stores it as useful thermal energy to offset or eliminate the need for fossil fuel consumption. Four basic functions are performed by a typical solar system. For this publication, each function is defined within specific sub-systems of a typical solar energy system as illustrated in Figure 1 and discussed below.

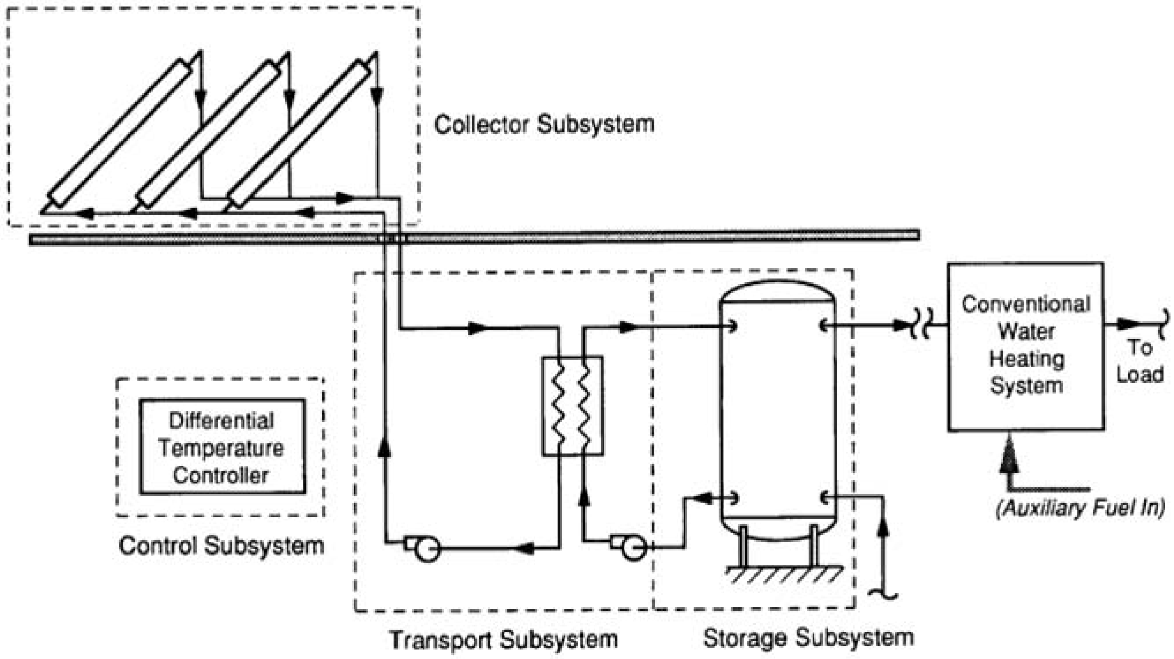

Figure 1

Typical solar thermal energy system

1.1 COLLECTOR SUB-SYSTEM. The collector sub-system intercepts incident solar radiation and transfers it as thermal energy to a working fluid. It is defined as the solar collectors, the hardware necessary to support the solar collectors, and all interconnecting piping and fittings required exterior to the building housing the system.

1.2 STORAGE SUB-SYSTEM. The storage sub-system retains collected thermal energy for later use by the process load. It is defined as a storage tank and its fittings, as well as necessary supports.

1.3 TRANSPORT SUB-SYSTEM. The transport sub-system delivers energy from the collectors to storage. This sub-system is defined to include the heat transfer (or working) fluid, pump(s), the remaining system piping and fittings, an expansion tank, and a heat exchanger (if required).

1.4 CONTROL SUB-SYSTEM. The control sub-system must first determine when enough energy is available for collection. It must then activate the entire system to collect this energy until it is no longer available as a net energy gain. The control subsystem thus consists of electronic temperature sensors, a main controlling unit that analyzes the data available from the temperature sensors, and the particular control strategy used by the controller.

2. SOLAR ENERGY APPLICATIONS

2.1 TYPES OF LOADS. Due to the intermittent and varying amounts of solar radiation available, solar systems used to heat service water are usually not intended to meet the full thermal energy demands of the process being served. For any given thermal load, an integrated system should be designed which consists of both a solar energy collection system and a backup system that can meet the full load requirements. The solar system size and configuration will be a function of the annual or monthly energy loads. It is up to the designer to specify a system that will be expected to provide a given fraction of this load. This is in contrast to the design of a conventional heating, ventilation, and air-conditioning (HVAC) system, which is typically sized to meet an anticipated maximum or design load with no provision to be augmented by another source. For this reason, solar systems are often sized to meet the average expected load. Important characteristics of a load include the amount of energy required, the time of the demand (load schedule), and the temperature range required. Each of these factors is discussed below solar service water applications.

2.2 SERVICE WATER HEATING. Heating domestic hot water and low-temperature process water (both referred to as service water heating) will normally be the most thermally efficient means of using solar energy. The reason is that the demand for thermal energy for these applications is approximately constant during the entire year, with the result that auxiliary fuel savings can be realized over the year. In the preheat configuration, solar heated water is useful at any temperature above that of the incoming water. An additional benefit is that, when preheating process hot water, thermal energy may be delivered at a relatively low temperature, which increases the efficiency of the solar collection process.

3. BASIC MATERIAL CONSIDERATIONS IN SOLAR ENERGY SYSTEMS. The designer should be alert to fundamental materials problems that can occur with solar energy systems, and careful attention must be given to the materials and fluids used. Large temperature fluctuations, severe ambient weather conditions, and the variety of possible fluids and metals that can come in contact with each other are often a cause of system failure. Some of the basic issues that must be addressed are discussed briefly below.

3.1 METALLIC CORROSION AND EROSION. Common causes of corrosion include the presence of dissimilar metals (galvanic corrosion), the presence of dissolved oxygen, or fluids with a chemical composition that adversely affects the wetted metal surface. Corrosion may be minimized in solar systems by avoiding dissimilar metals, decreasing the amount of available dissolved oxygen, and treating particularly corrosive fluids with inhibitors (However, when using a non-toxic fluid, inhibitors should be avoided since they require considerable maintenance and often become mildly toxic upon degradation). Metallic erosion can occur in the system piping if excessive fluid velocities occur. For the copper piping required for solar systems designed under this guidance, a velocity limit of 5 feet per second is to be used. Maximum allowable fluid velocities are dependent upon the type of metal used. Correct pipe sizing and analysis of fluid flow paths should be used to avoid this problem.

3.2 SCALING. Scaling commonly refers to mineral deposits, such as calcium and magnesium compounds, that collect and adhere to pipe interiors and equipment. Scaling is promoted in systems by increased temperatures, high mineral concentrations and high (alkaline) pH levels. The result of scaling is flow restriction, high fluid velocities, and a decreased heat transfer rate. Scaling problems are most often associated with poor-quality water supplies and can be avoided by proper analysis and treatment of fluids to be used in the system.

3.3 THERMAL EXPANSION. Differences between thermal rates of expansion for dissimilar materials often cause problems throughout a solar system. This publication addresses the thermal expansion issue for locations in the system where the most problems occur.

4. COLLECTOR SUB-SYSTEM

4.1 DEFINIT … structure,
and all piping … outlet.
For roof-mou … roofline.

4.2 SOLAR …

4.2.1 OPER … cases,
diffuse) radia … id. While
there are ma … ts in
common. The … n to
thermal ener … urface to
be transferre … ally used
to decrease t … rking fluid
as possible. … mbient
conditions ra … peratures
as high as 35 …

4.2.2 COLL … ost often
are flat-plate … s. A
general desc …

4.2.2.1 FLAT-PLATE. … d and are best suited for low temperature heating applications, such as service water and space heating. These collectors usually consist of four basic components: casing, back insulation, absorber plate assembly, and a transparent cover. The absorber panel is a flat surface that is coated with a material that readily absorbs solar radiation in the thermal spectrum. Some coatings, known as "selective surfaces", have the further advantage of radiating very little of the absorbed energy back to the environment. Channels located along the surface or within the absorber plate allow the working fluid to circulate. Energy absorbed by the panel