FRESNEL CONCENTRATING COLLECTOR

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INTRODUCTION

During the oil embargo of 1973-74, the Northeastern part of our country was shown to be particularly vulnerable to shortages of fossil fuels which, for the most part, were coming from overseas sources. Other energy technologies had to be found. To displace fuels in many applications, though, alternative energy sources had to be able to deliver high quality energy reliably. Therefore, even though the direct sunlight available in the Northeast may only total one half that available in the sunniest region of our country, there appeared to be a real potential for cost effective solar hardware even seven years ago. The energy user who could diversify into alternative energy sources could reduce the impact of sudden fuel price increases and also reduce the risks of having to shutdown operations because of a lack of sufficient heat, process steam or conventional cooling.

The two major hurdles we had to overcome before we could begin an extensive effort to produce active alternative energy equipment were:

1. To provide solar energy even during the hard cold weather for which the northeast is infamous, and

2. To provide this alternative energy at a price competitive with traditional fuels.

With energy consumption increasing worldwide we believed that, in a reasonable amount of time, prices of traditional fuels would increase sufficiently to make focused solar energy a viable alternative.

Concentrating the sun allows heat losses to be minimized once the energy has been captured. Therefore, even sunlight during the winter months could be utilized. With the sun's energy being reflected from 864 square feet of mirrored surface onto a few square feet of heat transfer material, subzero temperatures become less of a factor in useful energy production.

Although focusing the sun overcame our first perceived hurdle without difficulty, it tended to amplify the effects of the second hurdle. Any complexity added to solar energy equipment increases the already large front-end costs associated with equipment which gathers significant quantities of low density energy. Our research efforts over the last seven years, for the most part, were directed towards the need to develop mechanical and procedural methods for reducing hardware costs. See figure 1.

HARDWARE DESIGN

Major goals which directed our efforts in engineering cost effective designs for concentrating solar energy were:

1. The minimization of the overall weight of the solar energy collection equipment,while utilizing inexpensive materials;

2. The simplification of components and optimization of the number of different parts along with the manufacturing procedures needed to produce them;

3. The embodiment of designs which can be readily shipped, rapidly assembled and optically aligned, easily tested and quickly repaired by available labor; and

4. The incorporation of features and components which augment reliable, safe and durable operation.

Minimizing the weight of the collector prescribed the implementation of two concepts:

1. The distribution of forces from wind and gravity loading on the equipment, and

2. The use of a Fresnel concept.

Distributing the forces of wind and gravity over many parts allows lightweight components to be adequate for bearing the six tons of force anticipated from a 90 mph wind. The Fresnel concept is complementary to the concept of distributed loading. Eight thin one foot square mirror tiles treated for outdoor use have been supported by lightweight aluminum stressed-skin support panels which are pivoted on their centers of gravity to produce the motion necessary for elevation tracking. Using the Fresnel mirror concept and distributed loading permits wind to pass through the collector structure when the mirrored columns are positioned to "feather" in the wind like open Venetian blinds. The small surface area of each column allows common materials and construction techniques to meet the demands on these parts for stability and durability. Consequently, material weight is minimized and the corresponding cost associated with material quantity avoided.

The simplification of components and their material manufacturing processes was aided by several iterations of design, and construction of several generations of prototype equipment. Our current designs use large numbers of identical parts. Because the demands for strength in any one of these parts is small, exotic materials are avoided. During the installation of equipment at a site, special erection equipment is usually unnecessary due to the manageable size of individual parts. We found these choices in design promoting our goals for reducing the overall installed cost of equipment.

The embodiment of practical aspects of design which provide the packer, shipper, site erection crew and operator with items which make their jobs easy, promotes acceptance of the technology and enhancesits cost/benefit ratio.

We have found that by incorporating operational schemes, such as keeping the reflector surface upside down except during operation, limits reflector exposure to dust, ice, snow and vandals and enhances safety. Upon loss of power or occurence of other stow parameters, the unit returns the mirrors to this inverted position "over the top" so that the intense focused radiation at no time comes below the receiver. The design of other components and software subroutines incorporates this kind of failsafe orientation. We have found that "add on" safety packages are seldom as reliable, and have an undesirable "add on" cost.

Although developing the objectives for our goals demanded more common sense than any other resource, the technical capabilities of Rensselaer Polytechnic Institute, the organization within which we performed our research, were essential to every stage of finalizing and testing component designs. With the right combination of simplicity and complexity, we believe we have achieved a design for collecting solar energy which is compatible with the special needs of our region of this country.

SYSTEM TESTING

Based on the preliminary work and receiver heat transfer analysis, two receiver designs were selected for manufacture and testing. The first was a conically wound copper monotube boiler with 30 degree cone half angle, and the second, a steam unit heater employing steel tubes with aluminum fins. (See Figs. 2 & 3).

Solar energy input was determined by an Eppley normal incidence pyrheliometer with a 5 1/2 degree aperture which had been recently calibrated by the Atmospheric Sciences Research Center in Albany, N.Y. This was coupled to a strip chart recorder which provided a record of instantaneous insolation readings. Integrated values corresponding to the discrete time periods for collector output measurements are utilized to calculate collector efficiencies throughout the day.

Output was determined by measurement of the quantity of water converted to steam and the pressure of the saturated steam transferred to the RPI steam system. System efficiency figures include losses from 120 feet of insulated steam line. Water flow was calculated by two methods: 1) by a Badger Recordall Flowmeter and 2) by measurement of lost weight from the boiler feed tank. The test fluid loop is illustrated in Figure 4 . Note that steam condensate is returned to the boiler feed tank from the steam trap. In the test of the fin tube boiler, the variation of efficiencies to some extent are a function of water source. That is, part of the time water is fed directly to the boiler from the city water supply at 60F. When sufficient condensate accumulated in the feed tank, the water source was switched to the feed tank at >150F.

The results of performance testing of these boilers are presented in Figures 5 and 6 . The fin tube boiler exhibited an average daily efficiency of 57%. The conical monotube boiler had an average daily efficiency of 68% and a peak efficiency of 79%. The graph of the test results indicates the dependence of efficiency on solar conditions. The collector has an effective aperture much less than the pyrheliometer. Thus the pyrheliometer accepts a greater amount of circumsolar radiation.

Significant improvements in performance can be expected when the department store mirror tiles are replaced by thin low iron glass mirrors with 10% better reflectivity. Also, the forming of the curves of the reflector columns to more precise tolerances are now possible which will result in an additionalimprovement in performance.The fin tube boiler had very wide fins between and in front of the fluid tubes, which contributed to enhanced convective losses. The use of copper fins would improve the performance of this type of receiver.

CONCLUSION

This advanced point focusing solar technology has demonstrated potential for near term commercialization as an effective renewable energy technology. The unique design features combine to produce a highly-efficient, low cost, safe, adaptable, durable system which is simple to manufacture, install and maintain.

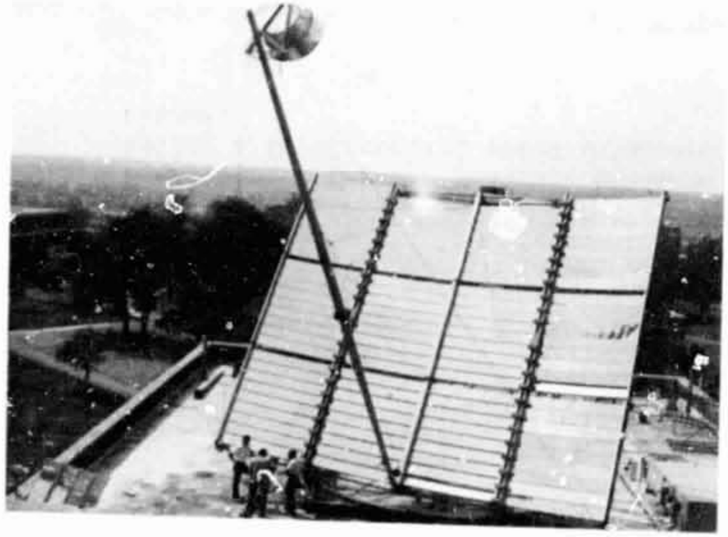


Figure 1: 80 SQUARE METER FRESNEL CONCENTRATING SOLAR COLLECTOR

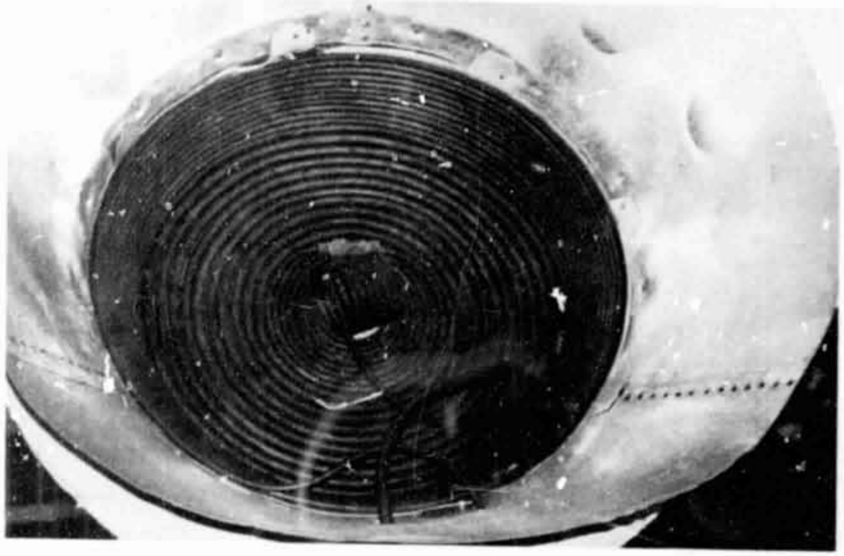


Figure 2: CONICAL MONOTUBE RECEIVER

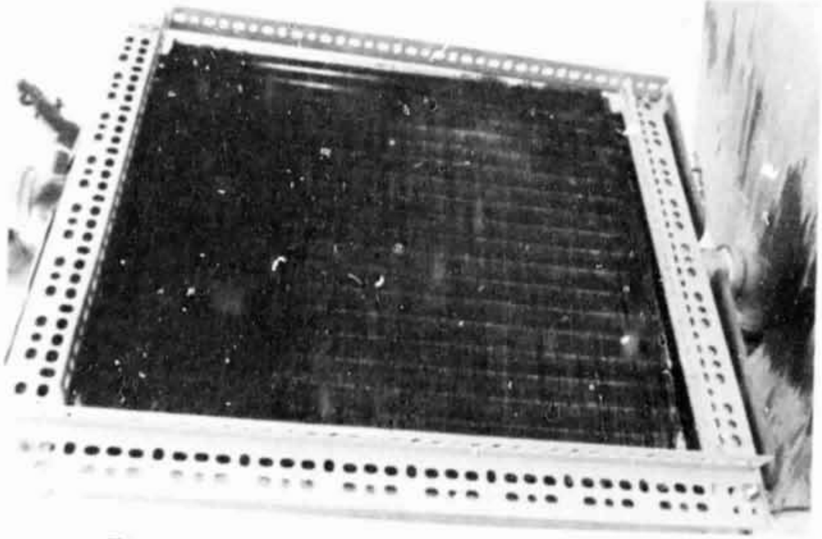
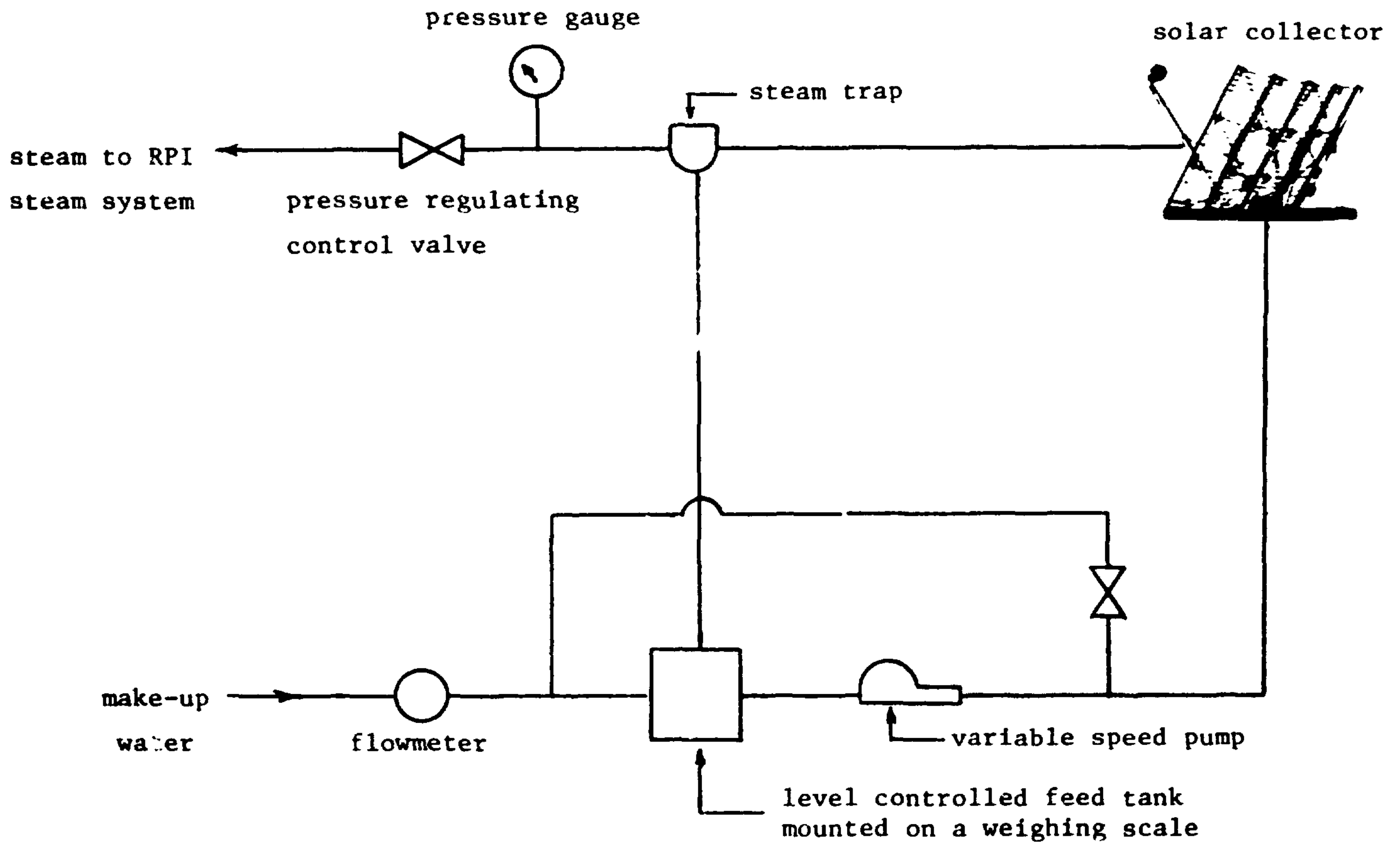


Figure 3: PARALLEL FIN TUBE RECEIVER



NOTE: Feed control for the monotube boilers is provided by the variable speed pump. For the fin tube boiler a level control valve maintains fluid level in the boiler and steam is taken off the top header.

Figure 4: POINT-FOCUSING SOLAR COLLECTOR TEST FLUID LOOP

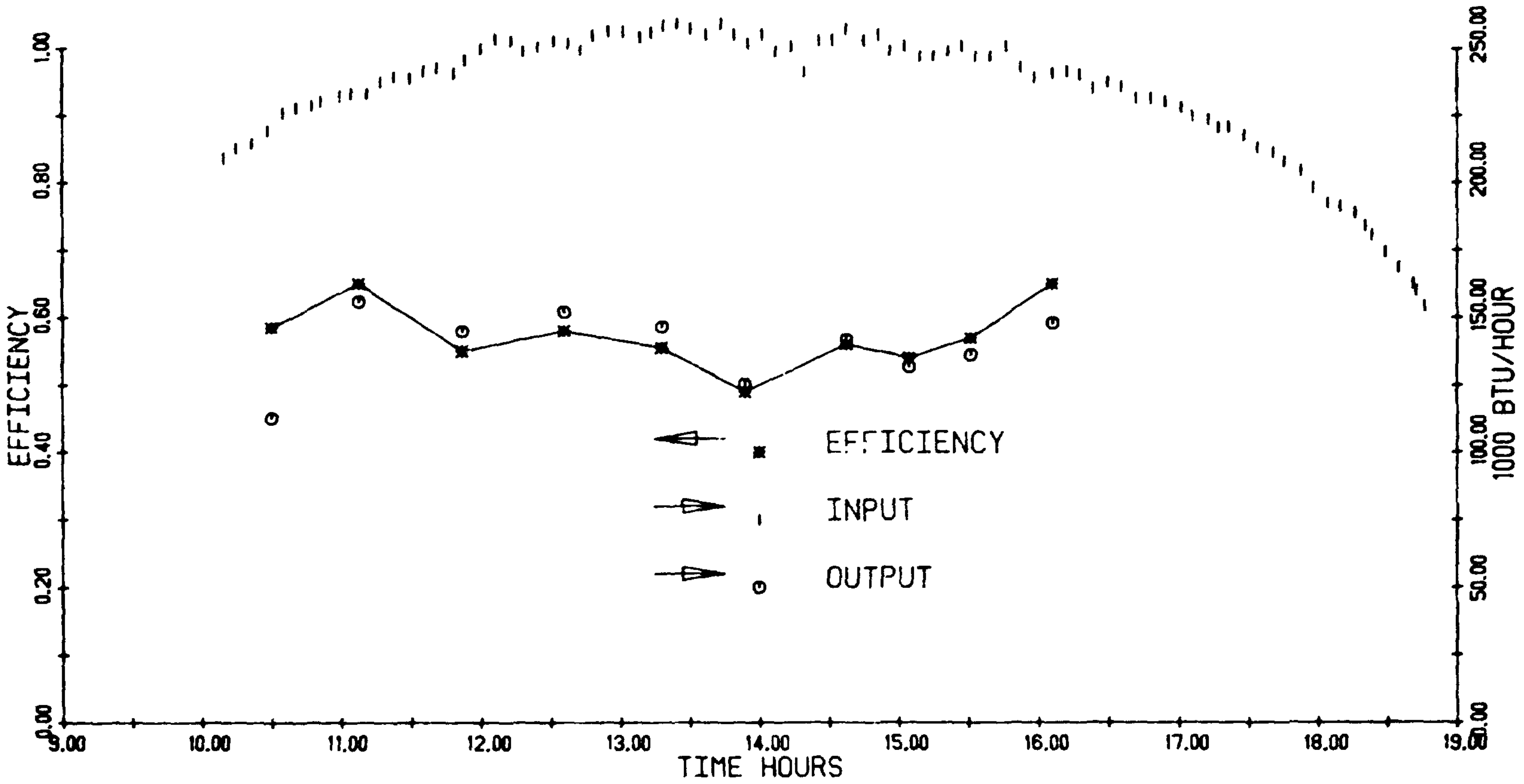


Figure 5: AVERAGE EFFICIENCY VS TIME 250 F STEAM OUTPUT, OCTOBER 9, 1980

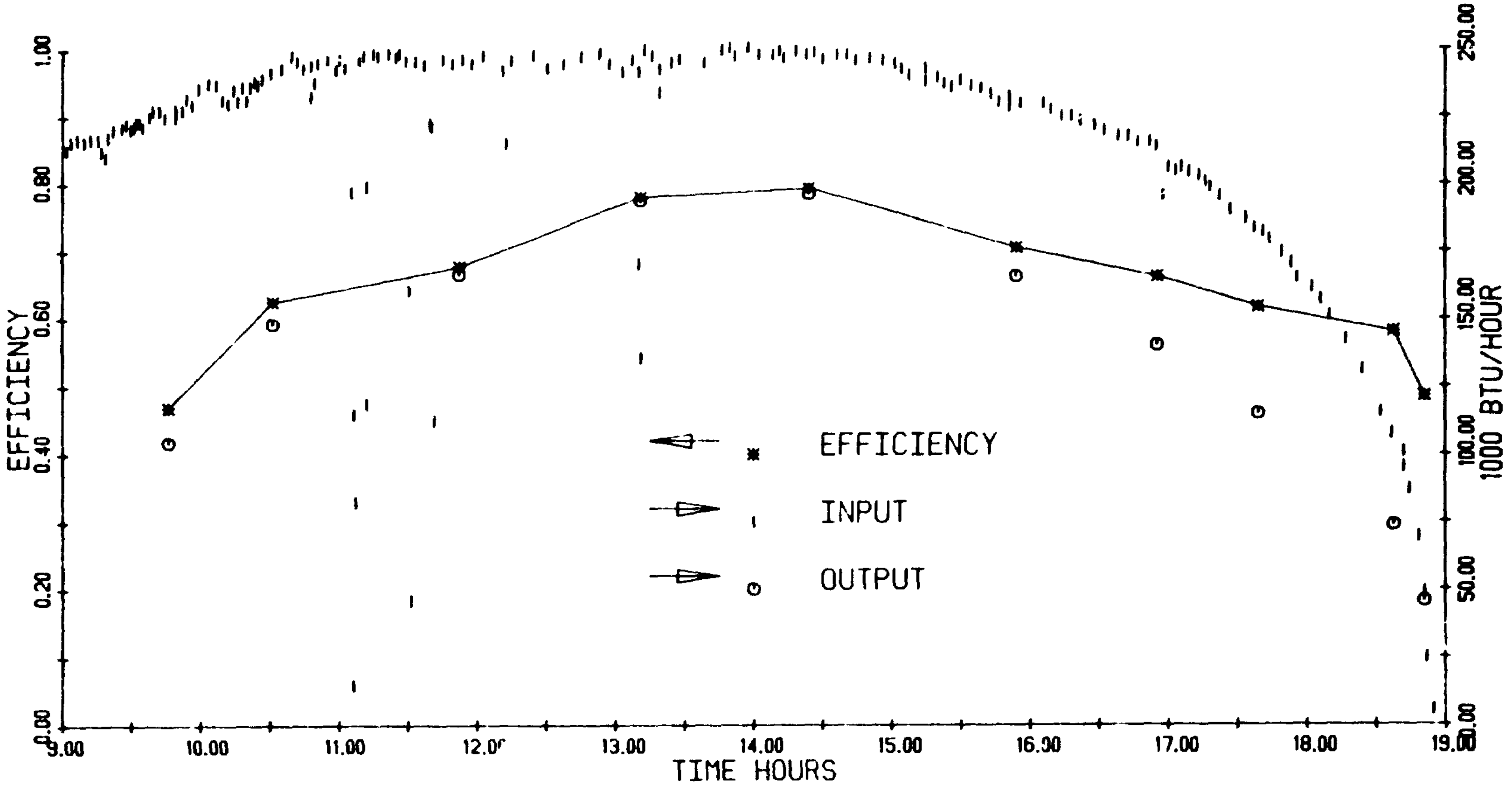


Figure 6: AVERAGE EFFICIENCY VS TIME 250 F STEAM OUTPUT, SEPTEMBER 8, 1980