A STUDY OF MASS PRODUCTION AND INSTALLATION OF SMALL SOLAR THERMAL ELECTRIC POWER SYSTEMS

J. Butterfield
Arthur D. Little, Inc.
One Maritime Plaza
San Francisco, California

ABSTRACT

This study of concentrating collector industrialization included technological constraints, materials availability, production capacity, and manufacturing and installations plans and costs at different production levels. Several constraints were identified.

Cobalt, for the engine and receiver, is supply limited. Alternative lower temperature alloys and higher temperature materials (ceramics) are discussed. Economics and production efficiency favor co-location of cellular and thin glass production for reflectors. Assembly and installation are expensive for small sites and few alternatives exist to apply mass production techniques to lower these costs for the selected design. Stepping motors in the size and quantities required are not commercially available today but could be in the future.

The study concluded that additional development should be concentrated on design modification to permit industrialization of the assembly and installation process, the use of alternative materials in the engine/receiver subsystem, the design of motors and gearboxes matched to concentrator requirements, and development of an integrated process for reflector production.

PROJECT DESCRIPTION

This project is based on a conceptual design of a concentrating solar collector system developed by Jet Propulsion Laboratories. The hardware elements of the system were divided into four basic component packages:

- Power Conversion Component -- including the receiver, engine, and generator units.

- Reflector Component -- including second surface "thin" glass mirrors, cellular glass support gores, and mounting hardware.

- Structure and Foundations Component -- including receiver and engine support structure, reflector support ring structure, ballast support structure, intermediate structure, pedestal, pedestal foundation, and intermediate structure track and foundation.

- Drive and Control Component -- including the elevation actuator, azimuth drive, two-axis shadow band sun sensor, on-board controller, and power communication connections.

Each component was described in terms of the process steps and materials and equipment needed for the manufacture of 5,000, 50,000, and 500,000 concentrators per year. The transportation requirements from points of manufacture to installation sites and the on-site assembly and installation processes and techniques were also developed. Based on the criteria established for concentrating collector systems, the maximum size of any one site would be 500 collectors or approximately 10 megawatts electric.

INDUSTRIALIZATION ISSUES

Materials-related Issues

In the course of the analysis two components of the system were found to be resource limited -- the receiver and buffer storage units of the power conversion package and the stepping motors and generator of both the drive and control and power conversion components. In both instances cobalt was the material in short supply that would tend to limit industrialization.

The receiver and buffer storage units use cobalt in a high-temperature superalloy called Haynes 188. At the intermediate volume level, 50,000 units per year, the concentrator manufacturer would use 27% of domestic cobalt consumption; at 500,000 units per year the requirement would be 83% of the world's annual use. Since the dedication of these quantities of cobalt for concentrator systems is unrealistic in view of the current priority uses of cobalt, two other high-temperature alloys were investigated and found to be practical if the design temperature were lowered by $100^{\circ}F$. These alloys are Inconel 601 and Incoloy 800H.

In addition to being commercially available in the necessary quantities, these alloys possess two other advantages; they are considerably less expensive and more workable than the cobalt alloy. In the longer term, ceramics -- particularly sintered silicon carbide and hot pressed silicon nitride -- offer both cost and higher operating temperature advantages. However, 10-20 years of research and development will be needed to develop the strength requirements necessary for solar applications and the processing technology to obtain net or near net shapes in ceramic products.

The generator in the power conversion component and both of the stepping motor drives use cobalt in their permanent magnets. Although the quantity of cobalt in any one unit is relatively small, at the higher volume levels the total material requirement is significant. However, alternative designs using wound coil units have been designed and produced commercially. Although such units carry a premium cost, they have an offsetting advantage of being capable of higher torque than units currently produced with permanent magnets. Higher torque drives, in turn, permit simplification of the gear drive units without significant degradation in the pointing accuracy of the drives.

Process Technology Issues

Although the manufacturing technology for all of the components of a concentrating collector system exists in industry today, two important developments must still be made. In the case of the power conversion component, the majority of the elements, although similar to automotive, aircraft, or gas turbine technology, contain one or two differences which will limit volume production. The first is industrial capacity. For the cellular glass gores, the thin glass reflector, the engine recuperator, receiver, and buffer storage units and stepping motors, industrial capacity exists to fabricate the units needed for the collector system at the 5000 unit annual volume but not at the 50,000 unit per year level. In some instances, such as for reflectors, it can be argued that the separate locations of existing industrial production are inappropriate for the process needs of solar collectors. Nevertheless, in virtually every instance the potential fabricators of the units or subsystems would be drawn into plant and equipment investments based on the growth of viable collector system business.

A separate problem exists for components such as structures and foundations. The components of a collector system are by design high bulk-low value elements. As a result, it is highly desirable, indeed necessary, to subcontract or otherwise locate the production facilities for these components on a regional basis to minimize transport costs. At higher volumes of production this poses little if any problem but at the lower end of the volume scale, transportation costs represent an impediment to industrialization.

Site-specific Issues

The conceptual design of the concentrating collector employs an 11-meter diameter dish, long and heavy structural components, and components such as reinforced precast concrete foundations and drive, control, and power conversion packages that are unlikely to be fabricated in the same production plants. As a result large concentrator systems are not transportable when fully assembled; therefore, a site assembly process is required. In addition, since alignment of the reflector panels, engine, and sun sensing mechanism is critical, a portion of the assembly process on site must be conducted in a protected environment. When this factor is combined with the relatively small number of units to be located at any one site, the result is not only a relatively costly assembly and installation charge but also an essentially flat cost curve relative to increasing annual production volumes.

Concentrator Costs

A summary of the costs associated with an installed collector is contained in Table 1 below.

TABLE 1

SUMMARY OF COMPONENT AND PROCESS COSTS FOR
THE CONCEPTUAL DESIGN OF A CONCENTRATING SOLAR COLLECTOR

	Per Unit Costs in Third Quarter 1979 Dollars		
	5,000 Concentrator Units/Yr	50,000 Concentrator Units/Yr	500,000 Concentrator Units/Yr
Power Conversion Component	$25,250	$12,300	$ 6,925
Reflector Component	2,136	1,747	1,747
Structure, Foundation, Assembly, and Installation	16,080	12,706	12,592
Drives and Controls	5,366	4,174	3,656
Installed Cost/Concentrator	$48,832	$30,927	$24,920

As can be seen, the components which are produced in traditional manufacturing plants such as the power conversion package, drives and controls, and reflectors demonstrate cost reductions with increasing volume. Costs for the structures, foundation, assembly, and installation, however, are relatively constant at high and intermediate volumes and are sharply increased at low volumes due to the higher costs of fabricated structural elements and transportation and limited applicability of "mass production" techniques.

AREAS FOR FURTHER RESEARCH

Since the conceptual design for a concentrating collector system is but the first in a series of designs, the costs estimated in this study should be utilized as an indication of where effort should be expended to achieve cost reductions rather than as absolute or immutable values. Based on these costs the primary benefits of redesign efforts or of alternative designs may be experienced by increasing the industrialization associated with structures, foundations, assembly, and installation. Three possibilities suggest themselves:

- Smaller concentrators which require less field assembly and installation processing may permit reductions in cost with increasing volume.

- Larger sites of up to and over 50 megawatts electric will favor mechanization and automation of site processes and tend to drive costs lower.

- Alternative designs that permit subassembly of component parts of a collector system in the fabrication plants will permit reductions in site-related activities and, more importantly, will tend to retain collector costs on an experience curve related to volumes produced.

In addition to the points indicated above, other components of the collector system will either require or benefit from further development activity. These include:

- Directed development of ceramics for the receiver and buffer storage units.

- The involvement in the engine development program of alternative suppliers to increase the source availability.

- Co-development of drive motor and gearbox packages matched to meet both the torque and accuracy requirements of a collector system.

- Integrated process development for complete reflector panels. This would include gore fabrication and shaping, "thin" glass fabrication and mirroring, lamination of the two components, sealing, hardware installation, and environmental testing.