CAPITOL COMPLEX SOLAR ENERGY PROJECT REPORT

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This is a report by the Department of General Services to the Capitol Planning Commission on the Solar Energy Project on the Capitol Complex, and it does not necessarily represent any official position by the State in regard to the potential use of solar energy in general.

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HISTORY

Early in 1974 an energy study of the Capitol Complex was initiated jointly by the Department of General Services and the Capitol Planning Commission. The study identified the then current energy demands and projected what the impact would be of the addition of the Wallace and Hoover Buildings to the Complex. It was also important to try to determine what the best source of energy would be through the remaining 70's, the 80's and the 90's. The results of the study were the guidelines for planning the new buildings and the Power Plant.

Solar energy was given brief consideration as a prime energy source, but was quickly rejected. One of the main reasons was that at the time of the study there was no known proven solar technology that operated in the 350°F to 400°F range, producing the 115lb steam requirements of our boilers and steam lines. Although there were no known operating systems, sufficient theoretical information was received to warrant further study.

In August 1974 we received a feasibility study on the use of solar energy for the Capitol Complex. This study was prepared for the State by Environmental Consulting Services, Inc. of Boulder, Colorado. The study suggested that parabolic concentrating units, 12 feet in diameter, might be a feasible solar energy system that could supplement our energy requirements.

This solar energy study convinced us that we should follow up the recommendations and attempt to obtain funds to install and monitor a modest system of 2,000 square feet of concentrators. If a small installation proved successful, consideration could be given to expand up in the range of 200,000 square feet. The estimated cost of a demonstration system was $200,000 and this amount was appropriated by the Legislature in 1975.

The search for a system began. The following general guidelines were established:

1) The system should be capable of being expanded to 200,000 square feet or more.

2) The design should be simple and uncomplicated.

3) There should be simple maintenance requirements.

4) The system should adhere to sound principles of solar concentration.

5) There should be a low cost of operation.

6) Search for well established companies that could make a long term investment in R&D.

7) Search for companies that were in a sound financial condition.

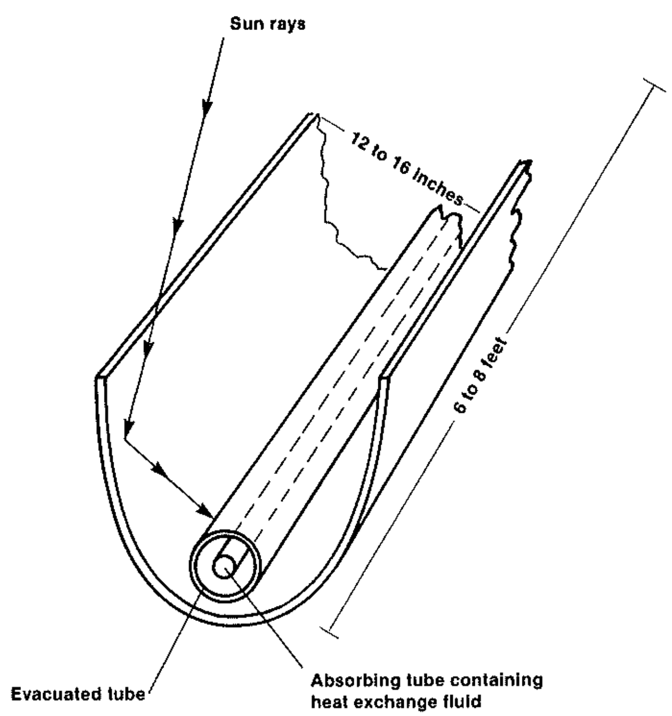
8) Search for companies that offered a strong committment to solar energy

9) And that the system should work.

The 12 foot parabolic dish concept was quickly rejected as not being a feasible design that could expand well to a large scale installation. The principle of a parabolic dish was supplanted by that of a long parabolic trough, with an aperture of perhaps 12 to 16 inches.

The parabolic configuration was selected because rays of the sun coming from a wide range of angles are all reflected to a common point.

By placing an absorbing tube filled with a circulating fluid at this focal point, the fluid would be heated by the sun's rays and pumped to a heat exchanger. There the heat extracted from the fluid would convert water into steam and then the fluid would be returned to the absorber to be reheated.



Parabolic Trough

After the principles of the system were established, the search began for a manufacturer who was interested in producing the units and eventually marketing the system. In 1975 and in 1976 there were very few manufacturers that could come close to meeting our guidelines. We had to seek out and encourage Chamberlain Manufacturing Company to speed up their Research and Development. Their research team said no, their marketing team said go. We finally convinced them we were serious and willing to be part of their R&D.

This in turn led to a request from Chamberlain that we try to convince the General Electric Company to also speed their R&D on the GE evacuated tube that would be placed at the focal point of the Chamberlain parabolic trough. At that time GE was the only company that would even talk to Chamberlain about producing a tube and they were moving very slowly. In fact, GE had in essence turned Chamberlain down. We initiated discussions with GE urging them to shift gears. Sometime late in 1976 or early 1977 they agreed to supply tubes to Chamberlain and the project moved forward.

In 1977 the State of Iowa supported Chamberlain's and General Electric's joint proposal to ERDA for a grant of $385,000 to develop a compound parabolic concentrator with an evacuated tube absorber. In 1978 the grant was awarded.

The system design and fabrication proceeded and was successfully tested. Based upon the promising test data, in 1979 the State again actively supported a request by Chamberlain/GE to the now Department of Energy to fund an installation of 2,000 square feet of this system on the Capitol Complex.

The Department of Energy decided to walk away from their initial investment and declined to fund any further.

The Department of General Services requested a State Appropriation for this system, but this request got caught in all the other 1980 budget cuts and no funds were made available.

After the initial decision that ruled out the parabolic dish, we examined several concepts in addition to the parabolic trough described above. Concurrent with progress on the trough, in 1976 we became aware of an entirely different solar approach. This system designated as the Solar Linear Array Thermal System, acronym SLATS, consisted of a battery of 20 foot long mirrors that reflected the sun's rays back out in front of the mirrors and focused on an absorbing tube containing a heat exchanging fluid.

This system was being developed by the Sheldahl Corporation located in Northfield, Minnesota. Because the Company and the system met all our guidelines we visited the Sheldahl Plant in Minnesota and observed a small scale installation in operation. The preliminary performance data appeared promising. In 1976, SLATS was the only system that we knew of that had the promise of fabrication and delivery of 2,000 square feet sometime in the near future. We gave Sheldahl strong encouragement to proceed.

Sheldahl did proceed and had a demonstration unit sent to Sandia Laboratories in Albuquerque, New Mexico for testing.

In 1977 together with our consulting engineers who assisted us, we went to Sandia and attended the final presentation and analysis of the data obtained from the test period. Based upon the recommendations of our engineers, in 1977 an order was placed for a 2,000 square foot installation of SLATS. By that time, Sheldahl had spun off their solar project to form a new small company, Suntec, officed in St. Paul, Minnesota.

In 1977 we knew of no other system available on the scale we wanted that showed more promise of success. Further, knowing of the concurrent development of the compound parabolic trough and evacuated tube it was our plan to eventually install and test the two different solar technologies side by side. A project unique anywhere in the world.

Construction began in 1978 but was then delayed for almost a year due to problems in the fabrication of the mirrors. The mirrors were finally installed in mid 1979 and the system began operating under the restrictions of not having the operating controls completely installed.

It wasn't until early 1980 that we could begin collecting meaningful data.

SOLAR RADIATION AND ITS CONVERSION

Solar radiation as it passes through the earth's atmosphere is scattered to varying degrees in all directions by dust, haze, water droplets and other fine particles of materials in the atmosphere. It is this diffusion of the sun's radiation that causes the sky to appear blue on clear days. Some of the energy of this diffuse radiation reaches the surface of the earth and can be captured and converted to heat energy by flat plate solar collectors.

There is a second component of solar radiation, the direct or beam radiation, the type of sunlight that can cast a shadow. This type of radiation can be reflected from a large surface to a smaller surface and thereby concentrate the solar energy.

Clouds can block direct radiation and thus solar concentrating systems are degraded in a direct manner by increasing cloud cover. Solar concentrators do not collect diffuse radiation. Flat plates collect both diffuse and direct.

The amount of total solar energy available at any spot on earth varies depending upon the latitude, the season, the angle the sun's rays strike the surface, and of course the time of the day. Assuming the latitude of Des Moines, and a horizontal surface, if every day of the year was beautiful, bright and cloudless, there would be an average of 1,777 BTU's per square foot available each day for conversion. If the surface was tilted to a 40° angle with horizontal, 2,100 BTU's per square foot per day would be available. If the surface were able to track the sun from sunrise to sunset and always maintain the optimal angle relative to the sun, 2,700 BTU's per square foot per day would be available.

Many types of flat plate collectors have about 30 square feet of collecting surface per unit. Assuming that square footage, and a 40° angle, each unit under ideal conditions could collect 63,000 BTU's per day.

But there is a solar piper that has to be paid. An average flat plate collector operates at about 50% efficiency, with 70% being tops. Thus between 31,500 and 44,100 BTU's might be the actual amount of usuable solar energy obtained from each unit.

Recognizing that when a gallon of fuel oil is burned it releases 141,000 BTU's, and one c.c.f. of burned natural gas releases 101,800 BTU's, and assuming a 75 to 85 percent boiler efficiency, it would take three or four flat plate units one day to collect the amount of solar energy equal to the burning of one gallon of fuel oil, and two or three flat plate units to collect energy equal to the burning of one c.c.f. of natural gas. *It must be emphasized that these equivalencies assume ideal collecting conditions all day long.*

The costs of natural gas and fuel oil are both rising rapidly, but assuming a cost of $1.00 per gallon for fuel and .25¢ per c.c.f. of natural gas, 3 flat plates could save between .25¢ to $1.00 per day off of a heating bill.

Making the same assumptions as above, 2,000 square feet of concentrators could save about 18 gallons of fuel oil or 25 c.c.f. of natural gas per day, or daily savings of $18.00 or $6.25 respectively.

Concentrating systems, such as the 2,000 square foot demonstration unit on the Capitol Complex, merely reflect direct solar radiation from a larger surface and concentrate it onto a smaller collecting surface where the energy is absorbed. By concentrating the available BTU's on a relatively small surface, higher operating temperatures are attainable. A concentrating system takes the same available 2,100 BTU's per square foot per day, can operate in the same efficiency ranges as flat plate collectors, and convert solar radiation into usable form.

Most flat plate collectors operate in the 170°F. - 180°F. range and thus can only produce hot air or hot water. Concentrating systems can operate at much higher temperatures and thus can produce high pressure steam. SLATS operates in the 350°F. - 400°F. range and can produce the 115 pound steam operating pressures needed for the Capitol Complex system.

High pressure systems are required where steam must be piped considerable distances. On the Capitol Complex all the buildings receive steam piped from the Central Energy Plant. The Wallace Building is located at the farthest distance and is about 3/4 of a mile away.

In addition, steam can be used by steam absorbtion units to produce chilled water that can be used for air conditioning. It is not the purpose of this report to explain steam absorbtion technology, but in simplistic terms an absorbtion unit operates with principles similar to the gas refrigerators that had a degree of popularity in the past. Absorbtion units, within limits, operate more efficiently the higher the temperature. In the range of temperatures that can be produced by flat plates, they are extremely inefficient. Thus another big advantage of concentrating systems over flat plates is that the solar energy produced in the summer months can be effectively utilized for air conditioning.

SLATS

Earlier in this report it was related why SLATS and Suntec were selected for the Capitol Complex Demonstration Unit. It was also determined that 2,000 square feet of concentrating surface would be a size sufficient to provide for a good field test. Problems that might not surface in a smaller installation would more probably surface and their degree of magnitude better assessed. The 2,000 square feet was subdivided into 2 banks of mirrors, a north bank and a south bank, each of 1,000 square feet.

As might be expected there were some of the usual problems that most any new system would experience. One of the more vexing problems was the unreliability of the controls.

The system is designed to be under automatic control. Instruments constantly measure the solar energy available. When there is sufficient solar energy, the system is automatically turned on and the mirrors track until they find the sun. Then the sun's rays are reflected back out in front of the system onto the absorbing tube. The fluid pumped through the tube is heated and goes to the heat exchanger where steam is produced. The fluid is then recycled back to the absorbing tube where it is reheated.

As the sun rises higher in the sky, the instruments sense this and adjust the focus of the mirrors. In the afternoon as the sun falls, again the mirrors are periodically adjusted. At the end of the day the instruments sense the absence of the sun and automatically turn the mirrors upside down and shut off the system. If during the day a storm approaches and the sun is covered by clouds, the instruments sense this and turn the mirrors upside down until the storm passes.

In many climates, including Des Moines, many sunshiney days have skies filled with passing clouds. Such clouds could cause the system to spend too much time focusing and refocusing. A time delay is built in to allow a certain amount of time to elapse after the instruments first sense a cloud before the mirrors are turned upside down. Thus, on a nice sunny day, every passing cloud does not turn the system off.

The fact that there were difficulties in just about every aspect of the controls which caused at times a considerable loss in collected solar energy, was something that was not unforeseen. Adjustments can be, and were made to bring the system up to an acceptable operating level.

Perhaps the most serious problem uncovered was the difficulty in preventing the north bank mirrors from slipping out of adjustment. This difficulty was not experienced at first to any comparable degree on the south bank which at times out performed the north by a factor of 3 or 4 to 1.

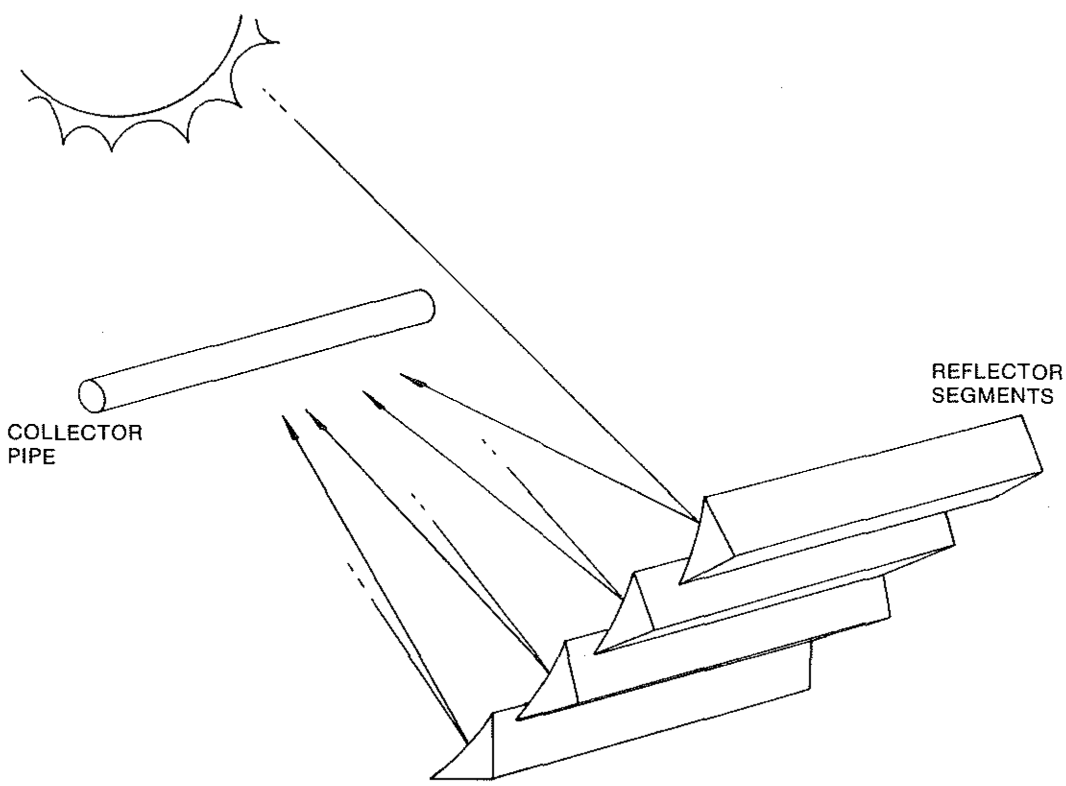
This type of problem points out two very serious defects:

1) Maintenance to keep the mirrors from slipping out of alignment could be a considerable cost item in the operation of the system. However, in theory, this could and should be corrected by some redesign.

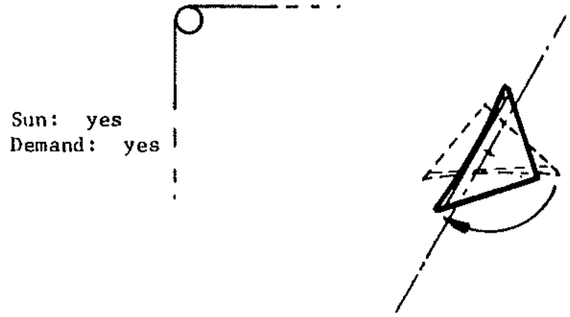
2) The efficiency of the system is dramatically reduced by slight misalignments of the mirrors. Maintaining a sharp focus on the absorbing tube is very critical. Although in theory, this too is correctable, the system design calls for a 9 foot distance from the mirror surface to the absorbing tube. In practice, on a large scale, this 9 foot focal distance may be too much of an obstacle to overcome.

Lesser problems such as the effect of dirt and dust settling on the mirrors, and dirt collecting on the glass in front of the absorbing tube have not yet been quantified. We have not been able to get the basics of the system fully corrected and thus not able to make comparisons based on the same solar conditions.

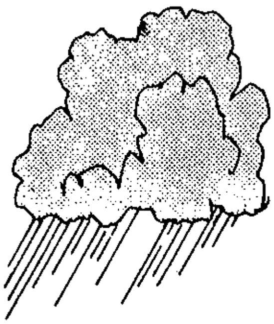
After about a year of operation, taking into consideration the problems experienced and the performance based upon known solar energy available, the system might be judgedby some to be a failure.

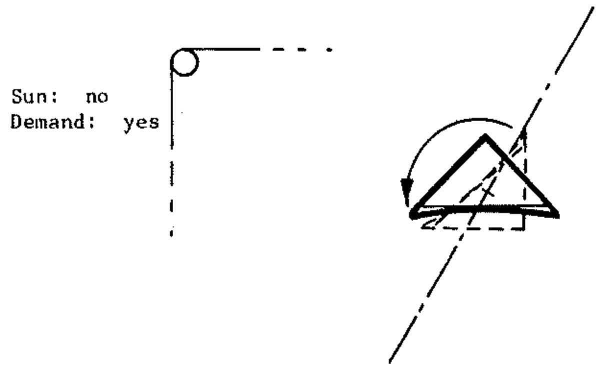


Basic SLATS Configuration

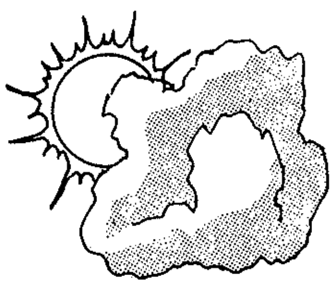


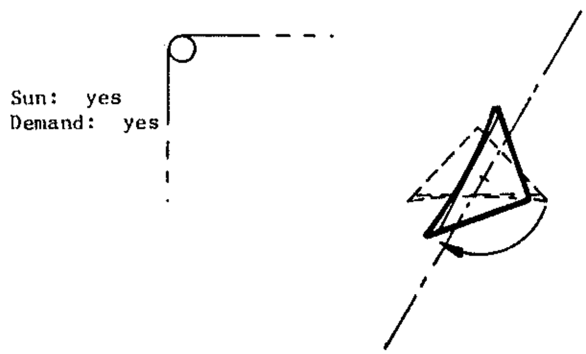
Sun Rise - Elements rotate up to collect mode



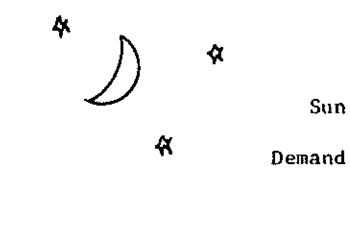


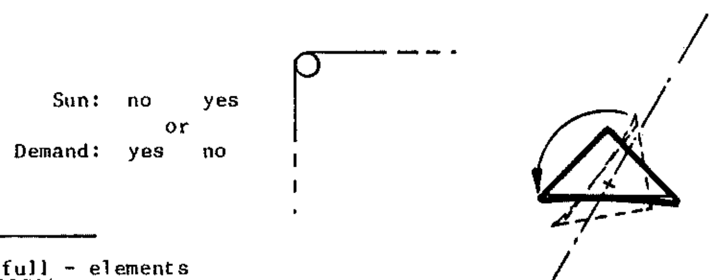
Impending Storm - Elements rotate face down to protect mode





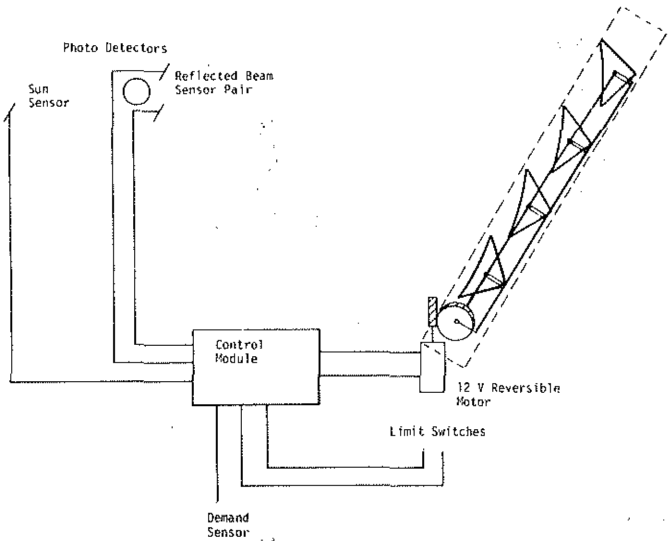
Storm Subsides - Elements return to collect mode





Night or storage system full - elements rotate to face down - protect mode

Operational Modes



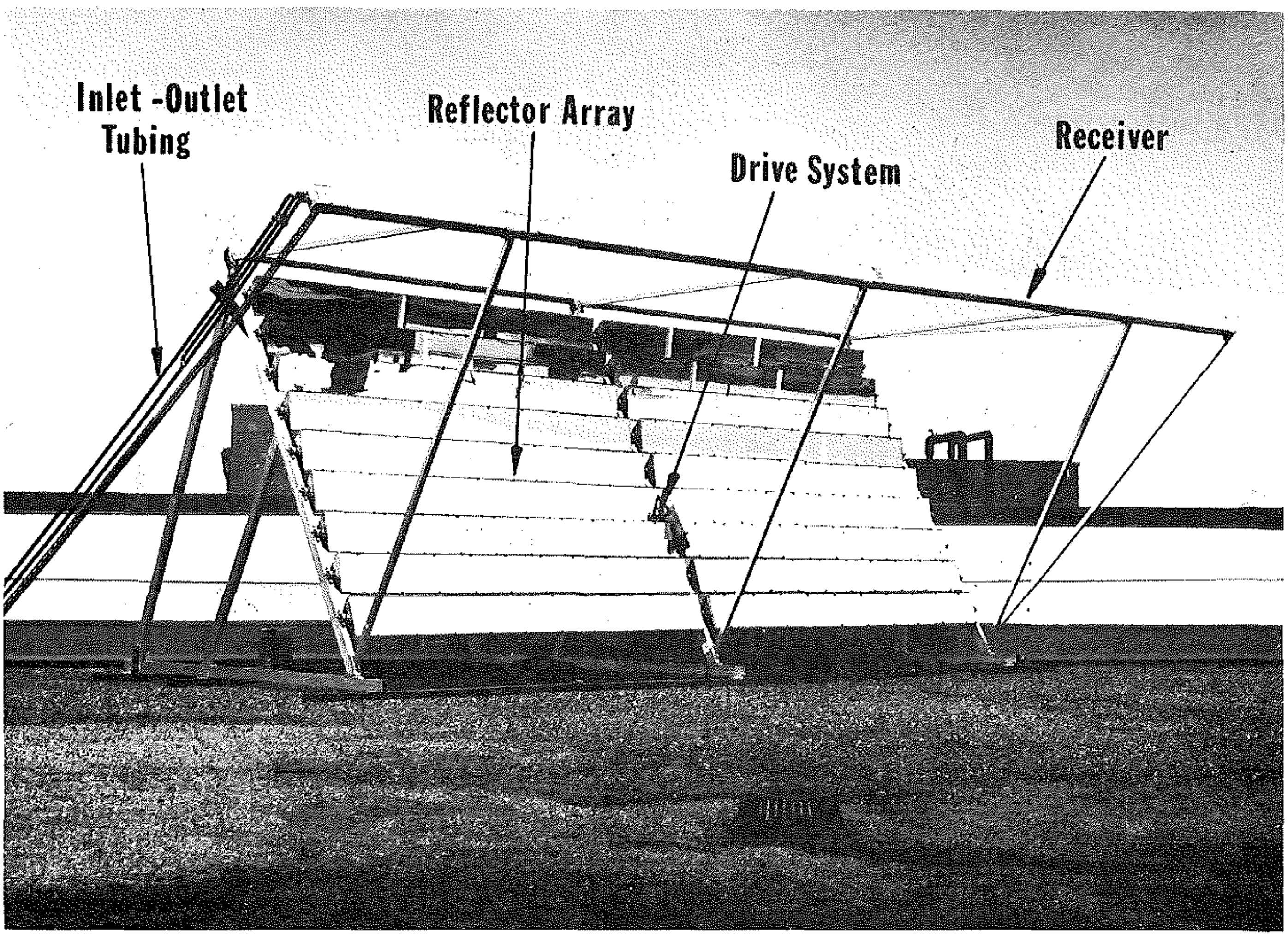
Drive and Tracking Concept

Before being branded as a failure, however, consideration must first be given to what the standards of success or failure are. What were the objectives that we were trying to accomplish?

The data based upon the totals for the first year of collecting are meaningless, they only reflect the magnitude of the problems that have to be corrected. It is the data on the best performance that indicate how the system might perform.

The best performance by the south bank for a single hour was 40% efficiency; the best for a single day, 25% efficiency. It can be assumed that performance by the north bank should be about equal to that of the south. It is just a matter of making the appropriate adjustments.

Assuming that the mechanical adjustments can be made and the problem with the controls corrected, it does not appear insurmountable to be able to bring the system up to approximately 50% efficiency. 50% efficiency, however, is so marginal that at best it would represent only a minimum of acceptability.



Solar Linear Array Thermal System, 150-Square-Foot Array

There is a popular conception that because the sun rises and falls every day and that the ultimate source of energy on earth comes from the sun, that man with his wisdom and technology can easily and cheaply harness this energy and solve most of the world's energy problems.

To say this may not be so, without making a serious effort to prove or disapprove it, is not acceptable. We must take basic principles, translate them into a technology, then test and learn what works, what doesn't work, and study how improvements can be made. Advances of the world are built upon the failures of the past and learning from the mistakes of others.

It is the recommendation of the Department of General Services that we continue to test and correct for an additional year. It would be the goal to prove or disprove a 50% efficiency level of performance. It would be totally unfair to make a conclusive judgment now before there has been an opportunity to correct problems and then collect data to better determine what are the true capabilities of SLATS.

The Department of Energy funded several large installations using the parabolic trough/evacuated tube technology. The data collected from these installations should be investigated and compared to our climatic data and the performance of SLATS. There may be other concentrating technologies being tested and data being accumulated.

Sometime in 1982 or 1983 there will probably be sufficient data to make some judgements about whether or how soon the State could proceed in our involvement with the utilization of solar energy.

But no matter what that decision, the citizens of Iowa have reason to take pride in the contributions made by the demonstration unit on the Capitol Complex.

The Department of General Services wishes to acknowledge and thank the Iowa Energy Policy Council for the support they have given this project.

APPENDIX

Chart A. Daily Direct and Scattered Solar Radiation at the Capitol Complex, Des Moines, Iowa.

Month September, 1980

Collector Orientation	Horizontal	15°Tilt	30°Tilt	Lat Tilt(41.4°)	45°Tilt	Lat Tilt+15°	60°Tilt	75°Tilt	Vertical Wall	Seasonal Tilt
Day										
1	1329	1503	1550	1536	1523	1455	1425	1178	1046	1540
2	1565	1790	1860	1836	1815	1704	1656	1275	1050	1843
3	No Data	Gathered	No Data Gath	ered No Data Ga	thered No D	ata Gathered	No Data Gat	hered No	Data Gathe	red
4	1198	1434	1486	1476	1464	1397	1367	1129	986	1479
5	1380	1598	1657	1646	1632	1558	1525	1265	1098	1650
6	1336	1520	1565	1556	1545	1487	1462	1266	1130	1559
7	1463	1666	1733	1725	1712	1639	1606	1342	1170	1729
8	1459	1715	1797	1790	1775	1690	1651	1340	1135	1794
9	870	971	987	984	981	963	954	894	845	985
10	1540	1806	1893	1889	1875	1792	1754	1450	1239	1893
11	1157	1230	1267	1269	1265	1238	1225	1111	1042	1270
12	1245	1362	1419	1422	1416	1374	1353	1184	1069	1424
13	No Data	Gathered	No Data Gath	ered No Data Ga	thered No D	ata Gathered	No Data Gat	hered No	Data Gathe	red
14	677	682	685	685	684	682	681	675	669	685
15	1255	1398	1457	1465	1460	1425	1407	1251	1151	1465
16	472	473	474	474	474	473	473	472	471	474
17	1464	1774	1891	1908	1900	1835	1801	1527	1313	1909
18	1462	1778	1910	1932	1925	1858	1822	1525	1300	1933
19	1305	1445	1523	1537	1534	1497	1477	1307	1181	1538
20	1317	1506	1608	1629	1625	1582	1559	1344	1194	1629
21	1458	1734	1881	1913	1909	1849	1817	1526	1303	1913
22	1067	1346	1442	1465	1463	1427	1407	1226	1085	1464
23	1523	1921	2096	2139	2137	2077	2041	1728	1476	2138
24	666	703	714	717	717	714	712	696	679	717
25	1283	1527	1634	1663	1663	1632	1612	1433	1291	1662
26	1469	1808	1982	2032	2033	1987	1958	1685	1457	2030
27	1319	1525	1645	1680	1681	1651	1631	1441	1291	1679
28	1402	1707	1870	1920	1923	1886	1861	1623	1421	1918
29	870	922	954	964	964	958	953	904	868	963
30	1341	1651	1817	1872	1875	1845	1822	1597	1402	1868
31										
Totals										

The Seasonal Adjustment Angle has been taken to be 40°.
Horizontal data is obtained from an Epply Pyrometer. Fully tracking direct solar intensity is obtained from an Epply Normal Incident Pyrheliometer. All other solar intensities are calculated using altitude and azimuth data supplied by Dr. L. P. Staunton, of Drake University.

All intensity data is in Btus per square foot.

Chart B. Daily Direct Solar Radiation (Concentrating Collectors) at the Capitol Complex, Des Moines, Iowa.

Month September, 80

Collector Orientation	Fully Tracking	E-W Tracking (Lat Tilt)	N-S Tracking (45° Tilt)	Seasonally Adjusted	N-S Tracking (45° Tilt 13° East of South)	Seasonally Adjusted (13° East of South)
Day						
1	1270	1255	1078	1067	1071	1047
2	2218	2160	1714	1694	1770	1746
3	No Data G	athered No Dat	a Gathered No	Data Gathered	No Data Gathered No Data Gat	hered No Data Gathered
4	1375	1366	1102	1092	1031	997
5	1598	1591	1238	1228	1232	1207
6	1335	1324	958	950	947	924
7	1677	1659	1285	1277	1289	1271
8	2025	2007	1534	1526	1547	1524
9	509	506	319	316	276	264
10	2176	2170	1551	1542	1592	1569
11	638	635	572	571	571	568
12	1094	1091	888	886	905	897
13	No Data G	athered No Dat	a Gathered No	Data Gathered	No Data Gathered No Data Gat	hered No Data Gathered
14	70	69	39	38	44	44
15	973	971	829	828	807	799
16	12	11	8	8	8	8
17	2241	2207	1595	1596	1621	1594
18	2307	2285	1734	1735	1758	1733
19	1302	1284	995	996	1028	1018
20	1424	1421	1246	1246	1233	1227
21	2295	2267	1774	1775	1832	1812
22	1435	1429	1130	1129	1040	1026
23	2647	2611	2003	2004	2039	2011
24	219	215	119	119	118	113
25	1471	1447	1169	1169	1135	1122
26	2449	2414	1851	1850	1882	1854
27	1467	1458	1265	1263	1273	1264
28	2077	2061	1671	1666	1661	1644
29	370	352	324	325	309	307
30	2006	1986	1639	1632	1614	1598
31						
Totals						

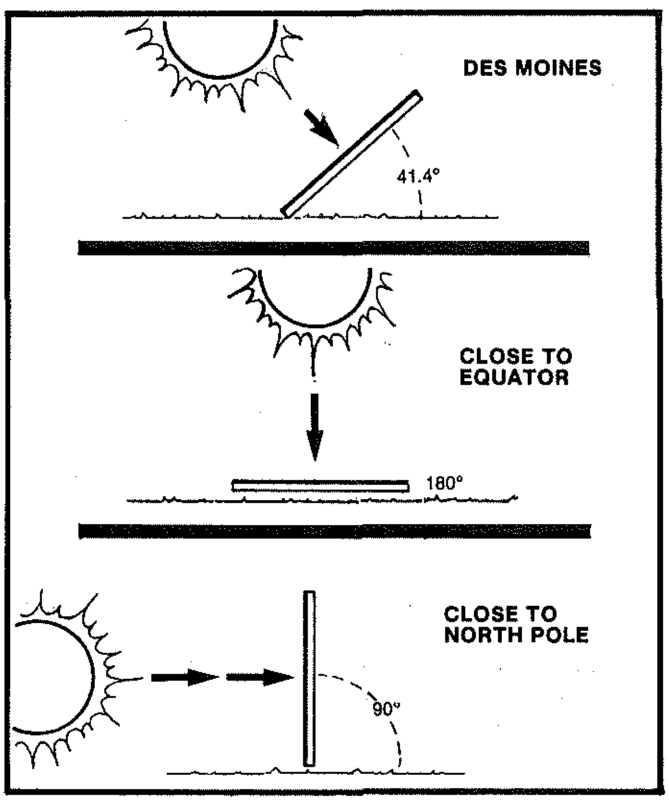
DATA COLLECTION AND PERFORMANCE EVALUATION

I. IMPORTANCE OF THE SOLAR ANGLE

Everyone recognizes that early in the morning when the sun is low on the horizon, the ground doesn't receive much solar energy, but at noon when the sun is highest in the sky, the ground then receives the maximum. During the morning hours a wall facing south receives sunlight at a more direct angle and thus receives more solar energy than at noon when the sun is overhead.

What is not as obvious are the seasonal changes due to the changing tilt of the earth's axis relative to the sun. As the angle between the sun and earth changes so does the amount of solar energy striking a given point on the earth's surface.

Most solar collecting systems, particularly flat plates, are in a fixed position and this fixed angle relative to the sun can't be changed constantly. For such systems it is important to determine the best compromise angle to permit not only the optimum performance during the day, but also to take into consideration the seasonal changes. This "best" angle corresponds to the latitude where the system is located. The farther north the latitude the lower in the sky the sun will rise at its highest point. The closer in latitude to the equator, the higher in the sky the sun will rise at solar noon. A fixed solar system in Canada should be positioned closer to the 90° angle of a wall; a solar system close to the equator would approach being positioned flat on the ground.



II. DATA COLLECTION

It is relatively easy to measure the BTU output of any solar collector system. In order to determine the efficiency of the system, instruments are necessary to measure how much solar energy is available. The instrument measurements taken as part of the Capitol project are totaled on a daily basis. Comparisons to daily input can be made with daily output.

Chart A shows the daily total amount of solar energy available per a given fixed angle at the exact site of SLATS in Des Moines. The effects of local atmospheric and weather conditions can be noted by comparing the fluctuating daily totals. September 16 was probably a very cloudy day, September 23 was undoubtedly a beautiful clear day.

By computer, the amount of solar energy that is available is calculated for various fixed angles to the sun. For example, the first column headed *Horizontal,* shows how much solar energy was received per square foot by the earth itself or by a solar collector if it were lying flat on the gound. The fourth column headed *Lat Tilt (41.4°)* shows how much solar energy was received by a surface angled 41.4° to horizontal (Des Moines' latitude). The sixth column headed *Lat Tilt plus 15°* is included because if a fixed solar system is only going to be used for heating (winter use), the Des Moines angle should be increased from 41.4° to 56.4° (plus 15°). Thus during the winter months when the sun remains lower in the sky, the increased angle will enable the collector to receive more solar energy than it would if the angle were less. Of course in the summer months, less energy will be collected but the need for heat is much less.

As pointed out above, September 23 was the best solar day during the month of September, 1980. A fixed solar collector at the Des Moines angle of 41.4° received 2,139 BTU's per square foot on that day. 2,139 BTU's sq/ft compares favorably to the annual maximum average of 2,100 BTU's sq/ft and is only slightly less than what could be expected for a perfect solar day in September. Note that if the system were at a fixed angle for heating only (56.4°), the solar energy collected would have been a little less. However, the demands for heat in September are certainly less than in the winter months.

Chart B shows the daily total amount of solar energy available to a fully tracking system at the Des Moines site.

A continuous tracking system is one that can continually adjust to the changing angle of the sun relative to the collecting system, and thus always be at the optimum angle. At the Des Moines location, 2,700 BTU's per sq/ft per day represents the average maximum available on an annual basis. Again looking at September 23, it can be noted that 2,647 BTU's sq/ft were available to a continuous tracking system.

III. SLATS PERFORMANCE

SLATS is a continuous tracking system and has 2,000 sq/ft of mirrored surface that reflects the sun's

Chart C. Capitol Complex Solar Collector Performance for the Week of 9-22-80 to 9-28-80.

Day	Date	Collector #1 Output	Collector #2 Output	Total Output	System Output	Fuel Type Replaced
Monday	9-22-80	118,000	60,000	178,000	107,000	Gas
Tuesday	9-23-80	342,000	270,000	612,000	589,000	Gas
Wednesday	9-24-80	0	0	0	0	Gas
Thursday	9-25-80	122,000	83,000	206,000	35,000	Gas
Friday	9-26-80	366,000	324,000	691,000	629,000	Gas
Saturday	9-27-80	254,000	220,000	474,000	405,000	Gas
Sunday	9-28-80	206,000	165,000	371,000	292,000	Gas
Totals		1,408,000	1,122,000	2,532,000	2,057,000	

The Collector Outputs are the energy outputs as measured at each row.

Total Collector Output is the sum of Collector #1 and Collector #2 Outputs.

System Output is the solar collector's total output taking into account the heat losses involved in the fluid piping loop, this is approximately the amount of steam produced.

All data is in terms of Btus.

rays onto an absorbing tube. Thus 2,000 (number of sq/ft) times 2,647 (BTU's available that day per sq/ft) equals 5,294,000, the BTU's that could have been collected on September 23.

Chart C shows the total number of BTU's produced per day by the south bank, collector number 1, and the north bank, collector number 2. The difference between the total output and the system output represents the heat loss through the pipes, pumps, heat exchanger and other parts of the system.

On September 23 the total output of the system was 612,000 BTU's or only 11½% of what was available. The north bank performance was 21% less than the south bank. The relative difference in performance during the week ranged from 49% to 11% less between north and south.

That is not satisfactory performance. The total output was too low, the two banks did not perform equally and fluctuated widely in their relative performance. The best performance day was the 26th, when SLATS produced 14% of the amount available.

It was mentioned earlier in this report that many solar collecting systems perform at 50% or less efficiency. It was also pointed out that for very brief periods, SLATS has approached 40% efficiency. Assuming a 50% efficiency, on September 23 SLATS would have had a total output of 2,647,000 BTU's or about 1,323,500 BTU's from each bank. 2,647,000 BTU's is the equivalent of about 18 gallons of fuel oil or 25 ccf of natural gas.

It is the long range consideration to install perhaps 200,000 sq/ft of solar concentrators on the bluff overlooking the railroad tracks. A 200,000 sq/ft system operating at 50% efficiency would have produced on September 23 the equivalent energy of burning 1,800 gallons of fuel oil or 2,500 ccf of natural gas. It is not uncommon for the State to burn 3,600 gallons of fuel oil or 4,900 ccf of natural gas per a winter day.

Once again it should be stated that all the available solar energy BTU figures are based upon perfect solar days. If the cloud cover in Des Moines averaged, say 20%, the annual averages available per day would also be reduced by 20%.

IV. COMPOUND PARABOLIC TROUGH WITH EVACUATED TUBE

As described in the body of this report, a parabolic configuration will focus the sun's rays coming in at various angles onto one central focus point. The parabolic sides function in principle as a continuous tracking system. Thus in the morning or late in the afternoon when the sun is lower on the horizon, the parabolic sides of the trough will still focus the rays onto the evacuated collecting tube. Of course, when the sun rises higher in the sky more of the sun's rays will directly strike the collector. The parabolic sides still focus that which doesn't strike direct.

In theory, if the width of the opening of the trough is wide enough, no seasonal adjustments need be made.

It would be ideal if no adjustments were necessary. As usual in many technologies, there are trade-offs. Balancing the trade-offs, troughs of lesser width opening are recommended even though they need to have their angle adjusted seasonally.

In a large installation the mechanism to make the necessary adjustments adds to the initial cost of the system and introduces a necessary maintenance item. Until at least a small scale installation is tested, the magnitude of these anticipated factors can't be determined.

V. CONCLUSIONS

It should be evident from this report that solar energy is not going to be a major source of energy on the Capitol Complex in the near future. Simple technologies can look good upon paper, small individual units may test well, but until thorough testing is done on a larger scale and over an extended period, one must reserve judgment.

Much has been learned by the experience with SLATS. Similar experience with other systems is necessary before a determination can be made as to which one performs best in Des Moines and whether even the best performer is good enough to be acceptable. It is easy enough to determine what the performance should be under ideal conditions. Nothing will substitute for actual testing under Des Moines atmospheric and weather conditions.

VI. HOME AND SMALL COMMERCIAL INSTALLATIONS

Because of our interest in solar energy and the knowledge acquired from the Capitol Complex project, the Department of General Services has taken solar data and cost figures and developed two graphs that relate the costs per square foot for installation to the payback time in years. One graph is for systems designed for hot water heating, the other, for space heating.

The graphs take into consideration the existing energy source, electric, L.P.G., natural gas, oil or heat pump. For example, it appears that if a system designed for just space heating costs, say $20.00 per square foot, the payback varies between 12 and 18 years depending upon the type of primary heat source.

The dissemination of this type of information is more properly the role of the Energy Policy Council. In their opinion the costs of the energy source, oil, gas, electric, may be so variable that such graphs may mislead more than inform. They might disagree with some of our assumptions. Modifications might need to be made.

In any event, the Department of General Services is passing on to the Energy Policy Council for whatever use that they deem appropriate, these graphs and the information upon which we based our assumptions. If helpful, this too can be construed as a positive benefit from the State's initiative in high temperature solar technology.

ADDENDUM

After the body of this report was written and the copy was being prepared in final page proof form, some significant increases in performance were achieved.

Considerable effort was expended in adjusting the mirrors, particularly the north bank. On June 26, 1981, the total system output exceeded one million BTUs for the first time. At solar noon on that day, the instantaneous peak efficiency of 42% was attained, and the total efficiency for the day was 27%. This about doubles the performance of the previous best day, but obviously there is still a long way to go.