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Report on Visit of U.S. Solar Energy Specialist Team to the Soviet Union

3-16 September 1977

Edited By
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Solar Energy Research Institute

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Solar Energy Research Institute
A Division of Midwest Research Institute

1536 Cole Boulevard
Golden, Colorado 80401

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ACKNOWLEDGEMENT

This report was prepared by the editor from a collection of notes assembled by Mr. Victor Bremenkamp, the Coordinator of the Delegation. The original notes were provided by various members of the Delegation. The editor has tried to construct a coherent account of the proceedings, including as much technical detail as could be reasonably extracted from the notes. Both Mr. Bremenkamp and Dr. Lloyd Herwig, the Head of the Delegation, have been of considerable assistance, searching their memories for information when the available matorial was obscure. The copy-editing contribution of Ms. Jean H. Goldberg is much appreciated.

Copies of the individual papers presented at the Seminar on Solar Energy Applications are available. Please address any requests to: M.D. Goldberg, Solar Energy Research Institute, 1536 Cole Boulevard, Golden, Colorado 80401.

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INTRODUCTION AND SUMMARY

This report provides an account of the visit by a team of US solar energy specialists to the Soviet Union during the two week period from September 3 to 16, 1977. The visit was for the purpose of exchanging information on recent results of solar R&D in the two countries including a workshop/seminar, as agreed to by both sides in March, 1977. The visit was made as a continuation of activities under the June, 1974 Agreement between the US and USSR in the field of energy. The team consisted of the following members:

Lloyd O. Herwig, Scientific Advisor, Division of Solar Energy, Energy Research and Development Administration (now Department of Energy), Head of Delegation

Victor D. Bremenkamp - Assistant to the President, Associated Universities, Inc., Coordinator of the Delegation

John D. Balcomb - Engineer, Los Alamos Scientific Laboratory

Frank Biggs - Research Physicist, Sandia Laboratories

Henry W. Brandhorst - Scientist, NASA Lewis Research Center

John D. Furber - Staff Member, Office of Technology Assessment, US Congress (Consultant, Associated Universities, Inc.)

George O. Lof - Director, Solar Energy Applications Laboratory, Colorado State University

Allen Rothwarf - Senior Scientist, Institute of Energy Conversion, University of Delaware

Alan Skinrood - Supervisor, Solar Project Division, Sandia Laboratories

John R. Thomas - Program Manager, US-USSR Programs, National Science Foundation

Lorin Vant-Hull - Solar Energy Laboratory, University of Houston.

The itinerary for the full trip is included in this report as Attachment I.

A major portion of the visit was spent participating in joint seminars and workshops held in the city of Ashkhabad, Turkmen Republic, in the extreme southern regions of the USSR. These joint seminars and workshops included about four full days of parallel discussions in each of three principal solar technology areas - solar heating and cooling, solar thermal power production, and photovoltaic power generation. The host institution in Ashkhabad was the Turkmen Academy of Science, and the meetings were held in their relatively extensive facilities. Approximately 100 Soviet specialists were present through the period of the seminars and workshops, including persons from most of the Soviet organizations that are engaged in solar research in the three technical areas. The complete program for the seminars and workshops is included in this report as Attachment II. The list of USSR Seminar participants is included in Attachment III. In addition to the joint meetings, the US specialists were given an extensive tour of the solar energy experimental laboratory at Bikrova, about 50 kilometers from Ashkhabad. It is believed that this visit to the Bikrova laboratory was the first time that Western scientists had been allowed to see the laboratory's facilities and work.

The opening session of the official visit was held on September 5 at the Ministry of Power and Electricity. Following agreement on the itinerary for the visit and agenda for the meetings, Dr. Uri Malevsky and Dr. Lloyd Herwig summarized their respective national solar programs. Upon the return of the U.S. delegation to Moscow from Ashkhabad, visits to several Moscow laboratories were made and some further fruitful discussions with Soviet specialists were held at the Krzhizhinovski Power Institute in the technical areas of solar thermal and photovoltaic power systems. Before the delegation left Moscow a visit review meeting with Mr. A. V. Stolyarov at the Ministry of Power and Electricity was held. Mr. Stolyarov is the USSR coordinator for US-USSR cooperation in solar and geothermal energy areas. The meetings concluded with the signing of a joint protocol statement which summarized the results of the visit (see Attachment IV).

Generally, the US team considers that the visit was highly successful in that Soviet specialist participation in all three technical areas included highly qualified persons who seemed to be fully cooperative and enthusiastic about presenting their views and engaging in detailed discussions for extended periods of time. The arrangements for seminars, workshops, and laboratory visits in Ashkhabad were responsive to the requests from the US delegation. The general cooperativeness and hospitality left little to be desired. Soviet specialist participation in quality and number was gratifying to the U.S. team.

A disappointment in the Moscow laboratory visits was the lack of contact with the Institute of Cosmic Studies, a laboratory which manufactures most of the terrestrial photovoltaic cells in the USSR. It was the USSR position that a visit there could not be arranged on short notice but that a request for such a visit before arrival of the delegation in the USSR could have been accomodated. Any further visiting by US photovoltaic specialists in Moscow should explicitly request in advance a visit to this laboratory.

The general conclusion of the U.S. team as a result of these meetings is that the Soviet programs in all three technical areas are generally from two to five years behind the US program. At the present levels of national commitments by the two countries to solar energy RD and D, the Soviet program is continuing to fall behind. There are a few specific areas of technology where there is a relative balance in status.

There are indications that the Soviet national commitment to developing solar energy technology and applications in the three areas considered is increasing. Although the USSR national effort had been relatively higher than that of any other country in the world during the 1960 to 1973 period, it has continued at about the same level in recent years - an estimated $5M per year more or less, largely for basic theory, application analyses, and modest laboratory experiments. An estimated 200 professional persons have been involved in solar R&D at least part time over the past fifteen years. A few demonstration experiments have been undertaken in solar desalination, water heating, cooking, and water pumping systems. It appears that most of the practical solar system experiments have fallen into disrepair and disuse. There are indications that the Soviet Union is going into a production phase on solar desalinization systems, photoelectric systems for water pumping, and solar cookers. However, there are no production lines in operation now.

Essentially all of the present solar experiments are located in laboratory areas associated with Academy of Science facilities in the republics, e.g., Turkmen (Ashkhabad), Armenia (Yerevan), Azerbezjan (Baku), and Uzbeck (Tashkent and Bukara). Most of the solar energy R&D is conducted by specialists at the Academy of Science institutions in the republics, at universities, and at central government institutes and centers.

Some additional general comments about solar activities in the Soviet Union are as follows: The groups of specialists in the many locations are too small to have good coverage of required specialties for addressing more complex research and system problems; the specialists do not appear to have access to current outside literature about world research results and goals; and, there is a corps of competent, well-trained solar scientists and engineers. This suggests that there is not a large enough USSR national commitment to be competitive with many other countries in the world, in that the USSR solar community must interact more broadly in world activities in these areas.

Although the basic USSR activities are judged to be generally two to five years behind the US programs, there are selected areas of their efforts that could lead to mutual benefits in future cooperative interactions. For example, the Soviet program in solar thermal power stations is leading to a 1 MW thermal power station design for a site in the Crimea region to be developed as a solar testing laboratory. Solar thermal specialists have developed a conceptual design for a 1 MWt-sized receiver in a tower design. Their approach and design results for the various components are of interest to US specialists. Soviet work on GaAs solar devices and systems and on an open-cycle cooling system were also of interest.

An offer was made by the US team to USSR specialists to consider testing a USSR-designed receiver at the Albuquerque, New Mexico solar thermal test facility. The Soviets' would design and construct a receiver to be brought to the US test facility for joint performance testing. Their initial reaction was not enthusiastic. Other suggested areas for future discussion included the open-cycle, lithium chloride, air-cooling cycle and performance testing by each country of state-of-the-art silicon, cadmium sulfide, and gallium arsenide solar cells from the other country.

The US team left a silicon standard cell at the US Embassy in Moscow to be exchanged as soon as practical for a similar Soviet standard cell. Later, it may be possible to exchange solar cell devices and test performance of cells produced by each country to verify improvements and test methods. Soviet achievements in development of gallium arsenide solar cells should be given further attention.

There was general agreement between representatives of the two countries but the cooperation should continue through further exchanges of information and through joint seminars and workshops. The next meeting is tentatively planned to be held in the US in September of 1978.

TRIP DETAILS

September 5, 1977 - Moscow

The US team met in an initial meeting with the Soviet hosts at the Ministry of Power and Electricity. Dr. Maltsev of the Soviet Secretariat was present at the meeting, along with several representatives from the ministry and Dr. Malevsky of Krzhizhnovsky Institute. After an exchange of opening remarks by both sides, several specific issues were discussed. The Soviets reiterated their intention to hold three parallel sessions as the US team had insisted. Co-chairmen for the various sessions were designated: Solar Power Stations - Tarnizhevsky and Skinrood; Heating and Cooling - Baum and Lof; Direct Conversion - Koltun and Brandhorst.

Following brief remarks concerning the possibility of making changes to the program, Dr. Malevsky gave a brief overview of the Soviet Solar Program. The priority item in the Soviet program is desalination. Fresh water (for livestock) is a problem in many agricultural regions and solar desalination provides the best available solution. Steps are underway to begin production of solar desalination units.

Malevsky then discussed the three areas to be covered by the seminar. Solar heating experts are ready to build systems, but production is being held up due to reliability and economic considerations. Storage for these systems is also in the developmental stage. Solar air conditioning is more advanced. A test unit is in operation in an apartment building located at the Bikrova Laboratory near Ashkhabad. Several other apartment units using solar cooling are under construction.

Solar power stations were studied very early in the Soviet program, and a station design was developed 20 years ago. This station was not constructed although the heliostat design was tested. The current thinking by the Ministry of Power is that small autonomous stations in widely separated locations may be the most economical. However, there are some engineers who feel a network of stations connected to the power grid would be viable.

Direct conversion (photovoltaics) is hampered by the high capital costs involved. The main use today is in space and remote area applications. A cost reduction of one to two orders of magnitude is needed. Studies of concentration to reduce cost have been made, but heat removal is a problem.

The US team was given an opportunity to ask questions about the program. The general trend of questions and answers lead the team to believe the Soviet program has not been well thought out, nor is there a central focus of development effort. Cost effectiveness does not seem to be a strong factor in program development. Planning for large scale production or use of solar energy equipment in the USSR appears to be talked about for some equipment but not implemented. Dr. Maltsev, in reply to a direct question, said that solar energy will be a small part of the total Soviet energy program. It is too expensive and the Soviet planners do not consider it useful in many parts of the country.

Dr. Herwig then gave an overview of the US program, emphasizing the development of new approaches, the testing of equipment and the rapid increase in RD&D progress since the US-USSR Cooperative Program began in 1973.

<u>September 6, 1977 - Moscow-Ashkabad</u>

This was a travel day.

<u>September 7, 1977 - Ashkabad - First Plenary Session</u>

The US team was welcomed by the Vice President of the Turkmen Academy of Science. He pointed out that solar research has been underway in Ashkhabad for 30 years. The Kara Kum Desert provides an ideal site for solar research.

Dr. Herwig then presented an overview of the US Solar Energy Program. Several questions regarding the US program were answered. Furber requested solar radiation data following the Soviet question on the topic. The Soviets replied that they are not yet in a position to exchange data in this area. The plenary session then adjourned for the workshop sessions.

<u>September 8-11, 1977 - Ashkhabad</u>

During this period, parallel workshops and seminars were held in each of the three technology areas: direct conversion (photovoltaics), thermal power (solar thermal), and heating and cooling. A visit was also made to the Bikrova Laboratory. Both of these will be described in greater detail later in the report.

September 12, 1977 - Ashkabad - Closing Plenary Session

The closing plenary session of the workshop/seminar was covered by the local TV and local and national press. Reports on the workshops had been carried on local television several times during the sessions. Dr. Maltsev of the USSR Secretariat opened the sessions. Each of the co-chairmen reported on his session, as follows:

Solar Power Stations

Dr. Tarnizhevsky reported that he felt the workshop was fruitful and had yielded tangible results. The US papers were of interest, especially those covering the design of large thermal storage systems and the setting of the optical elements in the field array around an elevated central receiver. He felt the most valuable part of the sessions was not the papers but the discussions and exchanges of ideas and opinions.

Dr. Skinrood thanked the Soviets for the opportunity for open discussions. The proposed power station experiment in Crimea is very interesting. An exchange of data from this experiment and the pilot plant in the US would be valuable.

Heating and Cooling

Dr. Baum noted the business-like and friendly approach taken in this session. He expressed the group's desire to continue with workshop-seminars. The exchange of papers prior to the meeting is of great value. It should follow that no papers need to be read at the actual meeting. Thus, most of the time could be devoted to discussion of research topics. In order to make these discussions more valuable, the papers should contain as much information as possible, including data.

Dr. Balcomb reported for the US team as Dr. Lof had been required to leave early. He thanked all paper presenters for their open and frank discussions. He expressed the US team's feeling that facility tours be made early in the visit in order to allow more fruitful discussion of the projects. Heating and cooling is an especially important area as it will be implemented at an early date.

Direct Conversion

Dr. Koltun reported that the quality of papers in this session had been excellent. Three thorough and lengthy discussion sessions had been held. Both sides benefitted from these in-depth discussions. The major topics of the session were decided well in advance (measurement and theory), and this was responsible for the high quality of the sessions. The next seminar should cover: (1) measurements, scientific terminology, and exchange of reference cells; (2) theory of high efficiency cells; and (3) low-cost manufacturing methods.

Dr. Brandhorst reported he felt the discussions were open, whole-hearted, and free. Much useful information was exchanged. Joint discussions with other specialists on concentrators and combined systems would be desirable.

Dr. Herwig then reported on his overall reaction to the seminar. The format of parallel sessions was very satisfactory in general. The exchange of papers in advance is very desirable, but the receiving countries should arrange for translation in order to assure maximum usefulness. This will require exchange of papers at least two months prior to the seminars. He went on to express his feelings that the Soviet solar scientists should have more contact with researchers in other countries. Increased attendance at international meetings such as the ISES would be one method of moving in this direction. The Soviet scientists are very capable, but need more support in order to achieve their potential. The US will be considering the next step in the cooperation, based on the assessment of the Soviet program. Opportunities for cooperation, both short and longer term, exist.

Following a short coffee break, the session was opened to discussions from the floor. Many of the Soviets in attendance spoke in support of continued cooperative efforts and expressed their pleasure with the workshops.

September 13, 1977 - Ashkabad-Moscow

This was a travel day.

September 14, 1977 - Moscow - Krzhizhanovsky Institute

A brief meeting was held at the Institute with Dr. Aladyev and other Institute personnel. Herwig and Aladyev engaged in a short discussion on the status of the US program. This was our first contact with Aladyev on this trip. Aladyev then gave his understanding of the Soviet program.

The Institute is mainly involved with the concept of a central power station and is looking at a 300kWe sized plant. A design for such a plant in the Crimea is underway. This will be a test station for future large-scale installations. Some work on solar hot water supply has been done; also, a hotel in the Crimea is being prepared for a solar installation, and a Pioneer Camp is using solar-heated water.

Dr. Garf then gave a briefing on the solar station design of 20 years ago. It was difficult to understand that this station had not been built. There is a definite tendency to give the impression that design equals completion of a project. This briefing was very detailed, but contained no new information.

Dr. Aparisi discussed various storage concepts. The studies lead quickly to pumped hydro-storage. This seems to be the best system to provide an annual, complete power system. This concept would be hard to apply in a desert region, but would provide a ready way to combine solar and hydro power stations. It was difficult to determine the depth to which various storage methods had been studied.

Dr. Malevsky gave a short briefing on the Crimea Solar Power Station. He had an artist's concept of the station, but that seemed to be the only drawing available. This plant seems to be in a preliminary design stage and far from completion. The 1980 completion date mentioned is not realistic.

September 15, 1977 - Moscow - Krzhizhanovsky Institute and Closing

Brandhorst and Koltun engaged in a discussion at the Institute on which solar spectrum to use for solar cell testing. The US uses AM 1.5 while the USSR seems to be using AM 2 or 3. A planned exchange of standard cells did not take place as the Soviets had none to offer. Brandhorst offered to calibrate and return Soviet cells if they would furnish them. The detailed discussions of techniques held at this session helped to clarify some of the issues left open at the seminar. Discussions included testing techniques and some general manufacturing techniques such as silicon ribbon.

Dr. Herwig and Mr. Stolyarov, the USSR coordinator for cooperation in solar energy, met with two additional persons from each country for approximately two hours to discuss the US team's impressions of the total visit and of the Soviet solar energy program and progress. The meeting ended with the signing of the joint protocol statement.

VISIT TO THE BIKROVA LABORATORY

The Bikrova Field Station is located about 15 miles from Ashkhabad, in an irrigated area near the junction of flat plains and rugged mountains. It consists of a number of buildings and outdoor test equipment. Dr. Baum, long-time director, introduced the work of his laboratory by stating that there are about 30 research workers at the facility and about 100 total employees. Work is being done on solar greenhouses, solar water heaters, a photovoltaic generator for water pumping, a thermoelectric generator, a cooling system with jet compression, solar stills, photoelectric studies, and a solar cooled house. Each of these work areas will be described in detail below.

The U.S. solar team is among the first groups of foreign solar specialists to visit this solar laboratory in the very southernmost region of the Soviet Union.

Greenhouses

One solar greenhouse is constructed with a solid, insulated north wall. Shelves with boxes of wet soil, about one meter square, occupy all of the north wall and are apparently used for starting certain kinds of plants. Wood framing is used for glass panes on the south slope, and the east and west vertical sides are also glazed with small windows. Single glass is used throughout.

For the first two years, vegetables were grown, with about 70% fuel savings. They were testing various storage designs and solar heat storage methods during that period. For the last three years, lemon trees have been cultivated, during which time no fuel has been required. The minimum acceptable temperature for the lemon trees is minus 5°C and, with the lowest outdoor temperatures during that period of minus 10°, inside temperatures have not fallen below 0. Some lemons were seen, which are expected to ripen in January. The design has been accepted by two farms, and there now is stated to be under construction one unit of ten hectares and another unit of six hectares.

Another greenhouse of typical size and shape, completely glazed, consisted of a rather narrow seed bed in the center, with two pools of water adjacent to the east and west long dimensions, both of which contained salt water. Each of these pools was about 1.5 meters wide and ran the full length of the greenhouse, about 100 feet. Metal troughs collected condensate at the lower inside edges of the glass roofs. The condensate was used for irrigation of the plants in the central seed bed. Plant growth seemed to be very limited, although a few seedlings were evident. Cooling water was being used on the exterior glass surface, being supplied from a distributor pipe with holes to spray water at the ridge of the greenhouse, then running down the outer surfaces to collecting troughs at the lower edges.

Inside the greenhouses, temperature and humidity were both very high. The air in the greenhouse was essentially saturated, and the temperature was probably above 100°F. The conditions were similar to those in a steam bath. The purpose of the water flowing on the outside of the glass was to reduce the interior temperature. This decrease in temperature would naturally reduce the yield of fresh water, since productivity of the solar still decreases as temperature decreases. However, it would appear that plants would have to be selected carefully, even under the condition achieved, because of very high humidity and temperature. It seems that there is some doubt as to whether this system can be practically used. One reason may be the need for water cooling on the exterior of the greenhouse. Fresh water is now being used, but the plan would be to use salt water in real operations. The use of fresh water would be far too extravagant for this operation, since there is probably not enough production to supply the plants as well as the outside cooling water. It is expected that the use of salt water as coolant would contribute problems with salt encrustation on the glass or perhaps corrosion in the collecting channels.

Solar Water Heaters

Approximately eight solar water heaters were in operation at the test station. Comparative tests are being made on flat plate solar water heaters of various designs and types. It was stated that water heaters from the Kirgiz, Azerbaijan, Uzbek, and Ukraine Republics were being tested and compared. The construction of most of the water heaters appeared good, and the test setup was well designed. Most of the heaters were arranged for single-pass through-flow, rather than recirculation from storage. Thus well controlled testing could probably be better realized.

(1) Aluminum "Roll-Bond" collectors (four panels) were being tested. The total area was about2x3meters.Ordinaryaluminummaterialswereused,withoutalloylinngs.It was stated that at 60° to 70°C outlet temperatures more than 50% efficiency could be achieved, and at 80°, 40 to 45%. At the time of the visit, water was entering the collector at 26°C and leaving at 67°C. The estimated once-through flow was about 100 cubic centimeters per minute. Atmospheric temperature was about 30°C.

(2) An installation intended for bathing and showers in group facilities consisted of a glass-covered flat tank of 160 liters volume intended for batch operation. It was mounted on a slightly sloping frame (about 15° from the horizontal) and was roughly 4'x8'x6" deep. It was stated that the tank is five centimeters deep. The material of the tank is ordinary mild steel, and the top surface is painted black. It was stated that the total cost of such an installation could be 40 to 50 rubles. Water would be supplied to the tank in the morning, allowed to heat throughout the day, then used in the late afternoon and evening.

(3) Another tank-type heater, nearly the same design as the second unit above, was used in a through-flow operation, and involved a somewhat shallower depth than the five centimeter tank above. It would presumably be used in a recirculation mode with a separate storage tank, or could be used in a batch heater mode of somewhat smaller capacity than the above unit.

(4) A heater made in the "factory" at Bukhara was under test on a test rack. The absorber panel was made of corrugated welded steel, with the corrugations running up the slope. Two sheets of steel appeared to be welded at the edges only, with the corrugations in effect forming tubes for water rising through the panels. Manifolds at top and bottom seem to be welded to the sheet. (It is possible that a tubular design was actually involved, with the metal sheet simply covering the tubes and providing heat conduction into the tubes. The tubes would underlie the corrugations.) The unit was heavily coated with what appeared to be an asphaltic paint.

(5) Two other water heaters under test were double-glazed, tank-type units said to contain eutectic salts which melted at 40° and 70°C, respectively. The depth of the salts in the unit was stated to be eight and ten centimeters. Water tubing in the salt container provided the heat transfer surface into water flowing through the salt bath.

Operation would presumably be exposure to the sun, melting of the salts for storage, and passage of water through the tubes for heat supply both day and night.

The extent of the solar water heater installations indicated a large interest in that application. Apparently, however, no single design has yet emerged as the preferred type. It is reasonable to expect that the results of the tests now underway could be important in establishing a superior design.

Photovoltaic Generator for Water Pumping

A 200 watt maximum power photovoltaic generator was demonstrated. Silicon cells, in the form of 0.6 square meter arrays in strips about six meters long and ten centimeters wide, received reflected radiation from two halves of an eccentrically mounted parabolic trough. The parabolic trough halves consisted each of 18 strips of back-aluminized glass mirrors, each about two inches wide. There are eight sections or mirrors, four in each trough, with the total reflector array totaling 7.5 square meters. The concentration ratio is 15. The unit is mounted on an east-west tracking platform with the axis at a fixed tilt to the south.

The cells are stated to have 7% efficiency at air mass 1.0. Their operating temperature reaches 80° maximum, natural air cooling being provided by two types of fins in back of the cells. The voltage was stated to be approximately 40 volts.

Thermoelectric Generator

A thermoelectric generator, about eight inches square, was being irradiated by solar radiation from a parabolic concentrator (designed and built by Boris Garf a number of years ago), five meters in diameter. The reflecting surface consisted of electropolished aluminum strips arranged in three concentric rings, each strip about two feet long and two to three inches wide. This material appeared rather dull, the polish apparently having deteriorated. In full sun, about 16 kilowatts thermal fall on the reflector surface.

The thermoelectric generator is water cooled, and was stated to be three-stage couples of bismuth, tellurium, and selenium alloys. Although a theoretical efficiency as high as 15% is possible, the unit is now stated to be generating about 100 watts which would be an efficiency, overall, of less than 1%. It was also stated that about 400 watts were desired for a pumping operation and that they hoped to eventually get as high as 1.5 kilowatts from such a unit. This output would represent an overall efficiency of about 10%. Problems of thermal cracking of the thermoelectric elements and the failure of the electrical connections to the elements have still not been solved. Apparently there is still considerable interest in thermoelectric generation with solar input.

Cooling System with Jet Compression

The decommissioned cooling system, with a 12 square meter parabolic cylinder concentrator, was seen at a distance. This plant was built in 1964, with a freon compression system operated by an ejector which received its high pressure vapor from the solar concentrator. A system was also in place for heating as well as cooling. A small building adjacent to the concentrator received the output.

It was stated that the system was not economical, that the efficiency was poor, that there was shadowing of the reflector by the focal tube and the superstructure, and that the jet operation was very poor. This process has been abandoned.

Solar Stills

Because of sufficient forage for sheep grazing in the desert but a lack of fresh water, there is a major plan to provide desalted water from saline wells in the desert. By spacing watering stations about 20 kilometers apart and providing outputs of five cubic meters per day, this area can be made productive. Pipelines are out of the question for such distances in this region. Solar distillation is the highest priority for solar energy use in the Soviet Union at the present time. The need for self-sustained, completely automatic solar stills in the desert is apparently well established. The water quantity required is 10 cubic meters per day per flock of 1000 sheep. Approximately one square meter of solar distiller is needed per animal, with an output of about one cubic meter per year. It was stated that production of these plants will commence next year, with a target of about 30 installations per year. The economics were claimed to be favorable, with a pay-back period of six to seven years, and a profit of 50 rubles per sheep. The total cost of the solar still was expected to be 40 to 70 rubles per square meter.

Six solar stills of various sizes were being tested. The largest was approximately two meters wide by twenty meters long, constructed of concrete and supported on legs about 1/2 meter above the ground. The elevation was for convenience in this research facility and construction on the ground would probably occur in the field. Reinforced concrete basins with steel framing for glass support were used. An asymmetric cover design was adopted. The south-sloping pieces of glass are about 1.5 by 0.5 meters, and the steep north slope is about 0.5 by 0.5 meters. The steel members are heavily painted, and a soft putty is used to contain the glass in the frame.

Water in the basin appeared clear, there was little deposit on the bottom, and it was stated that algae and organic growth were no problem in the desert installations because the feed water was from underground and contained no organics. It was also stated that the salt composition was almost entirely sodium chloride and a small amount of nitrates, and that no sulfates existed to cause scaling. The design apparently involves a basin bottom of about six centimeters of concrete, and a deep water pool of about 10 centimeters is normally contained.

The location of a proposed plant is about 150 kilometers from Ashkhabad, where not many roads exist. The need for concrete in these installations appears a serious drawback, because of the difficulty of construction in such remote areas. There was a mention of corrosion problems and salt removal problems, so apparently there still are needs for improvements in design and operation.

The Bacharden distiller, about 200 kilometers from Ashkhabad, is no longer in operation. Problems with the cracking of concrete, loss of water, and perhaps other difficulties occur. This unit was a large installation, about 600 square meters, so the loss represents a substantial failure. Much interest was expressed in suggestions that the Australian solar still design be investigated, because of the portability of construction materials under difficult transport conditions.

In summary, although top priority is being given to the solar desalination project and ample funds from the agricultural ministries are available for testing an actual construction of designs, there seems to be no sense of urgency. It appears that some good technical inputs into this program would be beneficial. It is possible that feedback of performance under genuine field conditions could be of value also to the US.

Photoelectric Studies

A good quality paraboloid concentrator of about 1.5 meters diameter and back-silvered glass, was focused on a small silicon cell array about one or two inches square. Water-cooled cells were used. A high concentration ratio was evident.

A small array, about 0.5 square foot, of vertical junction photovoltaic cells was on display, as were conventional silicon cells, mounted in glass tubes (for protection) of about 1.5 inch diameter.

Reflectors, about 1.5 foot in diameter, of plastic-formed structure, with what appears to be aluminized plastic film reflective linings, were shown. Rather than being perfect parabaloids, they are slightly faceted, with concentric rings about 1.5 inches wide. Quality appears excellent. The cost of one of these small units was stated to be about five rubles.

Solar Cooled House

The open cycle, lithium chloride air-conditioning system was inspected in the multifamily apartment house. The building is three stories high, with eight apartments. The construction of the building and the cooling system were done in 1972, and the system design was based on previous laboratory experiments at about two tons cooling capacity.

The present cooling arrangement is by two separate systems, used alternatively. One is a cold water circulation system through the ceilings of the rooms. The other is a cold air distribution system, the air being supplied from an evaporative cooler in which chilled water from the cooling cycle is sprayed. During the visit, the air system was in use. Heating of the building is provided by use of the panels and circulating pipes, with warm water being supplied from a gas-fired boiler.

The lithium chloride concentrator service is located on the house roof. The distribution pipe provides the solution at the upper edge of the slightly sloping roof structure. The flow across the roof is imperceptible. The liquid is collected at the lower edge of the roof and runs to the mechanical system in the basement. The capacity of the system is 40,000 kilocalories per hour, equivalent to about 15 tons of cooling. The combination absorber-evaporator unit in the basement is about ten feet long and four feet across, with about two to three feet of height for the pair of cylinders. The heat exchanger is a double pipe unit mounted on the west wall of the basement. Large-size circulation equipment occupies most of the basement, where as the lithium chloride system is relatively compact. An open rectangular water tank supplies the make-up water to the open cycle system, and a rectangular tank on the north wall is used for the supply of lithium chloride solution when charging takes place. Cooling water is recirculated from a spray pond on the west side of the house.

At the time of the visit, the pressure in the evaporator was five millimeters of mercury and the temperature 5°C. This cold water provided ample cooling to the rooms visited. This system has been operating for several years, but with limited reports of results; it is now evident that operation is indeed successful. It is probable that some problems are present, but the demonstration of satisfactory operation is very significant. No work of this type is being done elsewhere in the world. It was stated that two new apartment houses being planned for construction next year, with over 100 apartments each, would employ this same system.

SEMINAR/SOLAR THERMAL POWER PRODUCTION

Dr. B. U. Tarnizhevsky and Dr. A. C. Skinrood jointly shared this session. Three formal papers were presented on the afternoon of September 7, and a discussion period follows. Most of the Soviet's questions were directed at the Skinrood paper on receiver and heliostat design. There seemed to be little understanding of the mathematical structure of the Vant-Hull paper.

On September 8, six papers were presented. The only Soviet paper that contained significant new information was the one by Soziev. Further questioning elicited the fact that this paper involves the design study for the Crimea station. No heliostats have been built or tested. Ten people at the Krzhizhanovsky Institute are involved in this project. This Institute seems to be the lead institution in the project. The Soviets plan to build a 1-2 MWt plant in the Crimea (approximately 700 miles south of Moscow). Land has been allocated, and the money for detailed design has been authorized. Detailed design will be completed in 1978, and construction will start in 1979. Up to 500 heliostats, 2x4 meters in size, will be used. The mirrors will be flat, and the question of open-loop versus closed-loop control has not been decided.

In the discussion of Skinrood's paper on thermal storage, the Soviets indicated that they are more interested in pumped hydro-storage. They stated that they have worked on thermal storage using change-of-phase materials, but that they did not have any detailed information with them.

The paper by I. Baum had some good analytical work on an individual heliostat. His calculations indicate that off-axis aberration of focusing heliostats can be reduced by off-setting the planes of individual mirror facets. This idea warrants investigation. Baum is a very capable individual.

The two papers by Frank Biggs on mirror performance were well received, although it was again evident that the Soviets have done no work on computer modeling of heliostat fields.

The paper by Zakhidov presented calculations similar to those of Trombe. It was not a strong paper. He stated that the only way to build the plant is with a terraced heliostat field.

On September 9, three more papers were presented. The Soviets were very interested in Lorin Vant-Hull's presentation of his optimization code. They have no comparable analytic tool.

The paper by Tepliakov presented the receiver design which is being worked on for the Crimea plant. The receiver is to be a recirculating drum type with flat panels. The absorber size will be 9x12 meters and the receiver will weigh eight metric tons. Peak flux is $150\text{-}200 \times 10^3$ kcal/m^2-hr (0.17-0.23 MW/m^2). A selective coating may be used and a north mirror field will be used. Various open receiver geometries were considered: conical, cylindrical, and pancake. They are also working on Brayton systems, but one is not being considered for the Crimea plant.

Aksinov's paper dealt with the economic analysis of power plants, as well as desalination plants, in the Kozakhstan Republic. He stated that solar plants could be economic if fuel has to be transported more than 250 km. The work is in the initial stages and will be completed early in 1978. Large plants and the advisability of connection to a grid will be studied. His studies are based on costs provided by the TEP Institute in Moscow.

The session included a discussion period at the conclusion of the presentation of the papers. The topics included the advisability of connecting solar plants to a grid, optimum plant size, and possible areas of US/USSR cooperation.

In the course of discussions of grid connections, it became clear there is little difference between the US and Soviet position on such connections. Both are doing studies and will consider whichever type of plant best fits the needs.

The Soviets were very interested in studies on the effect of plant size and cost, since they had not done this type of study. They are looking at data from eight locations in the southern USSR to see whether connecting them together would increase reliability, since cloudy weather would probably not occur simultaneously for these widely separated locations.

Regarding joint programs, Tarnizhevsky stated that since the US was considerably ahead of the USSR in many areas, it would be difficult to define mutual programs other than information exchange. When Skinrood broached the possibility of testing a Soviet receiver at the STTF, Tarnizhevsky said their schedule was so uncertain that it would be difficult to make a commitment. They do not presently have a formal long-range plan. Tarnizhevsky would like to continue the information exchange program with the United States.

In summary, the Soviets are clearly three years behind the United States in the development of solar central receiver power plants. They have some excellent people - Tarnizhevsky, Tepliakov, and Baum; but they apparently are not receiving much funding. With the exception of some heliostat facet tests, there was no evidence that any experimental work had been performed. Their trade-off studies are weak, and no computer codes for heliostat performance predictions have been written. They will continue to fall further behind the United States if the present lack of funding continues. The Soviets had little familiarity with research and development being done outside their own country. They did not have current information on either the US or the French program. They had not read the reports which have been available for more than a year.

It would be useful to obtain Soviet data on the Crimea experiment, since it will be an external, recirculating drum-type receiver, a configuration which the United States has not tested. Therefore, continuation of the US/USSR information exchange is recommended, at least on a limited basis. Further, it is useful to discuss approaches to problems with technical people who are independently seeking solutions.

The complexity of the Soviet governmental system (60 ministries) and the apparent autonomy of the academies and universities all combine to diffuse solar radiation in the USSR. The program organization of the United States is far better; the responsibilities seem to be better defined and organized.

This session was jointly chaired by Dr. H. Brandhorst and Dr. M. M. Koltun. The first day was a summary session of where the Soviet Union stands versus the United States as far as solar energy conversion with photovoltaic cells is concerned. In the area of silicon cells, the Soviet Union seems to be on the order of five to six years behind the United States. In the area of cadmium sulfide/copper sulfide cells, they seem to be where we were in the United States about two to three years ago. They do not seem to have organized themselves sufficiently to obtain the higher conversion efficiencies which are characteristic of both silicon and cadmium sulfide/copper sulfide cells. In the area of gallium arsenide cells, it was harder to assess where they stand. Technologically they have some innovative ideas in the area of photovoltaic cells, and this seems to be the main area where possible benefit for the United States may lie. In particular, the theories that they have on high conversion efficiency for devices are innovative. It is not clear at this point whether the ideas which they brought forth are indeed practical and workable; however, they may warrant some further exploration by the United States.

The first of the Russian papers given was by Komashenko of Kiev and dealt with the ceramic solar cells based on cadmium sulfide and cadmium selenide. This area of work is similar to that going on in the United States at the University of Delaware in the cadmium sulfide area, but Komashenko's work dealt with ceramic cells whereas the work at Delaware deals with thin film cells. The corresponding thin film work on cadmium sulfide/copper sulfide in the Soviet Union was being done by Koltun in Moscow, and in a later paper and discussion we will deal with that. The results of Komashenkos's work show essentially nothing new or startling in these materials. The experimental work is similar to the work going on in the United States now, which already exists in the literature from previous work. Their efficiencies are up to around 5% and their degradation and spectral responses are similar to those that have been seen in the West. The main interest here seems to be that they have sealed these cells, as well as other silicon cells, in typical fluorescent light tubes and, therefore, prevent degredation by adequate encapsulation in this way.

The second Russian paper, by Belyaer, was on selenides and tellurides. It dealt with the synthesis of powders and contained mainly details of chemistry and the difficulties involved with preparing good materials; none of the materials have yet been used for solar cells. Therefore, the relevance of this paper to the session was not very great. The Russians were quite interested in the American papers, and the discussions reflected this interest. They were interested in technical details as well as in processes.

Strebkov gave a paper on the concentration of solar radiation and a prediction of high efficiencies based on theory. The basic concepts of his paper are no different from those in other accounts given in western literature. The main thrust is the conclusion that, if the light increases, minority and majority carrier density will be higher than the bulk density of either type and one is in a new regime as far as the solar cell is concerned. In fact, the quasi-Fermi level becomes almost intrinsic. Under these conditions, certain features can be seen; most notably the Dember effect, which is small in most cells, becomes appreciable in this case. The use of a cell in which the structure is p on n rather than n on p gives a higher open circuit voltage since the Dember voltage adds to the open circuit voltage, rather than subtracting as it would in an n on p structure. As one goes higher in intensity, the Dember voltage goes from 50 mV to 200 mV at high intensity, and the open circuit voltage can reach a value of 0.65 to 0.67 at 200 concentration in 10 ohm/cm material. The theory supposedly yields a theoretical efficiency value of 40%; however, they claim that the observed value could be on the order of 30%. The basic fault in the presentation is that the calculations are based essentially on the voltage and short-circut current efficiency, without regard for the fill factor, and they are therefore off by a factor which reduces the theoretical value to roughly 30%. This means that in practice, with shading and other losses, their highest efficiency will probably be in the mid 20's. This is comparable to the results which can be expected from conventional theories for silicon and gallium arsenide. In short, their results are not substantially different from previous treatments of this problem. In another aspect of the same paper, they talk about the graded band gaps and the fact that under those conditions, if ideal grading were obtained, a radiative recombination-limited cell would approach the Carnot cycle efficiency for the sun spectrum, which would be on the order of 97%. This, of course, is not really possible, and it is not clear exactly how their efficiency calculations were carried out to get such high numbers. The paper itself does not seem to indicate that the efficiency would be that high.

In the discussions, the photovoltaic vertical junction cell was discussed; it has an efficiency as manufactured on the order of 7%. One of the interesting points about it is that, according to the diagrams which they drew, it seems to have both a horizontal and a vertical junction simultaneously, and the horizontal junction represents a significant part of the response of the cell. In another paper, Bazarov presented his concept of a combined electric generator photoelectric and waste heat freon engine. The photovoltaic efficiency was on the order of 5%, with 95% available for other useage. They mentioned using heat engines which would work on either rubidium or freon, and they favored freon because it is as good as the rubidium, is cheaper, and can be used in a turbine installation. They had curves, which are in the papers, for the amount of heat which is of use, and for the electric efficiency, based on the efficiency of the photovoltaic cell. There was nothing substantially new in this paper.

In a discussion session on the afternoon of September 8, the cadmium selenide/copper selenide and cadmium sulfide/copper sulfide cells were discussed at length. The work from the Russian's side did not seem to be anything new. The one area where they differ substantially from some of the American efforts was in the grid contact where they seemed to have been reasonably successful using copper, with lead or aluminum over it. In the work at Delaware, gold is used as the grid contact.

On September 9, Kagan gave a paper on gallium arsenide and gallium arsenide heterojunction cells. These cells had areas on the order of 1.5 cm^2, with AM0 current densities of 26 mA/cm^2 and efficiencies of 20%. The main thrust of this talk was an analysis of these cells and the measurement of the diode characteristics. He discussed varying the temperature of these cells and the comparison of the homojunction and heterojunction configurations, using a gallium aluminum arsenide layer to form the heterojunction. The characteristics of these cells were given. One of the innovations of the Russians was to make a cell with a layer which converts light to electron and whole pairs which then recombine and radiate the light through a wider band gap material to a p-n junction. This arrangement enabled them to design the cell for very high intensity, with the thick higher band-gap material taking care of any serious resistance problems in the planar geometry. They expected that this device would have an efficiency at AM1 of the order of 23-25%, and they expected that the cell would also have high efficiency at high intensity. The efficiency with which the layer would absorb light and reradiate light was on the order of 80%. Variation of the layer thickness was discussed. The suggested way to accomplish the thickness variation was to use various solid solutions of gallium aluminum arsenide.

The next paper, and the last paper which the Russians presented, was by Koltun on degradation, particularly in space cells. He talked about the need to protect the silicon cells from ultraviolet radiation, particle irradiation, and overheating, and the need for antireflection coatings, optical coatings and infrared reflection to maintain the heat balance of the cell in order to keep it from overheating. The structure and encapsulation of the cells were described. He also noted that polycrystalline cells could also be used in this way, and the decay of these polycrystalline cells of cadmium sulfide with copper sulfide or copper telluride was discussed. Cells that were kept in gas-filled tubes have been stable for four years.

Space is a harsher environment for them, and they had limited data on these cells in space. There were no really new revelations in any of these discussions, and there seems to be no advantage in the techniques that the Russians are using compared to those which the United States uses.

The Russians were very interested in the testing procedures and formation of reference cells, which were discussed by Henry Brandhorst, and the most questions were asked on this subject. In the discussion session, the question of the use of concentration techniques versus flat-plate techniques was brought up. Kagan was the proponent of the concentration technique and Koltun was the proponent of the flat-plate combined system which could be used on houses to provide both electrical and heating needs.

The discussion of topics for future exchanges and papers for future seminars was brought up, and a lively discussion ensued. The final list agreed upon was the exchange of standard cells and the development of common terminology and measurement procedures. Other areas of possible future exchange were discussion of high efficiency cell development and the theory leading to high efficiency cells of silicon, gallium arsenide, and thin films, unconventional theoretical approaches to extremely high efficiency systems, and low cost cell developments of any type.

The co-chairmen for this session were V. A. Baum of the USSR and George O. Lof of the United States. The following discussion highlights some of the key elements of several papers which are of particular interest.

Kakabayev presented a discussion of a freon-ejecting cooling system which had been tested at Bikrova and had been abandoned since the idea did not seem to work well. The system utilized a parabolic-cylindrical tube of electrically polished aluminum as the collecting element. Although the system worked, it had very low performance due to the low efficiency of the jet ejector, and the entire concept was abandoned in favor of the open-cycle system. The open-cycle system has achieved temperature reductions of 10° to 15°C below the outside temperature. The net capacity is 30,000-40,000 kcal-hr. The system is designed to work at an outside temperature of 35°C at an absolute humidity of 9 gm/m^3. At an absolute humidity of 20 gm/m^3, it would have no output. The Soviet attitude towards this cooling system is quite positive; they have two houses under construction using this type of cooling.

A paper by Malevsky et al. described a combined solar-fuel system for hot water supply to a hotel with a capacity of 250 persons in the city of Simferopol. The system described was relatively complex, incorporating an intermediate heat exchanger. Despite questioning, it was not possible to establish the purpose of this intermediate heat exchanger. The paper is of particular interest since it describes one of the very few ways in which the Soviets actually plan to utilize solar energy; that is, for the heating of water in the southern part of the USSR. The system has been started up with water as the fluid although they intend to transfer to ethylene glycol as the heat exchange fluid for winter operation.

A paper presented by Grosman described the lithium chloride open-cycle cooling unit which they have developed. This was a key paper of the seminar. They had done a thorough search of various working fluids and had concluded that lithium chloride was the best. In addition to the paper, the question and answer period brought up the following points. Contamination of the roof due to an occasional dust storm is handled by means of filters, a sump in the system, and cleaning out these elements as necessary on an occasional basis. One system is in existence at Bikrova; however, there are two additional lab setups which have been operated. They anticipate replacement of the lithium chloride approximately once a year due to losses and contamination. The losses are minor, constituting 2 to 3% per year. The systems are expandable to larger sizes for centralized production of cold water. They anticipate production of units of 300,000 kcal and above (100 tons of refrigeration). It is anticipated that the maintenance will not be a major problem in the larger machine. The cost of a 300,000 kcal/hr machine is anticipated to be in the range of 20,000 rubles for an experimental unit.

A paper presented by Sigalov was notable primarily because it described a system that they have developed for the protection of roll-bond aluminum collectors from corrosion. The system consists primarily of putting an additional layer (consisting of magnesium, titanium, and boron) on each of the inside surfaces. They have developed the process but do not have figures available on the corrosion testing results. They anticipate that the cost of a plated panel, would be less than 10 rubles per square meter. However, they also anticipate that the cost of the extra protective layer would increase the total cost of a panel by a factor of 2.5.

The Soviets in this session were very interested in cooperation. They are not used to giving presentations and were ill prepared for it. Their papers were fairly general and nonquantitative. The lack of detailed quantified results from experiments was surprising. It was not clear whether this is a general characteristic or was intentionally done in these cases. Generally speaking, the quality of the papers was found to be less than those in their publication Geliotekhnika.

The most important technical results of the trip, for the US program, is the information on the open-cycle lithium chloride absorption chiller. Clearly this approach is only suitable for a reasonably dry climate where there is little summer rainfall. However, it might be a good solution for solar cooling throughout the Southwest including all of southern California.

Attachment I

TRIP ITINERARY

3-17 September 1977

Saturday	3 Sept.	Arrival in Moscow
Sunday	4 Sept.	Rest
Monday	5 Sept.	Ministry of Power and Electrification Discussion of programs for the visit and seminar. Information on solar energy projected in the USSR and the USA.
Thursday	5 Sept.	Travel to Ashkabad
Wednesday	7 Sept.	Opening of US-Soviet Seminar on Solar Energy Application. Plenary Meeting Meetings of Sections I, II and III
Thursday	8 Sept.	US-Soviet Seminar Meeting of Sections I, II and III
Friday	9 Sept.	US-Soviet Seminar Meeting of Sections I, II and III
Saturday	10 Sept.	Visit to the Solar Energy Experimental Base of the Physico-Technical Institute of the Turkmen Academy of Sciences
Sunday	11 Sept.	Rest
Monday	12 Sept.	US-Soviet Seminar Plenary Meeting General Discussion Conclusion of the Seminar Talk with President, Turkmen Academy of Sciences
Tuesday	13 Sept.	Travel to Moscow
Wednesday	14 Sept.	Moscow University Photo-chemical conversion Krzhizhanovsky Power Engineering Institute Solar Station Discussion of the Record

Thursday	15 Sept.	Institute of Building Physics Solar Energy and Building Krzhizhanovsky Power Engineering Institute Photocells
Friday	16 Sept.	Ministry of Power and Electrification Discussion of the results and prospects of cooperation Signing of the Record
Saturday	17 Sept.	Departure from Moscow

ATTACHMENTS

Attachment II

PROGRAM
of the
THIRD US-USSR SEMINAR ON SOLAR ENERGY APPLICATION

Turkmen Academy of Sciences
Ashkabad
7-12 September 1977

Wednesday, 7 September

10:00 Plenary Meeting
Opening of Seminar

11:00 The US ERDA Program on Solar Energy;
Review of Solar International Cooperation
L. Herwig

Session I. Solar Power Stations
Cochairmen: B.V. Tarnizhevsky, USSR
A. Skinrood, US

12:00 An Educated Ray Trace Approach to Solar Tower Optics
L. Vant-Hull

Solar Stations for Combined Generation of Thermal and Electric Power
Yu. N. Malevsky, B.V. Tarnizhevsky, D. Yu. Ibragimov, R.I. Soziev

Comparative Analysis of Solar Thermal Power Tower Systems with Different Arrangements
C. S. Selvage

16:00 Study on Optics of a Reflector of Solar Power Stations
N.B. Rekant, R.R. Aparici, I.I. Kokhova

Session II. Solar Heating and Cooling Systems
Cochairmen: V.A. Baum, USSR
G.O.G. Lof, US

12:00 Architectural Features of Buildings with Solar Power Systems
A.I. Zavarov, A.R. Fert, A.V. Matvienko

Comparative Performance of Solar Heating With Air and Liquid Systems
S. Karaki, G.O.G. Lof, C.C. Smith

An Integrated Solar Heating System for an Urban Building
Yu. A. Konstantinovsky, Yu. N. Malevsky, B.V. Tarnizhevsky

16:00 Design, Construction and Testing of a Residential Solar Heating and Cooling System
G.O.G. Lof, D.S. Ward

Session III. Direct Solar Conversion into Electricity
Cochairmen: M.M. Koltun, USSR
H. Brandhorst, US

12:00 Lowering the Cost of Photovoltaic Power
J.D. Furber

A Study on the Possibility of Terrestrial Application of Heterophotoconverters at Their Irradiation with Concentrated Sun Light

Zh. I. Alferov, B.M. Andreev, G.S. Daletsky, M.B. Kogan, N.S. Lidorenko, S.B. Ryabikov, V.M. Tuchkevich

Recent Improvements and Investigations of Silicon Solar Cell Efficiency
M. Wolf

16:00 Physical Concepts of Photoelectric Conversion of Concentrated Solar Energy into Electricity
N.S. Lidorenko, V.M. Evdokimov, A.F. Milovanov, S.V. Ryabikov, D.S. Strebkov

Thursday, 8 September

Session I

10:00 Survey and Analysis of High Temperature Thermal Storage Methods For Solar Tower Systems
C. S. Selvage

Methods of Reduction the Number of Tracking Devices of Solar Power Stations
I. V. Baum

A Parameter Study of a Central-Receiver Power Station
F. Biggs, C.N. Vittitoe

Solar Power Plant Concentrators with Two Mirrors: Calculation and Optimization
R.A. Zakhidov, A.A. Vainer, A.Sh. Kodzhiev

16:00 Discussion

Session II

10:00 Technical and Economical Characteristics of Solar Cooling Systems in Buildings
V.A. Baum, A. Kakabaev, O. Klishchaeva

Design of Experimental Solar House Heating System
P.J. Huges, T.L. Freeman, H. Grunes, W.A. Beckman

Experience in Designing Solar Absorption Cooling Systems
O.A. Kremnev, V.Ya. Zhuravlenko, E.R. Grossman, I.P. Tolstikh

Estimation of Optimum Solar System Performance in Northern Climates
W.A. Beckman

16:00 Discussion

Session III

10:00 Theory of Heterojunction Solar Cells $CdS—Cu_2S$
A. Rothwarf

Thin-film and Ceramic Solar Cells Based on Cadmium Sulphide and Selenide
V.N. Komashchenko, A.N. Marchenko, G.A. Fedorous

Crystallite Size Considerations in Polycrystal-line Solar Cells
A. Rothwarf

Electrophysical Degradation of Photoelectric Converters at Long Operation
G.S. Daletsky, I.V. Karpenko, M.M. Koltun, Yu.N. Ksendzatskaya, V.M. Kuznetsov, S.V. Ryabikov, R.N. Tyrvenko, V.A. Karpukhin

16:00 Discussion

Friday, 9 September

Session I

10:00 Helios: A Computational Model for Solar Concentrators
F. Biggs, C.N. Vittitoe

The Use of Solar Power Tower Stations in Rural Regions of Kazakhstan: Technical and Economical Analysis
G.F. Sumin, A.K. Dzharzhanov, A.M. Karpenko, B.V. Aksenov

A Cellwise Method for Optimization of Large Central Receiver Systems
F.W. Lipps, L.L. Vant-Hull

An Approach to Thermal Optimization of Central Solar Power Station Receiver by Energy Concentration and Fluid Temperature
D.I. Tepliakov, R.R. Aparici

16:00 Discussion

Session II

10:00 Fabrication and Application of Aluminum Rollbond-type Absorbers of Solar Water Heaters Used in Hot Water and Cooling Systems
N.I. Koryagin, Yu.M. Smigalov, Yu.N. Malevsky, A.I. Malikhin

Passive Solar Heating of Building
J.D. Balcomb, J.C. Hedstrom, R.D. McFarland

System Analysis Approach to Evaluating the Environmental Impact of Solar Heating Installations
V.B. Kozlov

Comparative Effectiveness of Solar Water Heaters with Free and Forced Circulation
C.A. Azimov, G.Ya. Umarov, R.R. Avezov

16:00 Discussion

Session III

10:00 The Effect of Sunshine Testing on Terrestrial Solar Cell System Components
F. Forestieri, E. Anagnostou

Synthesis of Finely-Dispersed Selenides and Tellurides for Semiconducting Energy Converters
A.N. Belyaev, M.A. Berchenko, Yu.N. Malevsky

Interim Solar Cell Testing Procedures for Terrestrial Application
H. Brandhorst, J. Hickey, E. Ralph Curtis

A Possibility of Developing the Photoelectric System Utilizing Waste Heat
B.A. Bazarov, Ch. Bazarov, D.S. Strebkov, B.D. Tairov, V.D. Tereschin, A. Yakuzliev

Saturday, 10 September

10:00 Visit to the Test Station of the Institute of Physical Studies, Turkmen Academy of Science

Monday, 12 September

10:00 <u>Plenary Meeting</u>
Report of Results of Sessions Work
General Discussion
Close of Seminar

Attachment III

USSR PARTICIPANTS

Third US-Soviet Seminar on
Solar Energy Application

Mr. A.V. Stolyarov	USSR Coordinator for Solar Energy, the USSR Minstry of Power and Electrification (MINENERGO)
Dr. Yu. N. Malevskiy	USSR Deputy Coordinator for Solar Energy, Head of the Heliotechnology Laboratory of the G.M. Krzhizhanovsky Power Engineering Institute (ENIN)
Dr. V.I. Dobrokhotov	Deputy Head of Power and Electrical Engineering Department of the USSR Committee of Science and Technology
Mr. B.A. Sobinyakov	Glavniiproekt, the USSR Ministry of Power and Electrification
Dr. O. Ovezgeldiev	Vice-President of the Turkmen Academy of Sciences
Mr. V.N. Maltsev	General Secretary from the USSR side on cooperation with the USA in power engineering
Dr. B.V. Tarnizhevsky	Dr. of Sc., Head of a Sector, Solar Energy Laboratory of the Krzhizhanovsky sky Power Engineering Institute
Dr. A. Hanbergiev	Director of the Physico-Technical Institute of the Turkmen Academy of Sciences (PTI AN TSSR)
Dr. V.A. Baum	Head of the Division of Solar Energy at the Turkmen Academy of Sciences
Dr. R. Bayramov	Head of Heliotechnology Laboratory at PTI AN TSSR
Dr. R.I. Soziev	Solar Energy Laboratory ENIN
Dr. N.B. Rekant	Solar Energy Laboratory ENIN
Dr. V.B. Kozlov	Head of Department of System Analysis Research, ENIN

U. Kh. Yankovskis	Interpreter, the Krzhizhanovsky Power Engineering Institute

Attachment IV

PROTOCOL
of the Fourth Meeting of U.S. and U.S.S.R.
Specialists on the General Problems of
Utilizing Solar Energy (Theme 08.0209)
under the U.S.-U.S.S.R. Agreement on
Cooperation in the Field of Energy of
June 28, 1974

September 3-17, 1977

In accordance with the Protocols of previous Meetings of the U.S. and U.S.S.R. specialists on solar energy technology dated March 4, 1976, signed in Washington and of October 25, 1976, signed in Moscow, the U.S. Group of specialists visited the U.S.S.R. to participate in the Third Joint U.S.-U.S.S.R. Seminar on Solar Energy Technology held from 7 to 12 September 1977.

The U.S. side was headed by Dr. Lloyd Herwig, Scientific Advisor, Division of Solar Energy/ERDA.

The U.S.S.R. side was headed by Stolyarov A.V., Chief Engineer, Main Administration for Design and Research Work, U.S.S.R. Ministry of Power and Electrification.

The itinerary and program for the U.S. Group visit to the U.S.S.R. is given in Attachment I.

The list of participants in the discussions and joint seminar is attached as Attachment II.

During the U.S. delegation's visit, the results of cooperative efforts over the elapsed period, as well as the program of joint activities for 1978 were discussed.

The Third U.S.-U.S.S.R. seminar on solar energy technology, held in the Turkmen Academy of Sciences, Ashkhabad, September 7-12, 1977, involved 19 Soviet and 19 U.S. contributions concerning the U.S. and U.S.S.R. programs of research on and development of solar power plants, solar heating and cooling systems and solar direct conversion. The list of papers presented at the joint seminar are given in Attachment III. As a part of these meetings, discussions were held concerning topics for future cooperative efforts in preparation for the next meeting.

During the meetings in Moscow and Ashkhabad it was agreed that the general plan for cooperation would be continued. It was also agreed that each side could publish the papers of the conference, along with introductory remarks in their respective languages, as may be deemed appropriate.

Topics for possible collaborative efforts were discussed in a preliminary manner, with the understanding that they would be formally agreed to at the next joint meeting to be held in the U.S. in 1978. These topics are included as Attachment IV.

It was agreed that the next (fourth) joint seminar and working meeting should be held in the United States as called for in the agreement of March 4, 1976. Dates for the joint seminar will be established by correspondence, and should take place sometime in 1978. Papers prepared at this seminar should be exchanged officially at least 60 days in advance of the meeting in order to allow translation and distribution of complete texts to all participants.

It is expedient to retain in 1978 the Programs I, II and III and forms of cooperation agreed upon in 1976 and presented in protocols of March 4 and October 25, 1976. General topics for emphasis in these programs should be agreed upon through correspondence at least four months prior to the meeting in the U.S.

The U.S. side has come to the U.S.S.R. to assess as fully as possible the status of Soviet solar energy technology in cooperative Programs I, II and III. The U.S. side expresses satisfacton with the meeting arrangements in Ashkhabad and the general conduct of the visit, and in assessing Soviet technology and plans in Programs I and II. While much progress was made in assessing Program III activities, the U.S. side believes that visits to direct conversion laboratories in Moscow would have made the assessment of the Program III more complete.

Both sides confirm that joint scientific-technical seminars and annual meetings convened for discussion of cooperative work provides a unique opportunity to exchange new ideas, opinions and experiences in the field of solar energy and further U.S. and U.S.S.R. national efforts aimed at developing viable solar technology.

Both sides note with satisfaction progress achieved in solar energy R&D and confirm that the seminar held and the meeting of specialists which discussed the results of cooperation were productive, took place in an atmosphere of good will and mutual understanding.

This Protocol was done in Moscow on September 16, 1977 in Russian and English languages, both text being equally authentic.

(Signed by:)

Lloyd O. Herwig
US Energy Research and
Development Administration

Alexander Stolyarov
USSR Ministry of Power
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