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**ANNUAL COLLECTION AND STORAGE OF SOLAR ENERGY
FOR THE HEATING OF BUILDINGS, REPORT NO. 1**

Progress Report, May—November 1976

**J. T. Beard
J. W. Dickey
F. A. Iachetta
L. U. Lilleleht**

January 1977

Work Performed Under Contract No. EY-76-S-05-5136

**Department of Mechanical Engineering
Virginia University
Charlottesville, Virginia**

**ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
Division of Solar Energy**

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Period May-November 1976

J. Taylor Beard
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UNDER CONTRACT NO. E-(40-1)-5136

PREPARED FOR
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
DIVISION OF SOLAR RESEARCH

Mechanical Engineering Department
University of Virginia
Charlottesville, Virginia 22901
RLES Report No. UVA/527190/ME 77/101

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I. ABSTRACT

A new system for the annual collection and storage of solar heated water for heating of buildings is under development at the University of Virginia. The system is composed of an energy storage sub-system which stores hot water in an underground pool and of a solar collector sub-system which acts not only to collect solar energy throughout the year but also to limit the evaporative and convective heat losses from the storage system.

During the summer of 1976, a storage sub-system was constructed using the initial design specifications. A structural failure of that storage pool occurred in August resulting from a leak in the pool liner which caused a failure of the pool structure. A revised design of the storage pool sub-system has been implemented and construction was completed in November, 1976.

The collector sub-system has been designed and constructed. Collector operation began in February 1977. A vertical reflector on the north edge of the collector was added in March 1977.

Future research will include initial total system operation, performance evaluation, and analytical modeling.

II. NARRATIVE

A. Research Objectives

The research objectives include the design, construction, testing, and evaluation of a new system for the annual collection and storage of solar energy for the heating of buildings.

The initial design of the system included a 100,000 gallon water storage pool which resembled a swimming pool. The collector sub-system is that of a near horizontal open-flow (water-trickle) solar collector having two glazings. The solar collector acts not only to collect solar energy but also to reduce heat losses from the energy storage pool. Design modifications for improved structural and thermal performance are an important part of the research objectives.

The original objectives called for the construction of an initial solar energy collection/storage system to be completed in the first year and based on the evaluation of the performance, a second system to be initiated in the second year.

The testing and evaluation program is to include the use of standard instrumentation and measuring techniques as well as analytical simulation to determine performance under varying ambient exposures. The evaluation also will include economic, structural, and operational considerations.

B. Summary of the Progress

A new system for the annual collection and storage of solar heated water for the heating of buildings is under development at the University of Virginia. A two year research project will provide improved design, construction, testing, and evaluation of this system.

The initial design of the system called a 100,000 gallon water storage pool with a solar collector sub-system mounted horizontally on the top of the pool. The solar collector acts not only to collect solar energy but also to reduce heat losses from the energy storage.

Construction of the initial design of the storage pool began in June of 1976. In August of 1976 the pool suffered a significant leak and a failure of the vertical wall structures.

In September of 1976 a revised design was developed and has been implemented. The revised pool design provides for replacing the deep vertical earth surfaces of the initial design with 45° sloping earth surfaces. The sloping surfaces are proven to be stable without structural reinforcement and offer considerable cost advantages.

The construction of the pool sub-system was completed by late November. Operation of the solar collector sub-system with some design refinement began in February 1977. The vertical reflector along the north edge of the collector was erected in March 1977. A major delay in the collector installation was caused by the severe cold winter weather and the resulting ice accumulation on the storage pool.

The next phase of the research will be to determine system performance properties and operational characteristics. In addition, analytical modeling of the system performance is being developed to allow for simulation of performance under various climatic conditions.

C. Report of the Progress: Initial Design

In May of 1976, the University of Virginia began its research program to evaluate a new system for the annual collection and storage of solar-heated water for the heating of buildings. The system includes a near-horizontal solar collector on the top of an energy storage pool which resembles a swimming pool. The initial design was developed by Mr. John W. Dickey and is illustrated in Figures 1 and 2 in the accompanying legend.

The storage sub-system is different from the traditional solar pond systems in that a solar collector sub-system is located on the top surface of the pond thereby restricting evaporative heat losses and convective heat losses from the storage system. Provisions are made for the extracting of water from the storage system at any desired depth so that the inlet water temperature to the collectors may be controlled with the accompanying impact on the collector efficiency. One other feature of the storage system which is different from the traditional solar ponds is that no salt or membrane technique is used to assure stratification with the hottest water on the bottom of the pond. In fact, the system under consideration can operate with limited stratification or maximum stratification depending on the objectives of the application. For example, during the summer season when the pond is being charged with solar energy, it would be most desirable to bring the lowest temperature water to the collector so that the collection

efficiency will be the highest. However, toward the end of the winter season when the solar pond has low energy storage and low temperatures, a warmer water from near the top of the pool could be delivered to the solar collector resulting in a hotter water being delivered for heat exchange application.

1. Excavation
2. Treated Plywood Wall
3. Pool Lining
4. Pool Frame
5. Backfill Berm
6. Collector Panel Assembly
7. Buried Film
8. Floating Styrofoam-Bead Insulation
9. Inner Glazing
- 9'. Outer Glazing
10. Reflector Panel
11. Support Wire for Reflector

Figure 1, Initial Design, Annual collection and storage system

Figure 2, Special features for flow control SCALE: 1" = 7'-0"

Legend for Figure 2

- ① Off-take inlet on float with
- ② Cable level control from
- ③ Winch-drum to select temperature level to match seasonal heating requirements. Thermocouple on float to read temperature and make possible automatic control of off-take level.
- ④ Plastic pipe conduit to and from house with power and control wiring as well as make-up water tubing (under control of float-switch in sump connected to pool - not shown). This pipe blown full of styrafoam bead insulation-spacers on tubes.
- ⑤ ⑥ Circulating pumps for collector and heating loads.
- ⑦ Concrete block anchor for house return and collector circulation intake.

Note 20 foot wide black polyethylene film on sides of pool drawn over plywood and lapped onto pool bottom. Bottom seal (and possible side leaks) done with colloidal suspension.

D. Report of the Progress: Initial Pool Construction

The initial pool construction began in June of 1976 at an appropriate site near the University of Virginia. A large rectangular hole having approximate dimensions of 12 feet deep by 24 feet wide by 40 feet long was dug by a large backhoe. Because of concern about the stability of vertical earth walls, a wood structure with a plywood skin was installed in the hole. This wall structure extended approximately 5 feet above the original ground level in order to allow for the solar collector sub-system to be located on the top of a 15.5 foot deep water pool.

In early August the pool was lined with 10-mil black polyethylene sheets, sealed at the seams by heavy duty "Arno" duct tape. Upon filling the pool with water, significant leaks developed at the seams with a maximum leak rate of around 250 gallons per hour. Plans had been formulated to seal potential leaks with a colloidal suspension of bentonite and paper fiber, a standard lagoon sealant technique. This treatment was implemented, but it proved unsuccessful because the leak was too large.

Water leaked from the pool interior into the loose earth which had been backfilled around the outside of the plywood pool walls. This formed a fluidized mud (wet earth) with a density approximately three times that of water. In addition, the water soaked the plywood skin and wood structural members.

A decision was made to drain the pool so that the liner might be repaired or replaced. However, the fluidized mud

exerted forces large enough to cause a major failure of the plywood and structure. The damage to the pool was so severe that repair was judged to be impractical. In addition, an evaluation of the design concluded that a wood structure of reasonable cost would not be able to withstand the mud loads which would occur in the event of any future significant leak of a pool liner.

E. Report of the Progress: Revised Design and Construction

In September a new pool design was initiated having two major design differences illustrated in Figure 3. The long vertical earth surfaces of the initial design were replaced by 45° sloping earth surfaces. This design change was in response to our finding that modern swimming pool design typically calls for either heavily reinforced concrete vertical walls or for significantly sloping earth surfaces which require only a minimum vertical wall structure and are fitted with a polyvinyl chloride or other swimming pool liner material.

The second design difference was to include a factory-manufactured 20-mil polyvinyl chloride swimming pool liner. All the seams were heat sealed at the factory to assure their integrity. In addition, special care was taken to ensure that this liner would not be punctured. The earth surfaces were smoothed as much as possible and a Dupont Corporation "Tygal" (spun-bonded polypropylene) sub-liner was installed on the earth surfaces to prevent migration of sharp stones, et cetera, from penetrating the polyvinyl chloride liner.

The pool liner was installed, the pool was filled with water and was ready to receive the collector sub-system by late November.

Ground temperature measurements are to be made using thermocouples which are installed below the pool surface as indicated in Figure 4. A schematic of the system provisions

for monitoring and for delivering water from the pool to the collectors and from the pool to provide house heating are illustrated in Figure 5.

Figure 3, Revised Solar Pond Design

Legend for Figure 3

1. Pump House
2. Solar Reflector (North Side)
3. Outer Glazing of Collector
4. Collection Surface
5. Bead Insulation
6. Earth Berm
7. Pool Water
8. Pool Extension Wall
9. Support Structure

1. Reflector Panel - North Side of Pool
2. Styrofoam Insulation - East Half of Pool
3. Polyethylene Film
4. Stone (Crusher Run) and Earth Layers
5. Earth Berm Thermocouple Locations
6. Bottom Thermocouple Locations on East and West Center Line of Pool
7. Surface Thermocouple

Figure 4, Ground Thermocouple Locations

1. Collector Inlet Manifold	6. Underground Conduit Box
2. Water Filter	7. Water Meter
3. Flow Meter Orifice	8. Heat Exchanger
4. Circulation Pump	9. Lapsed Time Meter
5. Hot Water Pump	10. Overflow Tank and Pool Level Control

Figure 5, System for Monitoring and Delivering Water

F. Report of the Progress: Solar Collector Design

The solar collector selected for the annual collection/storage system is that of a near-horizontal open-flow (water-trickle) solar collector having two glazings as indicated in Figures 6 and 7. The glazing materials are separated by air pressure from a small fan with the inner glazing laying on the top of the corrugated metal collector plate. Water flows from the north and south perimeters of the collector system down the valleys of the corrugation to the center of the pool where it exits and flows through the styrofoam beads to the top of the water surface.

As illustrated in Figure 6, the collector is supported at the outer edge by a collector mounting bracket which attaches to the rim strip and the structure of the wall. Figure 7 illustrates that the collector is supported along its length by special support structures which are suspended on the support cables which traverse the pool and are anchored to the pool wall structure.

The inner and outer glazing materials are also anchored and sealed by a spline which is held in place by a batten strip on the rim strip.

The inner and outer glazing materials were originally planned to be "Tedlar". However, "Tedlar" is available only in rolls having an approximate maximum width of 4 feet. Consequently, in order to have a continuous sheet of "Tedlar" large

1. Outer Glazing
2. Inner Glazing
3. Collector Inlet Manifold
4. Corrugated Aluminum Collector Plates
5. Collector Mounting Bracket
6. Collector Support Cable/Rod
7. PVC Pool Liner
8. Plywood
9. Rim Strip
10. Batten Strip
11. Spline
12. Pool Liner Anchor Strip
13. Batten Support Strip

Figure 6, Collector Detail

1. Outer Glazing
2. Inner Glazing
3. Corrugated Aluminum Collector Plate
4. Support Cable

5. Support Structure
6. Styrofoam Beads Floating On Water Surface
7. Collector Water Outlet

enough to cover a 24 foot by 24 foot pool, some technique of joining the "Tedlar" sheets together is required. To date, there is no reliable adhesive material for joining "Tedlar" sheets together. The University of Virginia has experimented with a mechanical device for joining the "Tedlar" sheets such as a plastic channel which receives the "Tedlar" sheets and a spline. However, to date this technique has not been demonstrated successfully. It is anticipated that an extruded plastic channel can be design to receive the "Tedlar" film and the spline successfully to form a reliable seal and to do so without causing a mechanical failure of the "Tedlar". This work will be continuing in the near future.

The glazing material which has been selected for the present time is that of a 4-mil thick greenhouse film sold as Monsanto 602. This is a flexible polyethylene "Copolymer" greenhouse covering which has wide application throughout the United States. It is marketed locally in sufficient width and length to accommodate our needs.

Due to certain design changes the implementation of the collector sub-system to the storage pool was delayed until early December; however, in early December, an unusual period of sub-freezing weather began which caused ice to be formed on the storage pool and prevented our installation of the collector sub-system. The collector was installed in February 1977 (see Figure 8) and the reflector was erected in March 1977 (see Figure 9).

The system is now operational, and data collection and analysis has begun.

Figure 8, Annual Collector/Storage System, February 1977

Figure 9, Annual Collection/Storage System, March 1977

G. Activities to Disseminate Project Results

The results of this research project are limited at this time. Therefore, the activities to disseminate the research results are limited to statements of project description. Two papers have been presented, one to the conference on Solar Energy in Cold Climates (University of Detroit, June 7-8, 1976), and one to the conference "Solar Three: Capturing the Sun" (Northwestern University in Evanston, Illinois on November 20, 1976). The manuscripts developed for these conferences have been distributed at the conference and to various persons who have requested it by mail.

Research results will be available for papers proposed to be published and presented at the International Solar Energy Society Congress in India in November of 1977 and at the Winter Annual Meeting of the American Society of Mechanical Engineers in Atlanta, Georgia in late 1977.

VI. TIC DISTRIBUTION LIST

Patrick F. Akehurst
4138 Joppa Road
Baltimore, MD 21236

Ametek
Power Systems Group
One Spring Avenue
Hatfield, PA 19440

Attn: J.C. Bowen

Arkla Industries, Inc.
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Little Rock, ARK. 72203

Attn: T.M. Helms

Bruce L. Bakken
Solar Development Co. Inc
450 Southview Blvd.
South St. Paul, Minn.
55075

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School of Architecture
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New Haven, Conn. 06520

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Madison, Wisconsin 53706

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Prof. Karl W. Boer
Institute of Energy
Conservation
Univ. of Delaware
Newark, DEL. 19711

Dr. Gustavo Bert Brown
Centro de Investigacion
de Materiales
Circuito Exterior, C.U.
Mexico 20 DF/UNAM/
MEXICO

George A. Bush
Lawrence Livermore Labs
Livermore, CA 94550

Sheldon S. Butt
Director, Market Research
& Planning
Olin Brass Corp.
East Alton, Ill. 62024

David E. Cassel
Environmental Systems
150 South Street
Annapolis, MD 21401

David C.W. Chan
The Mitre Corp.
P.O. Box 208
Bedford, Mass. 01730

Jack M. Cherne
TRW Inc. - Solar Energy
One Space Park
Redondo Beach, CA 90278

Robert S. Cole
Department of Physics
U. of North Carolina
Asheville, NC 28804

Stanley A. Davis
Argonne National Lab
Bldg. 214
9700 S. Cass Ave.
Argonne, Ill. 60439

Prof. John Duffie
U. of Wisconsin
1500 Johnson Drive
Madison, Wisc. 53706

R. Dunkle, Ch. Scientist
CSIRO-Div. of Mech. Engr.
P.O. Box 26
Highett, Victoria
AUSTRALIA 3190

Prof. D.K. Edwards
School of Engr.&Applied
Science
UCLA
Los Angeles, CA 90024

James Eibling
Battelle Memorial Inst.
Battelle Columbus Lab.
Columbus, Ohio 43201

Guy Ervin, Jr.
Atoms International
8900 DeSoto Avenue
Canoga Park, CA 91304

Richard Evans
Manufactured Homes Div.
Boise Cascade
P.O. Box 8051
Roanoke, VA 24014

R.C. Evans
Evans Precision, Inc.
P.O. Box 366
320 Locust Street
Lancaster, OH 43130

Erich A. Farber
U. of Florida
Solar Energy Lab
Gainesville, FLA
32611

Edward C. Fordyce
Science Museum of Va.
217 Gov. Street
Richmond, VA 23219

Arthur P. Fraas
Oak Ridge Nat'l. Lab.
Bldg. 9102, Y-12
Oak Ridge, TN 37830

General Electric
Solar Technol. Programs
P.O. Box 8661
Philadelphia, PA 19101
Attn: D.L. Kirkpatrick

Ron Goodman
LOF Tech. Center
1701 E. Broadway
Toledo, Ohio 43605

P.F. Goolsby, Solar Pgms.
Prod. Development Div.
Reynolds Metal Co.
5th and Cary
Richmond, VA

Prof. Jack R. Howell
Dept. of Mech. Engr.
U. of Houston
Houston, TX 77004

George O.G. Löf
Solar Energy Applications
Laboratory
Colorado State Univ.
Ft. Collins, Colo. 80523

Robert E. Grenier
R.L.G Associates, Inc.
177 Blue Stone Drive
Woonsocket, R.I. 02895

George Immerwahr
Solar City Industries
1204 Jackson St, SE
Albuquerque, NM 87108

Harold G. Lorsch
U. of Pennsylvania
260 Towne Bldg., D3
Philadelphia, PA
(Please Forward)

Richard P. Hankins
Hankins and Anderson, Inc.
Box 6872
Richmond, VA 23230

Inter-Technology Corp.
100 Main Street
Warrenton, VA 22186

James R. Lowery
Code EH-24
NASA/MSFC
Marshall Space Fl. Cen.
Alabama 35812

Lloyd O. Herwig
Adv. Solar Energy R.&Tech
NSF/RANN
Washington, D.C. 20550

George S. James
NSF - Information Resource
1800 G. Street, NW
Washington, D.C. 20550

Martin-Marietta
Box 179
Denver, Col. 80201

Attn: Lanny Schooler

James E. Hill
Center for Building Tech.
U.S. Dept. of Commerce
Nat'l. Bureau of Stds.
Washington, D.C. 20234

Dr. Ali M. Kipper
Sch. of Engr. & Applied
Science
Geo. Washington University
Washington, D.C. 20052

P.H. Mathes
Granger Associates
1400 N. Uhle Street
Arlington, VA 22201

Kenneth G.T. Hollands
Dept. of Mech. Engr.
U. of Waterloo
Waterloo N2L-3G1,
CANADA

Richard A. Klecker
Western Sun Systems
Route 1, Box 1532
Bend, Oregon 97701

Prof. Marshall F. Merriam
Dept. of Material Sci.
Hearst Mining Bldg.
U. of California
Berkeley, CA 94720

Michael J. Holtz
A.I.A. Research Corp.
1735 New York Ave., NW
Washington, D.C. 20006

George J. Kominiak
Division 5834
Sandia Laboratories
Box 5800
Albuquerque, NM 87115

Benjamin D. McCubbins
Carolina Solar Corp.
301 N. Main Street
Salisbury, NC 28114

Honeywell Systems & Res.
Center
2600 Ridgeway Pkwy.
Minneapolis, Minn. 55413
Attn: Henry Mar

Richard J. Leuba
School of Engineering
NC State University
Box 5518
Raleigh, NC 27607

Stanley Moore
Los Alamos Scientific Lab
Group Q-DOT, Box 1663
Los Alamos, NM 87544

Prof. Hoyt C. Hottel
Dept. of Chemical Engr.
MIT
Cambridge, MASS. 02139

Dr. Noam Lior
U. of Pennsylvania
Dept. of Mech. Engr.
111 Towne Bldg., D3
Philadelphia, PA 19174

Robert H. Murray
Skidmore, Owings & Merrill
990 SW 5th Avenue
Portland, ORE. 97204

Prof. Everett D. Howe
Dept. of Mech. Engr.
U. of California
Berkeley, CA 94720

Lockheed Missiles & Space
3251 Hanover Street
Palo Alto, CA 94304

Glen E. McDonald
Power Appl. Br. NASA/Lewis
21000 Brookpark R.
Cleveland, OH 44135

Attn: W.E. Shannon

C. Leon Neal, Appl. Engr.
NC Science & Technol.
Research Center
Res. Triangle Pk., NC
27709

Optical Coatings Lab.
2789 Griffen Avenue
Santa Rosa, CA 95403

Attn: R.M. Winegarner

Owens-Illinois, Inc.
P.O. Box 1035
Toledo, Ohio 43666

Attn: R.E. Ford

PPG Industries, Inc.
One Gateway Center
Pittsburgh, PA 15222

Attn: R.G. Gallagher

Revere Copper & Brass
P.O. Box 151
Rome, NY 13440

Attn: W.J. Heidrich

P. Richard Rittlemann
Burt, Hill & Assoc.
610 Mellon Bank Bldg.
Butler, PA 16001

Robert L. San Martin
Energy Res. & Dev. Inst.
Box 3449
N.Mexico State Univ.
Las Cruces, NM 88003

Mehmet K. Selcuk
JPL - Bldg. 277 Rm.202
4800 Oak Grove
Pasadena, CA 91013

Prof. B.O. Seraphin
Optical Sciences Center
U. of Arizona
Tucson, AZ 85721

Benjamin Shelpuk
RCA Corp.
Bldg. 10-8
Camden, NJ 08102

William A. Shurcliff
19 Appleton Street
Cambridge, MA 02138

Robert W. Porter
1801 Nottingham Road
Newark, Del. 19711

Dr. Norman D. Shutler
Acting Dep. Asst. Adm.
for General Enforcement
Environ. Prot. Agency
Washington, DC 20460

Frederick F. Simon
NASA-Lewis M.S. 500-201
21000 Brookpark Rd.
Cleveland, OH 44135

Prof. P.R. Smith
Mechanical Engr. Dept.
N.Mexico State Univ.
Las Cruces, NM 88003

Dr. Harold Spuhler
Nat. Science Foundation
AERT/RA
1800 G. Street, NW
Washington, DC 20550

Elmer R. Streed
Nat'l. Bureau of Stds.
BR B-104
Washington, DC 20234

H. Tabor, Sci. Director
The Scientific Research
Dancider Bldg.
Hebrew Univ. Campus #3745
Jerusalem, ISRAEL

Dr. H.E. Thomason
Thomason Solar Homes, Inc
6802 Walker Mill Rd., SE
Washington, D.C. 20027

H.J.L. Thomason, Jr.
Thomason Solar Homes, Inc
6802 Walker Mill Rd., SE
Washington, DC 20027

Dr. P.D. Thompson
USDA
Agricultural Res. Center.
Bldg. 173, ARC-East
Beltsville, MD 20705

Prof. Raymond Viskanta
Sch. of Mech. Engr.
Purdue University
Lafayette, Ind.

Albert Weinstein
Westinghouse Electric
Mail Stop 999
P.O. Box 1693
Baltimore, MD 21203

J. Richard Williams
Assoc. Dean for Research
Engineering College
GA Inst. of Technology
Atlanta, GA 30332

Mr. Peter Wood
Energy Conservation Sys.
327 W. Vermijo
Colorado Springs, Colo.
80903

Marvin M. Yarosh,
FLA Solar Energy Center
State Univ. Sys. of FLA
P.O. Drawer N
Cape Canaveral, FL 32920

Charles Younger
Solar Energy Br./MS500-201
21000 Brookpark Rd.
Cleveland, OH 44135

Prof. John I. Yellott
Coll. of Architecture
Arizona State University
Tempe, Arizona 85281

Dr. Harry S. Zwibel
Civil Engr. Lab.
Code 1.80
Port Hueneme, CA 93043

Manager, Special Products
Scientific-Atlanta, Inc.
3845 Pleasantdale Road
Atlanta, GA 30340
Attn: S. V. Sheldon

Carolina Solar Corp.
301 N. Main Street
Salisbury, NC 28144
Attn: B. D. McCubbins

Solar City Industries
1204 Jackson Street SE
Albuquerque, NM 87108
Attn: George Immerwahr

R.L.G. Associates, Inc.
177 Blue Stone Dr.
Woonsocket, RI 02895
Attn: Robert E. Grenier

Evans Precision, Inc.
P. O. Box 366
320 Locust Street
Lancaster, Ohio 43130
Attn: R. C. Evans

Western Sun Systems
Route 1, Box 1532
Bend, Oregon 97701
Attn: Richard A. Klecker

Solar Development Co., Inc.
450 Southview Blvd. South
St. Paul, Minnesota 55075
Attn: Bruce L. Bakken

Patrick F. Akehurst
4138 Joppa Road
Baltimore, Maryland 21236

Institute for Energy
Analysis
P. O. Box 117
Oak Ridge, TN 37830

Mischer Solar
2801 N. Loop West
Houston, TX 77008
Attn: Joe Dodson

McDermott Hudson Engr.
P. O. Box 36100
Houston, TX 77036
Attn: Patsy S. Chapplear

Ben-Gurion University of
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Commissariat à l'Energie
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B.P. No. 2
91190 Gif sur Yvette
France
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Prof. Frank C. Hooper
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University of Toronto
Toronto, Ontario
Canada

J. Bougard
Service de Thermodynamique
Faculte Polytechnique de Mons
31, Boulevard Dolez
7000 Mons
Belgium