PROCEEDINGS

SOLTECH 91

- •Solar Industrial Program
- •Solar Thermal Electric Program

March 25-28, 1991

Solar Energy Research Institute
Golden, Colorado
SERI

Sandia National Laboratories
Albuquerque, New Mexico

U.S. Department of Energy
Washington, D.C.

VOLUME I

DE91002163 April 1991 CP-250-4254

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VOLUME I

Editors:

W. Traugott (SERI) • R. Hewett (SERI) • D. Menicucci (Sandia)

Printed in the United States of America
Available from:
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

Price: Microfiche A01
Printed Copy A14

Codes are used for pricing all publications. The code is determined by the number of pages in the publication. Information pertaining to the pricing codes can be found in the current issue of the following publications which are generally available in most libraries: *Energy Research Abstracts (ERA)*; *Government Reports Announcements* and Index (*GRA* and I); *Scientific and Technical Abstract Reports (STAR)*; and publication NTIS-PR-360 available from NTIS at the above address.

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PREFACE

This document is a limited Proceedings, documenting the presentations given at the symposia conducted by the U.S. Department of Energy's (DOE) Solar Industrial Program and Solar Thermal Electric Program at SOLTECH91. The SOLTECH91 national solar energy conference was held in Burlingame, California during the period March 26–29, 1991. The Solar Energy Research Institute manages the Solar Industrial Program; Sandia National Laboratories (Albuquerque) manages the Solar Thermal Electric Program. The symposia sessions were as follows:

- No. 1: Solar Industrial Program and Solar Thermal Electric Program Overviews
- No. 2: Current and Near-Term Solar Industrial Applications
- No. 3: Solar Detoxification of Organics in Water
- No. 4: Solar Thermal Electric Systems

For each presentation given in these symposia, these Proceedings provide a one- to two-page abstract and copies of the viewgraphs and/or 35 mm slides utilized by the speaker. Some speakers provided additional materials in the interest of completeness.

The materials presented in this document were not subjected to a peer review process.

- Successful applications.

- Applications and systems expected to be available commercially in the near future.

- Information about technology transfer/technical assistance/outreach services that SERI and Sandia are making available to actual and potential end users of the technologies, the solar industry and others (e.g., government energy policymakers, etc.).

SOLAR INDUSTRIAL/SOLAR THERMAL ELECTRIC PROGRAM EXHIBITS

You are also invited to view the displays, as well as models of solar equipment at the SERI and Sandia booths in the Exhibition Hall, In addition, several publications are available free-of-charge. These displays are available for viewing during the hours that the Exhibition Hall is open.

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SOLTECH91

Solar Industrial Program/Solar Thermal Electric Program Symposia

- Symposium No: 1
- Symposium Title: Solar Industrial Program & Solar Thermal Electric Program Overviews
- Date: Tuesday, March 26, 1991
- Time: 1:30 p.m. - 5:00 p.m.
- Chairperson(s): C. Carwile (DOE/HQ)

Time Slots	Presentations	Proposed Speakers (Name/Affiliation)
1:30 - 1:40	Introduction	Session Chairperson
1:40 - 1:55	Overview of the Solar Industrial Program	F. Wilkins (DOE/Headquarters)
1:55 - 2:15	Solar Detoxification	J. Anderson (SERI)
2:15 - 2:30	Solar Process Heat Program	R. Hewett (SERI)
2:30 - 2:45	Advanced Industrial Processes Project	M. Carasso (SERI)
2:45 - 3:00	Solar Industrial Applications Assistance Project	R. Hewett (SERI)
3:00 - 3:20	BREAK	

SOLTECH91

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Time Slots	Presentations	Proposed Speakers (Name/Affiliation)
3:20 - 3:40	Solar Thermal Electric Technology -- Status and Thrust	M. Scheve (DOE/Headquarters)
3:40 - 4:00	Commercial Application Activities -- Department of Energy Solar Thermal Electric Program	P. Klimas (Sandia)
4:00 - 4:20	Solar Thermal Electric Program -- Power Conversion Technology Development	R. Diver (Sandia)
4:20 - 4:40	The DOE Solar Thermal Electric Program Technology Project	T. Mancini (Sandia)
4:40 - 5:00	The Solar Thermal Design Assistance Center -- An Overview of Its Successful Technology Transfer Efforts	D. Menicucci (Sandia)

OVERVIEW OF THE SOLAR INDUSTRIAL PROGRAM

by Frank Wilkins
Department of Energy

INTRODUCTION

Energy and the environment; these are two interrelated areas that provide opportunities for solar technology in the 1990's. The war in the Middle East has once again raised national concern over the availability of imported oil. There is also growing national concern with environmental problems such as waste management and climate change. Industry uses over a third of all the energy the nation consumes each year; much of it from imported oil. The residue from industrial processes is 280 million tons of hazardous wastes; much of it now falling under tighter environmental regulations.

The Solar Industrial Program was established to develop technology that can provide industry with a solar alternative to fossil fuels. The Program was formed in 1990, when DOE reorganized its Conservation and Renewable Energy programs. It is part of the Waste Materials Management Division, within the Office of Industrial Technology. SERI and Sandia have been tasked to assist the Program in carrying out this mission, with SERI being assigned lead laboratory responsibility.

SOLAR INDUSTRIAL APPLICATIONS

There are three elements of the Program: detoxification of hazardous chemicals, process heat, and advanced industrial processes.

The detoxification of hazardous chemicals provides a near term market opportunity because of the need for new technology in environmental waste management, the size of the market, and the high cost of chemical waste destruction. It is also an excellent match to solar technology. Solar energy provides quantum energy from the ultra-violet and near ultra-violet portions of the spectrum which can destroy organic chemicals such as solvents, pesticides, dyes found in water. It does this in a low flux, low temperature process that is well suited for line focus or possibly flat plate solar technology. It also provides a thermal component which, when added to the quantum component, can destroy chemicals such as dioxin, PCB, and nitrates found in soil. It does this in a high flux, high temperature process well suited to parabolic dish and central receiver technology.

Process heat offers the potential of a multi-quad energy market and the displacement of imported oil. Cost reductions in the 1980's may have positioned the technology for institutional and industrial market penetration in the 1990's. The success of United Solar Technologies, Inc. with their trough project at Tehachapi, California has provided optimism that there are now niche markets for solar process heat. The cost of the technology has decreased by nearly two thirds since DOE's IPH program of the early 1980's, and manufacturers such as LUZ have demonstrated that the technology is reliable.

Advanced industrial processes is focused on gaining a better understanding of solar energy so that it can be applied to a wider array of industrial needs. There are many aspects of solar energy that remain unknown. This area of the program is attempting to unlock those mysteries, put them to practical use, and make them available to industry. The industrial sector is very diversified; including such areas as manufacturing, chemicals, metals, and agriculture. Solar energy can provide clean, domestically supplied energy for many areas of the industrial sector. The broader the applicability of solar energy throughout the sector, the better its chances for having a major energy impact in the United States.

PRESENT ACTIVITIES

The Solar Program is working with industry to identify those niche markets where solar systems can be deployed soon. In solar detoxification, we have established a cost-shared project with DOE's Office of Environmental Restoration and Waste Management to demonstrate the feasibility of solar energy to destroy solvents in groundwater. We are discussing with EPA and the DOD the establishment of a coordinated program that will show that solar energy can destroy chemicals such as dioxin and explosives found in soil. These activities are important because the government (DOE, EPA, and DOD) may be early users of solar detoxification technology. The market for environmental restoration for each of these organizations is measured in the billions of dollars.

We are also looking at the waste management market. SERI is performing treatability studies for industry, in which samples of industrial waste are tested to determine their applicability to solar destruction. In addition, a mobile detoxification unit is being built to destroy industrial wastes at the sites where they are located. These activities complement an R&D effort to make the solar detoxification processes more efficient, particularly through work on catalysts and solar reactors. The program will field systems as quickly as possible in order to drive the technology to a practical demonstration by the mid 1990's.

In the area of process heat, we are working to identify early markets and establish a cooperative industry-DOE program. The maturity of the technology, particularly line focus and flat plate, dictates that our emphasis within this area will be on helping industry accelerate market penetration. Sandia's Design Assistance Center will continue to work with industry and SERI will establish an assistance center that will complement Sandia's.

The advanced industrial processes portion of the program represents an area at the research end of the R&D spectrum. Applications under study include solar surface treatment of materials, making fine grained ceramic powders, making valuable chemicals from feedstocks, and powering lasers. To assist in identifying the most promising new applications of solar energy, contracts have been established with the National Academy of Engineers, MIT, and SRI International. Results from these studies will provide a long-term focus for the program. In order to provide laboratory and industry scientists a tool with which to conduct this research, SERI is building a unique high flux solar furnace. The furnace, using optics developed by the University of Chicago, has already achieved a concentration ratio of 25,000 suns, and is expected to reach 50,000 suns by the end of the fiscal year.

SUMMARY

The Solar Industrial Program was formed to help establish solar energy as an option for the industrial sector. This coincides to a time when increasing national concern over energy and the environment offers an opportunity for early markets of solar energy. Establishment of an industrial market will increase the solar industry's production base and help reduce costs. This will benefit solar technology not only for industrial use, but also for residential, commercial and utility applications. It will thus accelerate the time when clean, domestically available solar energy becomes a major alternative to fossil fuels in the United States.

SOLAR INDUSTRIAL PROGRAM

PROGRAM OVERVIEW

SOLTECH 91

MARCH 26, 1991

Frank Wilkins, Program Manager
Waste Material Management Division

SOLAR INDUSTRIAL PROGRAM
GOAL AND OBJECTIVES

GOAL: Increase industrial use of solar energy as an economical, environmentally sound energy option

OBJECTIVES:

- Develop systems and components that will be competitive for environmental restoration and waste management markets
- Assist solar industry in entering the institutional and industrial process heat markets
- Develop technology for new industrial applications using solar driven processes
- Ensure technology transfer to the private sector

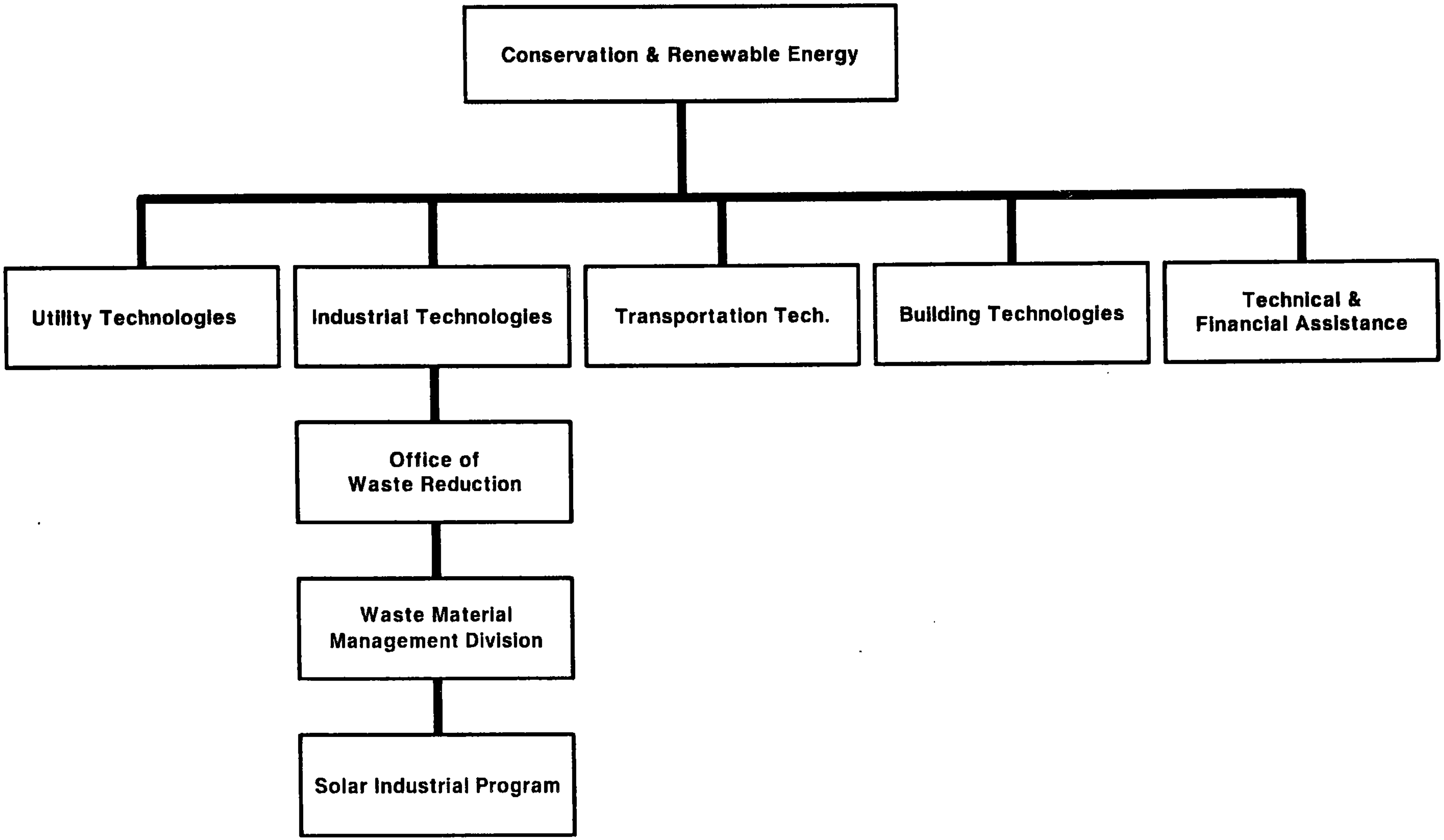
SOLAR INDUSTRIAL PROGRAM
STRATEGY

- **Resource Utilization**
  - Establish technical base at SERI and Sandia
  - Cost-share with other agencies

- **Industry Collaboration**
  - Involve industry in planning
  - Pursue cost-shared field experiments

- **Market Development**
  - Establish niche markets in detoxification and process heat
  - Expand solar market with new applications

CONSERVATION & RENEWABLE ENERGY ORGANIZATION CHART



SOLAR INDUSTRIAL PROGRAM
INDUSTRIAL SECTOR CHARACTERISTICS

- Diverse Market:

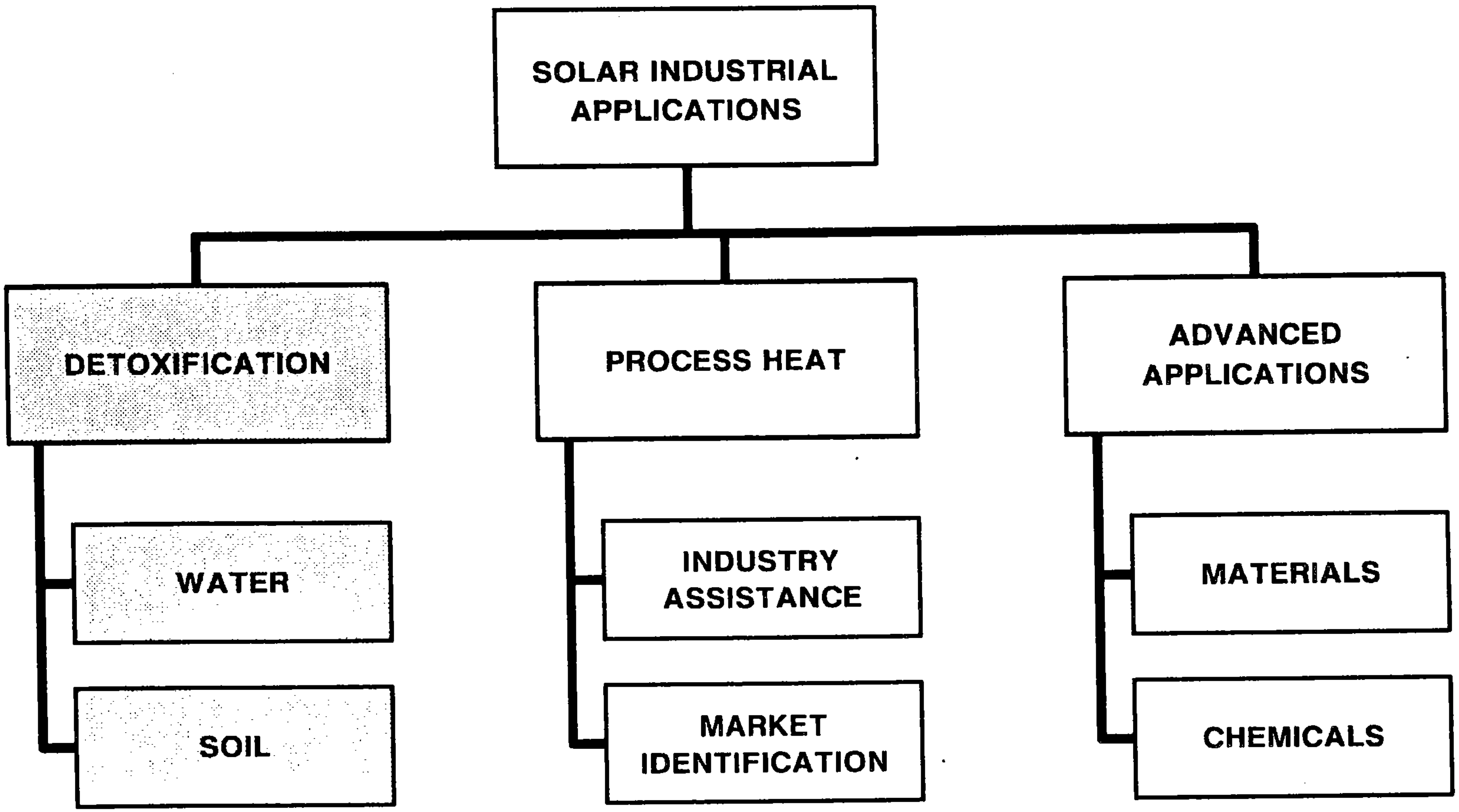
  Manufacturing, Chemicals, Metals, ...

- Consumes a Third of Nation's Energy

- Oil is Largest Energy Supply

- Energy Consumption Projected to Increase from 29Q in 1990 to 50Q in 2030

SOLAR INDUSTRIAL PROGRAM STRUCTURE



SOLAR INDUSTRIAL PROGRAM
SUMMARY

- Establish near-term industrial markets
- Work closely with industry
- Emphasis on products

Measure of Success:

Sale of solar energy technology

SOLAR DETOXIFICATION PROGRAM

John Anderson

Solar Energy Research Institute

March 26, 1991

SOLAR INDUSTRIAL PROGRAM
TWO MAJOR INDUSTRIAL MARKETS

- Energy
  - Increasing cost
  - Increasing reliance on foreign sources
  - Need for new technologies to enhance competitiveness

- Environmental
  - Increasing regulatory pressure in both:
    waste management
    remediation

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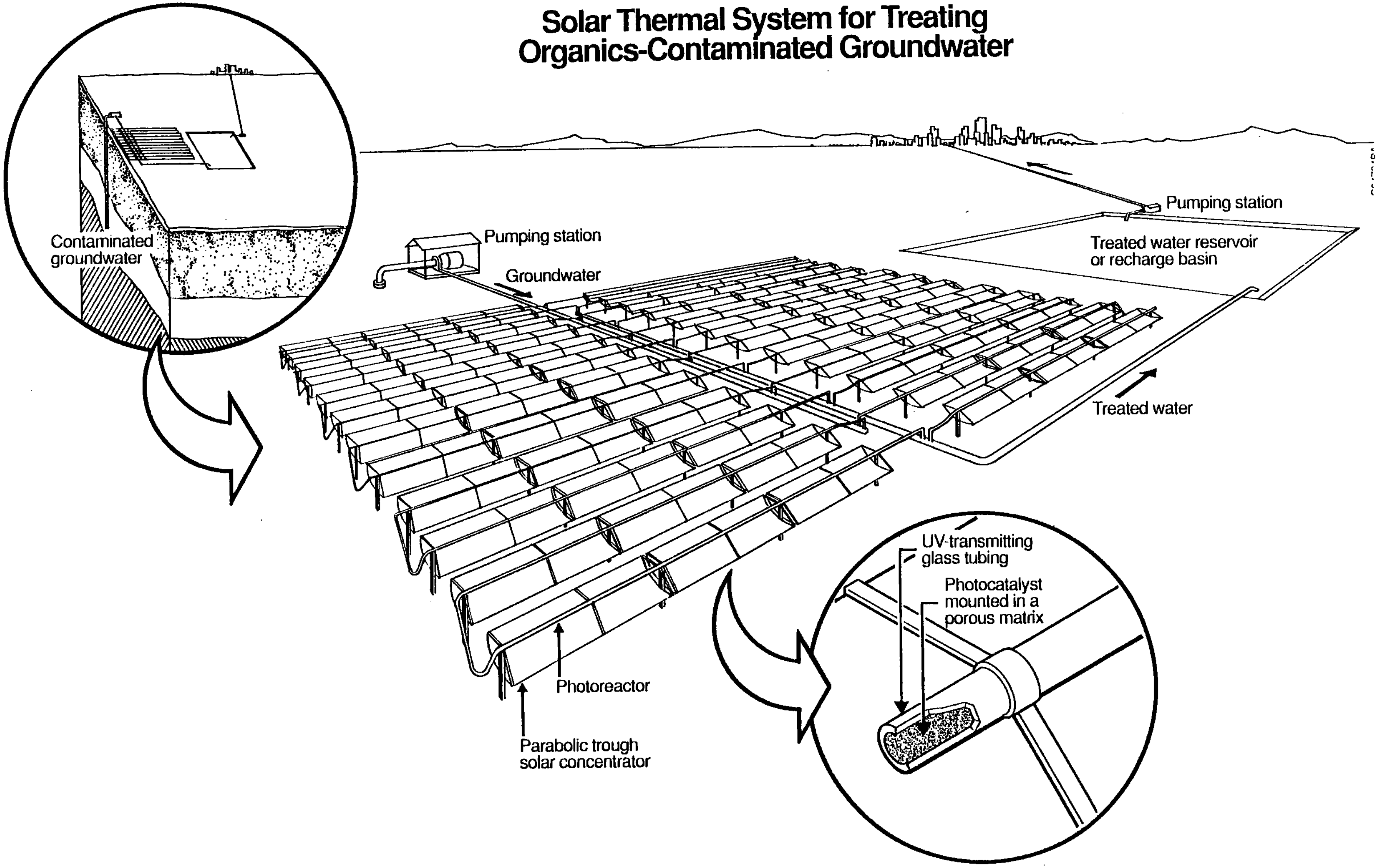
SOLAR DETOXIFICATION
STRATEGY

- Cultivate productive cooperation between existing solar and waste management industries
- Establish and nurture industrial "champions" of solar detoxification technologies
- Promote market development by working with potential users
- Advance the basic technology to improve costs and expand the accessible market

2 SOLAR DETOXIFICATION PROCESSES

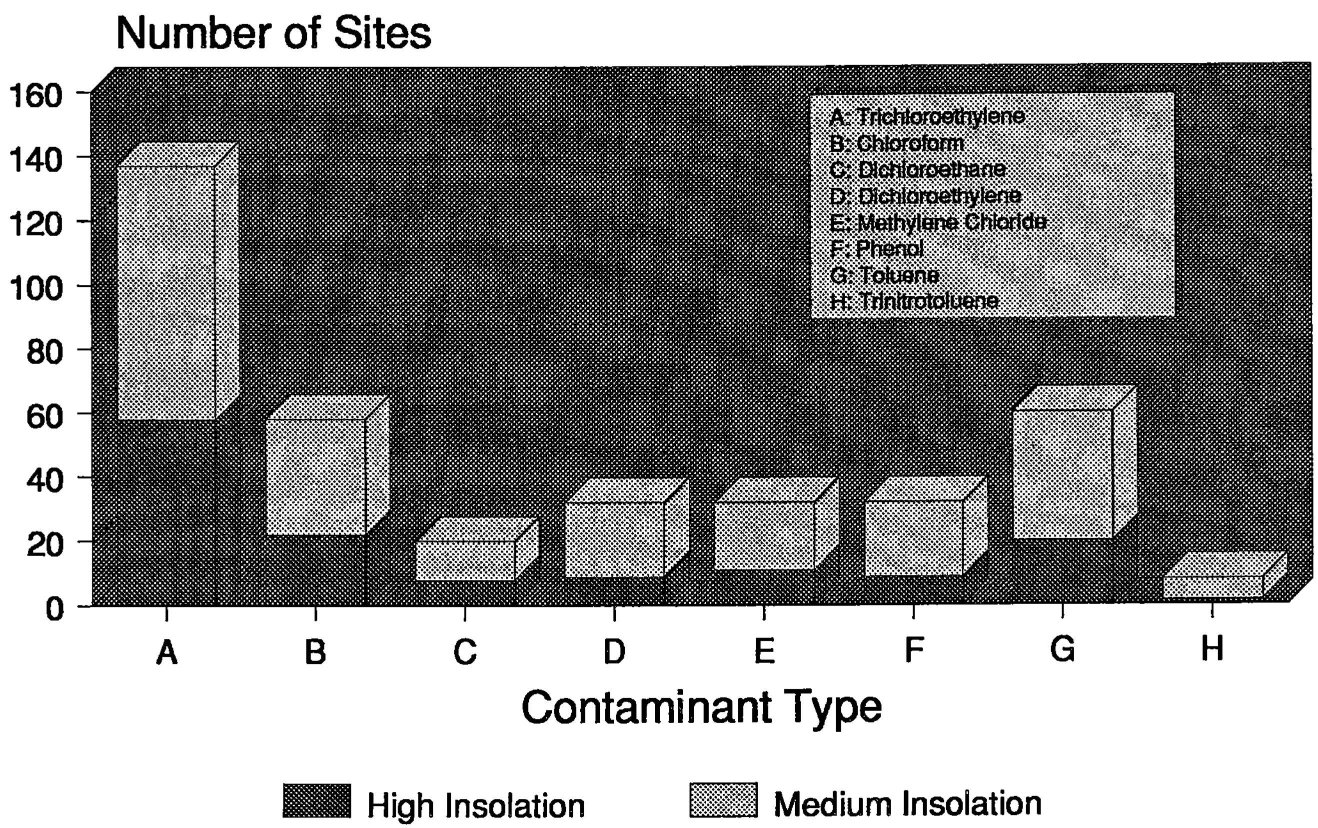
Detox of Water	Gas-Phase Detox/ Adsorbed on Solids
Wastewater, groundwater drinking water	Low Btu wastes, soils, used carbon, etc.
Photocatalytic	Photolytic, photocatalytic thermocatalytic
Ambient temperature	High temperature (>700 C)
Low solar fluxes (1 to 30 Suns)	High solar flux (300+ suns)

Solar Thermal System for Treating Organics-Contaminated Groundwater

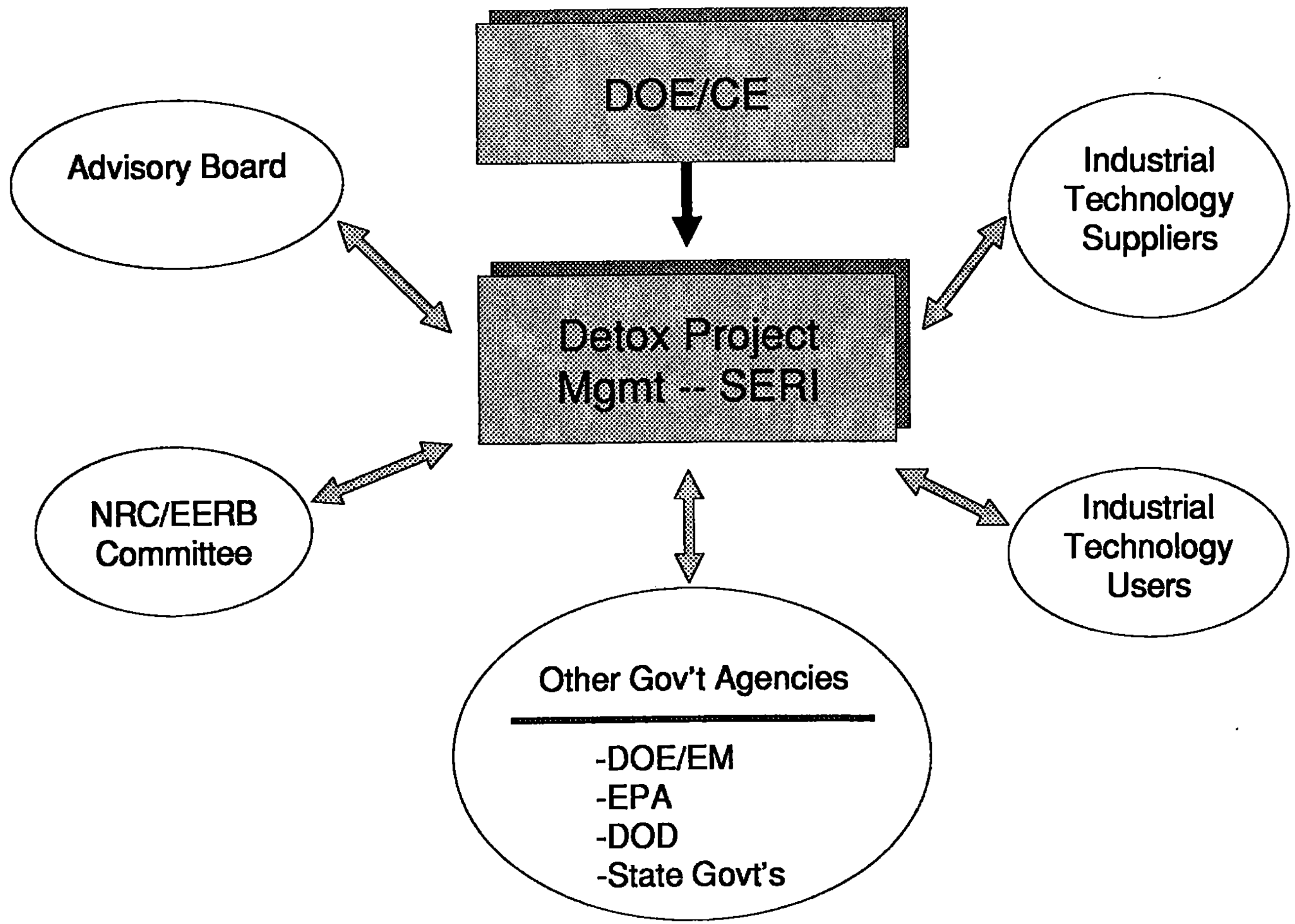


Sites with Potential VOC Contamination

Superfund Sites



SOLAR DETOX PROJECT RELATIONSHIPS



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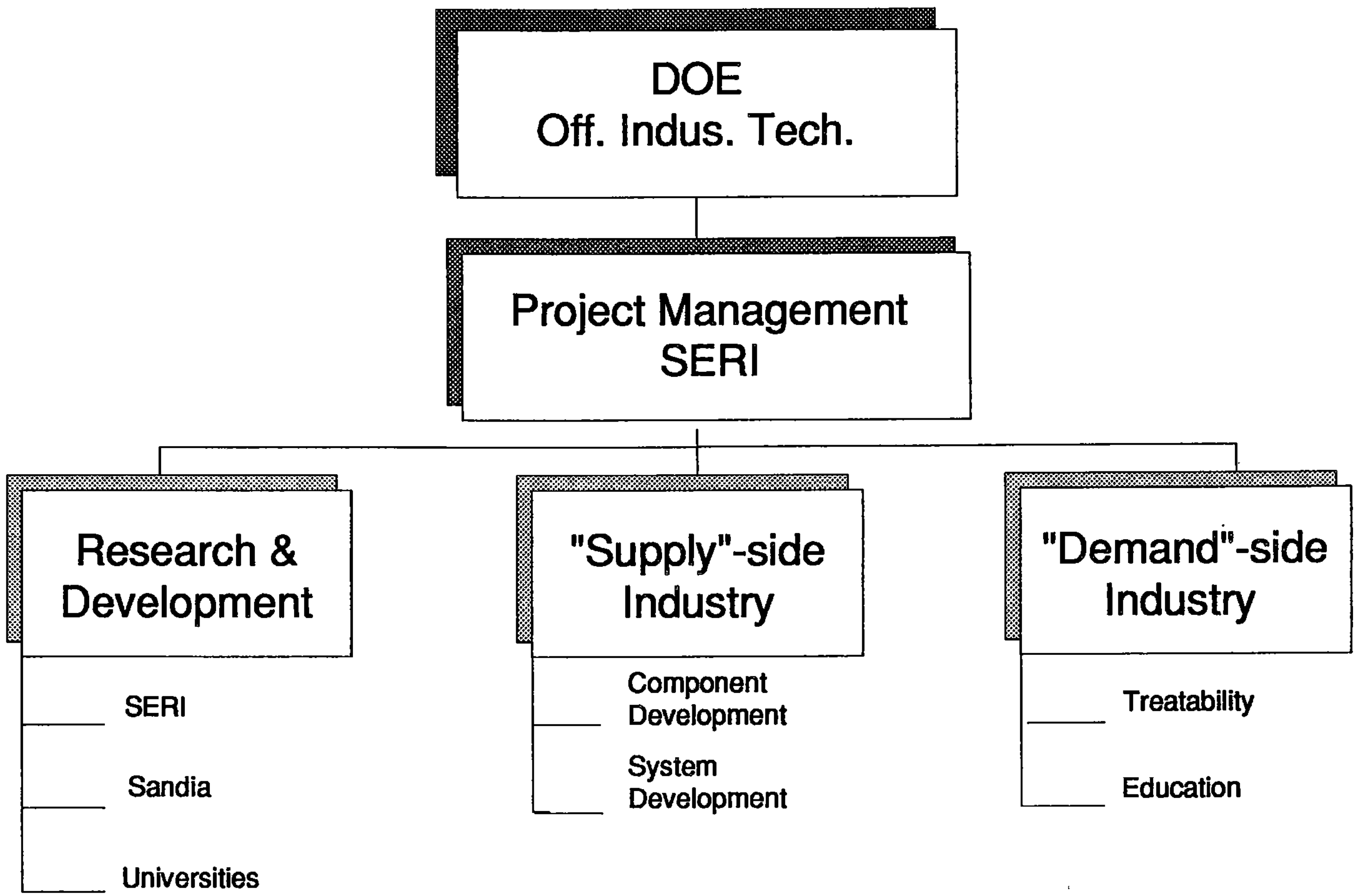
SOLAR DETOX PROJECT
RELATIONSHIP WITH INDUSTRY



INDUSTRIAL TECHNOLOGY DEVELOPMENT

- Focus on companies with long-term commercial interest in the technology

- Innovative concentrator development
  - Review old ideas and new materials
  - Deliver prototypes

- Solar reactor development
  - Criteria: flux distrib, pressure drop, mass transport
  - Deliver prototypes

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INDUSTRIAL "DEMAND-SIDE" ACTIVITIES

- Companies that want a "finished product" that they can buy and use

- Treatability testing
  - Laboratory tests (underway)
  - Mobile test unit(s)
  - Test and Evaluation Centers

- Other technology transfer activities primarily through organizations like:
  - Air and Waste Management
  - Water Pollution Control Federation
  - ASME, AIChE

- Several treatability contracts in progress

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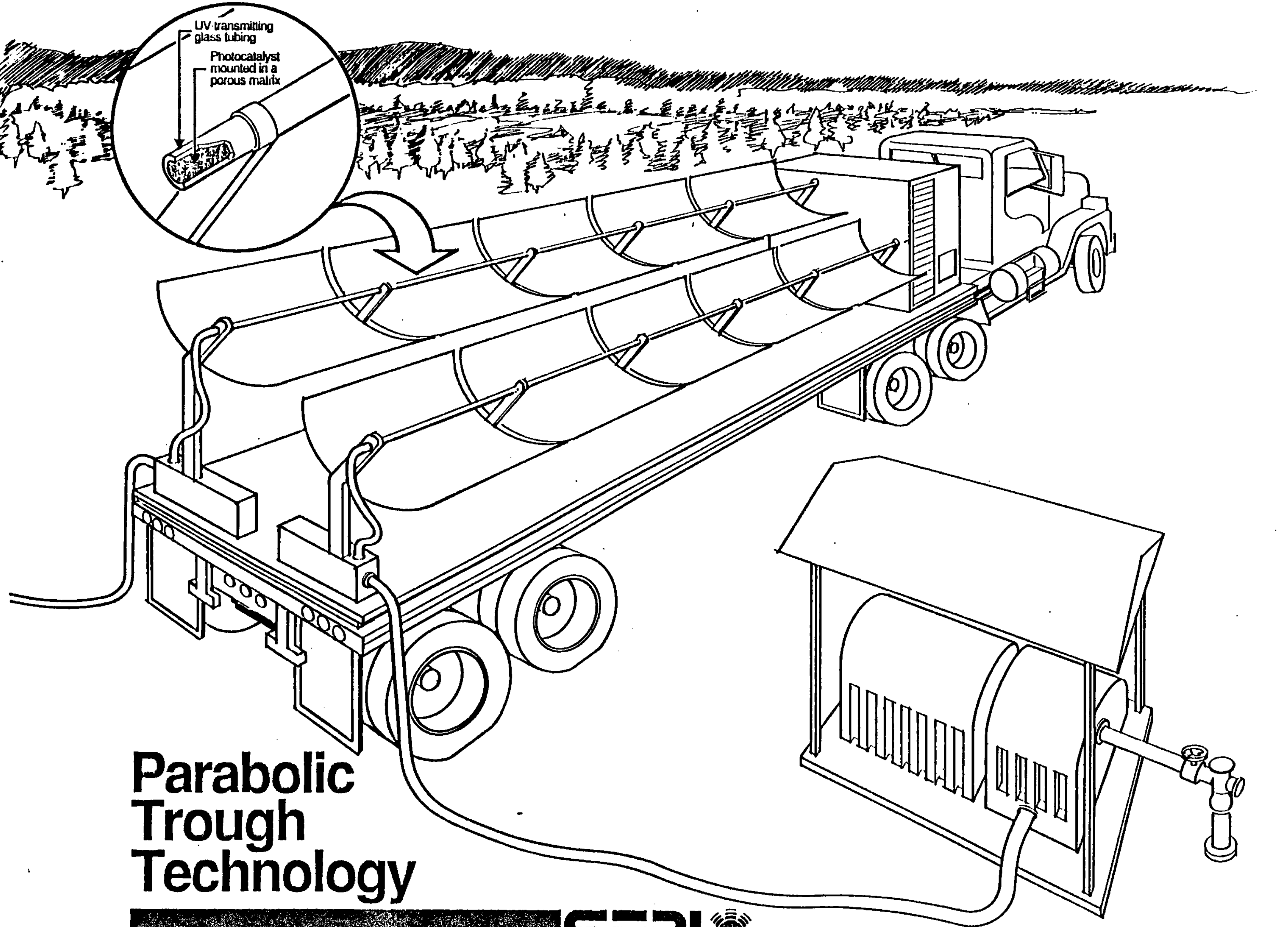
Solar Detoxification of Water



Parabolic Trough Technology

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SOLAR DETOX PROJECT
Strategies for "Reaching" Industry

- Direct interactions
- Professional publications/presentations
  - AIChE, ASME, ACS, DOE/DOD/EPA forums
- Media interactions
  - average 1-2 per month
- Responses to information requests
  - approximately 200 in the past year
- Exhibitions at major conferences
  - Air and Waste Management
  - Water Pollution Control Federation
  - AIChE, ASME, etc.

SERI/JVA/PROJ-8C

SOLAR DETOX PROJECT
MAJOR FEDERAL AGENCY CONTACTS

- DOE/EM
  - co-funding Field Experiment
  - interest from other DOE sites
- EPA
  - Review Board participants
  - funded project with MRI
  - interest from individual site managers
- DOD
  - USATHAMA - Review Board, Pinkwater
  - Army Corps - both solar and environmental experience
  - AFESC - potential groundwater demonstration project
  - NCEL - groundwater remediation

SERI/JVA/FED-1

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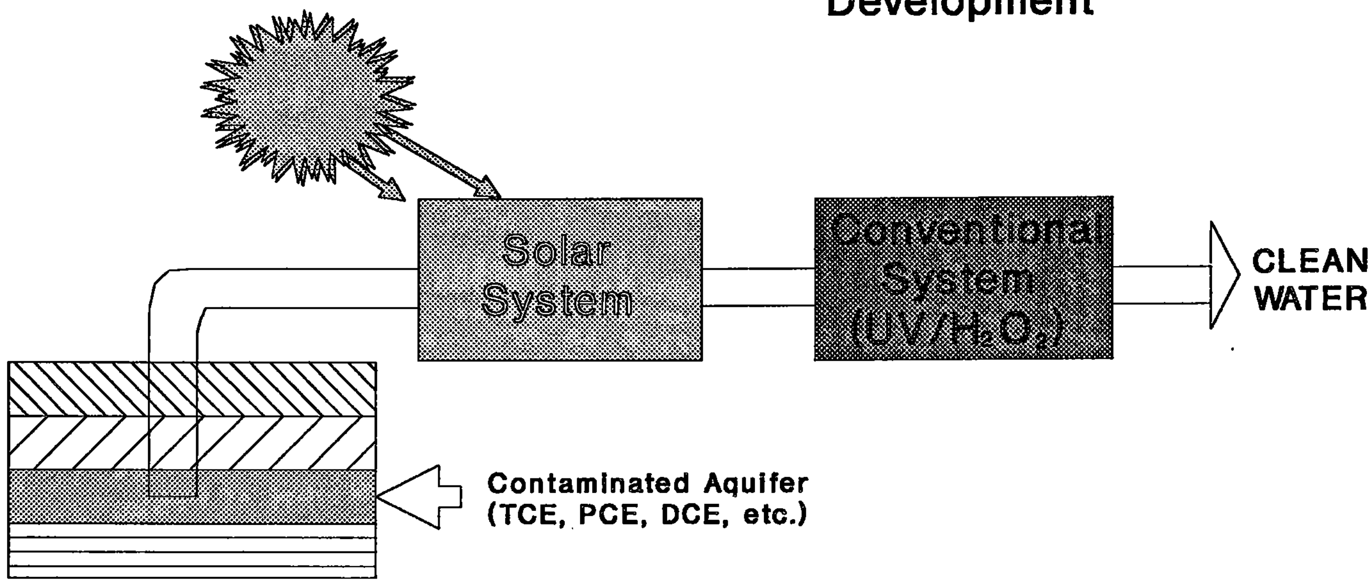
A SOLAR WATER DETOX FIELD EXPERIMENT AT A DOE SITE

A Joint DOE CE/EM Project Managed by SERI

- SERI
- Sandia
- LLNL

- Real World Test
- Establish Operational Procedures and Control Strategies
- Data to Guide Further Development



SOLAR DECONTAMINATION OF SOILS
A THREE-AGENCY JOINT EFFORT

- Based on earlier DOE work on solvents and dioxins

- Involves DOD and EPA
  - Funding
  - Technical inputs

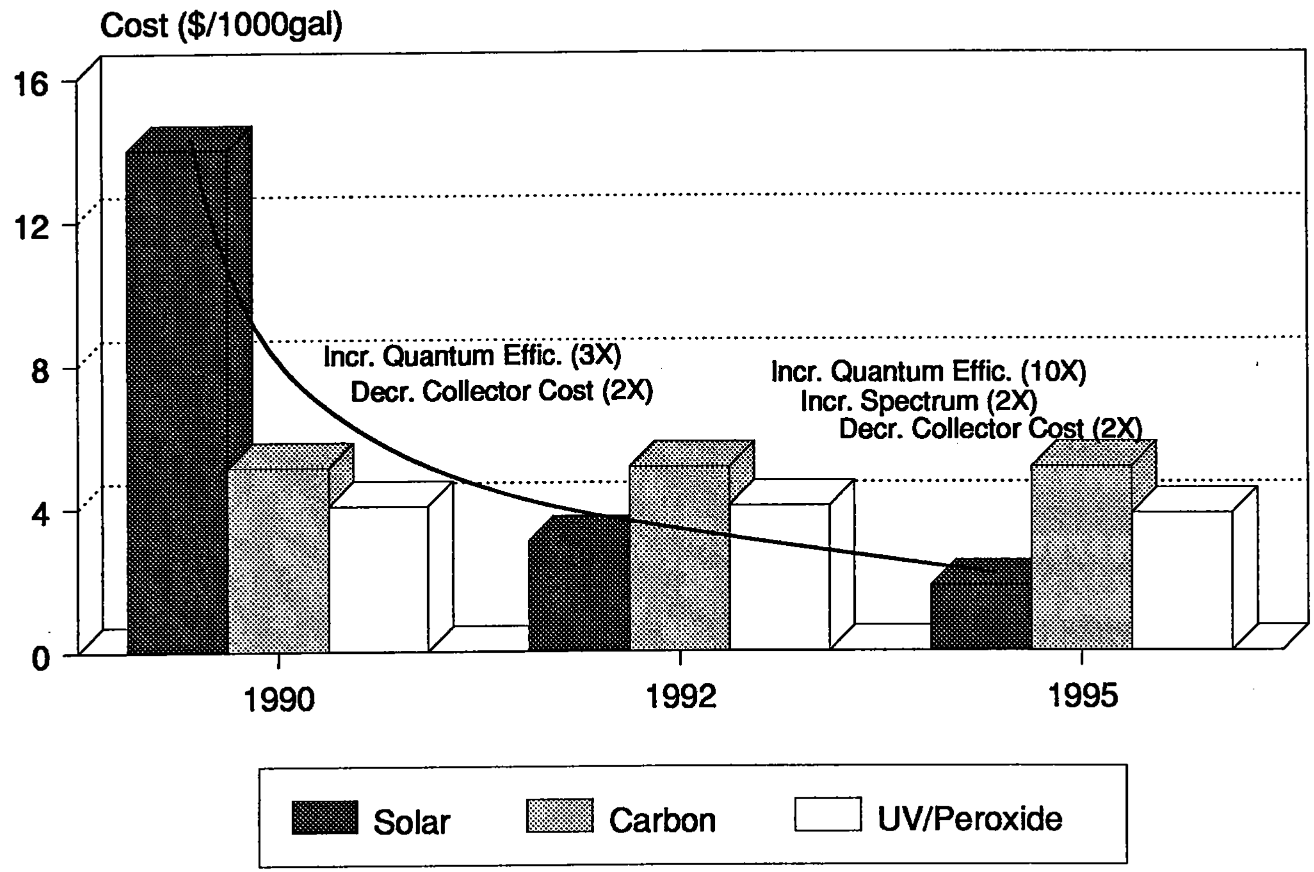
- Will aim at demonstration project
  - Systems analysis/feasibility studies
  - Bench-scale, on-sun tests
  - On-site field units

SOLAR DETOX OF WATER
TECHNOLOGY CHALLENGES

Issues	Approach
Reactor Design - fixed catalyst - good performance	In-house design (Field Expt) & Indus Reactor Dev (long-term)
Range of treatability	Testing for indus clients & EPA hazard chemical list
Improved performance (primarily catalyst system)	In-house catalyst mat'l work & Univ contracts
Reduced system costs	Indus concentrator development & Univ non-concen. reactor work

SERI/JVA/CHAL-1

PROJECTED COST OF 0.1 MGD SOLAR DETOX RELATIVE TO COMPETING TECHNOLOGIES



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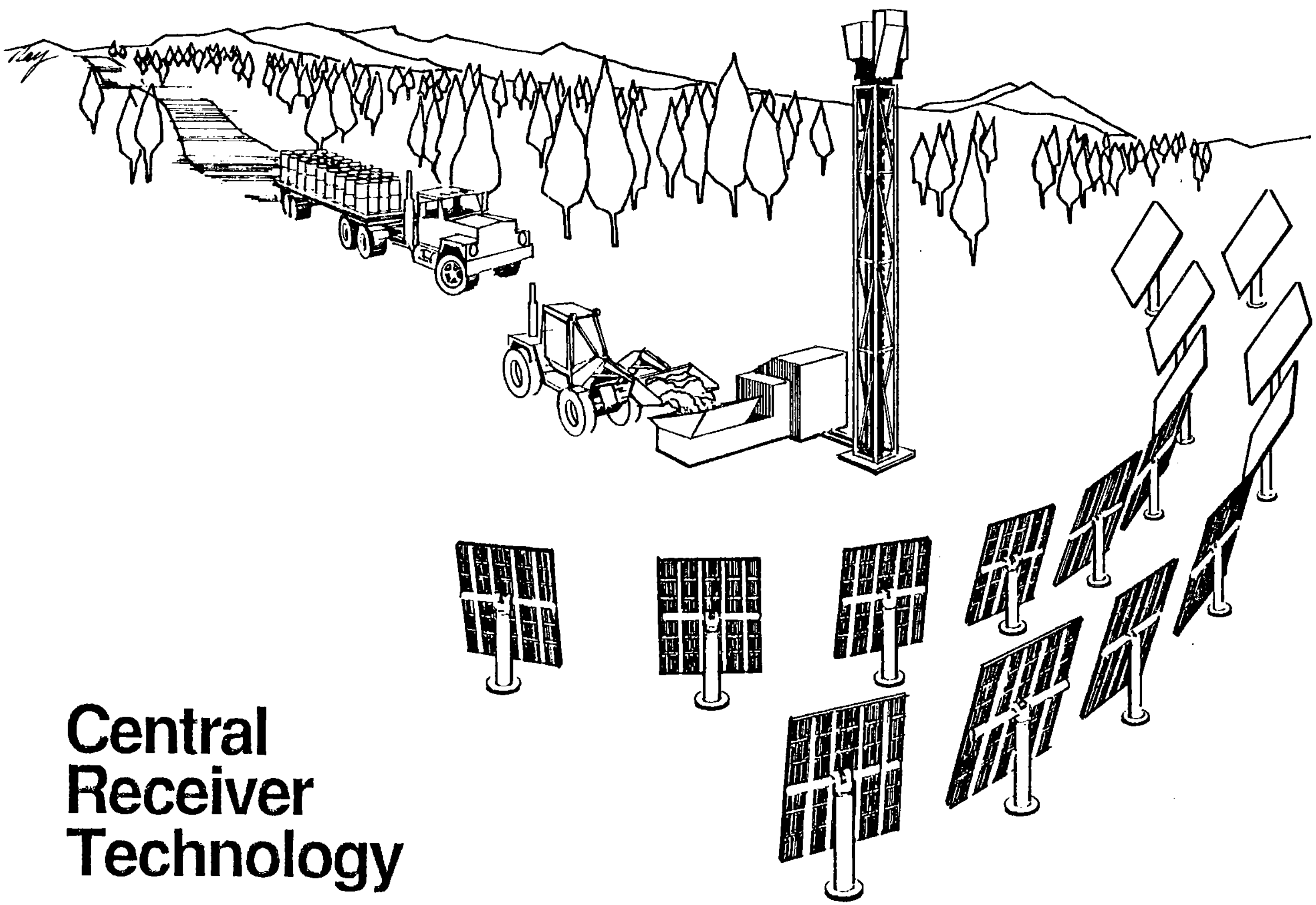
Solar Destruction of Chemical Waste



Central Receiver Technology

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SOLAR DESTRUCTION OF CHEMICAL WASTES
TECHNOLOGY CHALLENGES

Issues	Approach
Identify first application and best process	Indus consultant to joint SERI/SNL analysis
Reactor design	In-house designs (near-term) & indus designs (long-term)
Interface with source (e.g. soil remed, carbon regen)	In-house analysis (near-term) & indus designs (long-term)

SERI/JVA/CHAL-2

SOLAR PROCESS HEAT PROGRAM

Russell Hewett
Solar Energy Research Institute

The Solar Process Heat Program is a technical assistance/technology transfer/RDT&D activity within the SERI Solar Industrial Program. For program purposes, solar process heat technology includes solar systems (utilizing flat plate, evacuated tube and concentrating solar collectors) for the following applications:

- Water preheating
- Service hot water
- Low and high pressure steam
- Process hot air

With respect to markets, the program covers the following:

- Local/state/federal facilities and operations, including military (e.g., operations buildings, prisons, health care facilities)
- Commerce (e.g., restaurants, motels)
- Industry
- International markets (e.g., water distillation, water pumping)

For several specific application/market combinations, solar process heat systems have been and are available for commercial utilization. However, widespread commercialization has not been attained because of various technical, economic, and institutional barriers. Examples of such barriers include the following:

1. For many applications having great quad impact, the technology is not economically attractive due to:

    - Low natural gas prices
    - High initial capital costs
    - High O&M costs

2. Potential endusers (government and private) are not aware of, or familiar with, the technology

3. System designers are not familiar with the technology.

4. Some potential endusers have the perception that the technology is too risky.

The Solar Process Heat Program has been established to work with the solar industry and actual and potential endusers to remove barriers. The goal of the program is to help attain significant solar market penetration in economically-viable application/market combinations.

The program is organized into four tasks:

- Task 1: Solar Heat Applications Market Assessments
- Task 2: Collaborative Projects with and Technical Support to the Solar Industry
- Task 3: Technical Assistance, Technology Transfer, Outreach and Other Support for Actual and Potential Endusers.
- Task 4: Solar Process RDT&D in Support of Industry's Commercialization Activities.

Planned accomplishments for calendar year 1991 include:

1. Initiation of several prefeasibility studies to assess the merits of utilizing the technology in specific applications in specific organizations.
2. Establishment of several cooperative projects with industry.
3. Development of promotional materials for use in marketing and educational programs.
4. Completion of some targeted educational/familiarization programs.
5. Establishment and documentation of the financial analysis methods and decision criteria utilized by representative potential endusers in evaluating process heat equipment.

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SOLTECH91

SOLAR PROCESS HEAT PROGRAM

- R. HEWETT

March 26, 1991

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SOLAR PROCESS HEAT TECHNOLOGY

SOLAR SYSTEMS -- UTILIZING FLAT PLATE, EVACUATED TUBE

OR

CONCENTRATING SOLAR COLLECTORS -- FOR:

- Water Preheating
- Service Hot Water
- Low and High Pressure Steam
- Process Hot Air

FOR THE FOLLOWING MARKETS:

1) LOCAL/STATE/FEDERAL FACILITIES AND OPERATIONS (INCLUDING MILITARY)

- e.g., Office Buildings, Prisons, Health Care Facilities

2) COMMERCE

- e.g., Restaurants, Motels

3) INDUSTRY

4) INTERNATIONAL MARKETS

- e.g., Water Distillation, Water Heating, Water Pumping

FOR SEVERAL SPECIFIC

APPLICATION/MARKET COMBINATIONS,

SOLAR PROCESS HEAT TECHNOLOGY

HAS BEEN

AND

IS

AVAILABLE FOR COMMERCIAL UTILIZATION

REPRESENTATIVE PRODUCERS

1) FLAT PLATE

- American Energy Technologies
- Solar Development, Inc.
- RADCO Products, Inc.
- Sun Earth, Inc.
- FAFCO

2) CONCENTRATING

- Industrial Solar Technology
- BSAR
- ENTECH
- Solar Kinetics, Inc.
- Sun Steam

3) FACILITATORS/THIRD PARTY INVESTORS

- California Energy Investment Corporation
- United Solar Technologies

EXAMPLES OF OPERATING SOLAR PROCESS HEAT SYSTEMS
• FLAT PLATE

PROJECT	SITE	STARTUP
University of California • Water Heating for Dormitories	Santa Barbara, CA	1984
Los Alamos National Laboratory • Water and Space Heating and Air Conditioning for Library	Los Alamos, NM	Early 1980s
Alderson Hospital • Water Heating	Woodland, CA	1985
University of California • Water Heating for Dormitories	Davis, Ca	1984
Lakeside Community Hospital • Water Heating	Lakeport, CA	1983

EXAMPLES OF OPERATING SOLAR PROCESS HEAT SYSTEMS
• CONCENTRATING

PROJECT	SITE	STARTUP
Gould, Inc. • Process Hot Water	Chandler, AZ	1983
Paul Beck Recreation Center • Process Hot Water	Aurora, CO	1985
Adams County Detention Facility • Process Hot Water and Electricity	Brighton, CO	1986
J. Nordhaven & Sons • Process Hot Water	Hayward, CA	1988
California Correctional Facility • Process Hot Water	Tehachapi, CA	1990

EXAMPLES OF PLANNED SOLAR PROCESS HEAT SYSTEMS

California Corrections Facility at San Luis Obispo, CA

- Solar Water Heating System

Fontero Women's Correctional Facility (Near San Bernadino, CA)

- Solar Absorption Air Conditioning System

RATIONALES

1) Solar Technology Is Available

2) Technical and Economic Performances Have Been Demonstrated Over Time

3) There Have Been Significant Solar Technology Improvements

4) For Some Applications, Economics Are Actually or Potentially Attractive

5) Availability of Solar Tax Credits

6) Environmental Benefits

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BARRIERS (EXAMPLES)

For Many Process Heat Applications, The Technology Is Not Economically Attractive Due To:

- Low Natural Gas Prices
- High Initial Capital
- High O&M Costs

Potential End Users -- Government and Private -- Are Not Familiar With The Technology

System Designers Not Familiar With The Technology

BARRIERS (CONTINUED)

Some Potential End Users Have The Perception That The Technology Is Too Risky

Government Facilities and Operations Provide Some Very Attractive Possibilities, But Market Penetration Too Difficult Due To:

- Long Approval and Procurement Processes
- Lack of Familiarization

NATIONAL STRATEGIC CONTEXT

1) Industry -- Excluding Commerce -- Consumes More Than One Third of Nation's Energy

2) E.A. Mueller Study: Approximately 9.2 Quads Used for Industrial Processes

- Water Preheating/Heating
- Steam
- Process Hot Air

3) Increasing Political Pressures To Reduce Greenhouse Gas Emissions and Improve Air Quality

4) Requirements for Air Pollution Control Equipment Increase Costs To Industry

SOLAR PROCESS HEAT PROGRAM

GOAL: HELP ATTAIN SIGNIFICANT SOLAR MARKET PENETRATION IN ECONOMICALLY-VIABLE MARKETS/APPLICATIONS

(HELP GET SOLAR PROCESS HEAT SYSTEMS UP AND OPERATING THAT MEET COST AND PERFORMANCE GOALS!)

PLAYERS: SOLAR PROCESS HEAT PROGRAM

- Solar Industry
- Actual/Potential End Users (Including Government)
- State/Federal Energy Policy Makers
- State/Federal Environmental Control Regulators

Facilitators
- SERI
- Sandia

PLANNED ACTIVITIES: FY1991 - FY1992

Task 1.0: Solar Heat Applications Market Assessments

- Identification of Realistic Current and Near-Term Markets
- Identification and Documentation of Equipment Decision Making Methods and Criteria

Task 2.0: Collaborative Projects With And Technical Support To The Solar Industry

- Prefeasibility Studies To Assess Merit of Incorporating Solar In Operations At Specific Entities
- Cost-Shared Process Heat Projects With Industry
- Development/Continuation Of Ongoing Working Relationship With California Energy Commission

PLANNED ACTIVITIES: FY1991 - FY1992

Task 3.0: Technical Assistance, Technology Transfer, Outreach And Other Support For Actual and Potential End Users

- Targeted Educational/Awareness Programs -- In Collaboration With Solar Industry
- Systems Assessment And Other Services
- Provision Of Technical Assistance (As Appropriate)

Task 4.0: Solar Process RDT&E

- Industry-Directed RDT&E To Facilitate Commercialization
- Concentrator and Optical Materials Long-Term Performance
- Technical And Solar Facilities Support For Industry

PLANNED ACCOMPLISHMENTS

1) Initiation Of Prefeasibility Solar Process Heat Studies

2) Several Cooperative Projects With The Solar Industry

    - To Help Get Projects In Place

3) Completion of Some Targeted Educational/Familiarization Programs

4) Establishment And Documentation Of Financial/Economic Analysis Methods And Decision Criteria By Representative Potential End Users

PLANNED ACCOMPLISHMENTS

5) Establishment Of A Steering Group (Through SEIA) To Provide Industry With A Means For Articulating Needs

6) Development of Promotional Materials For Use In Marketing/Familiarization Programs

SERI'S ADVANCED INDUSTRIAL PROCESSES PROJECT

An Abstract and Presentation

Prepared for

SOLTECH 91
San Francisco, CA

March 26, 1991

by

Meir Carasso
Project Manager

SERI's Advanced Industrial Processes Project aims at moving to industrial commercialization materials manufacturing and processing methods which have been demonstrated to be technically feasible and have commercial merit, as well as at conducting ongoing collaborative R&D in innovative industrial processes using concentrated solar energy. The project consists of three elements: high flux optics, materials processing, and advanced systems and economic studies.

A centerpiece of SERI's high flux project is SERI's High Flux Solar Furnace (HFSF). It is located on top of South Table Mountain near Denver, Colorado, and has a nominal power of about 10 kilowatts. In the HFSF, a flat heliostat tracks the sun and reflects the incoming solar flux onto the primary concentrator. The primary concentrator, made of 23 individual facets, concentrates the incoming beam onto the target plane located inside the test building. Once on the target plane, the solar beam, now concentrated to a peak of 2500 times its normal density, enters the nonimaging secondary concentrator. Two unique features of the HFSF make this two-state concentration possible. One is the so-called off-axis design. The second closely-linked feature is the long focal length of the primary concentrator. The latter, particularly, enables the beam reaching the target to be narrow and to couple with the secondary efficiently. In December 1989, SERI's HFSF became operational using conventional optics and attained a concentration of 2500 suns. In September 1990, using a nonimaging compound parabolic concentrator designed for SERI by the University of Chicago, the furnace established a new world record for solar concentration in air, attaining an average concentration of 21,000 suns on a 1.5-centimeter-diameter target. A ray trace computer code calculated the peak flux to have exceeded 25,000 suns.

The significance of demonstrating that these very high solar flux densities can be attained at considerable power levels is that they make new process conditions, and therefore new industrial applications for solar energy, possible. These new process conditions include very high temperatures, very high heating rates, and very high flux densities over the broadband solar spectrum of about 300 to 2500 nanometers.

In the area of materials processing, several early experiments made use of the ability of concentrated solar flux to produce very high temperatures. One process combines silica and carbon in a high-temperature reaction to form silicon carbide. A number of tests were performed in which the product was formed inside a graphite receiver/reactor, where internal cavity temperatures of 1750°C to 1800°C were measured. SERI verified the success of the experiments via chemical analysis, which indicated that the samples consisted of 80 percent silicon carbide. Current activities aim at exploring the production of ultra-fine ceramic powders.

Another promising area of application is in materials surface engineering. This area exploits the ability of the concentrated flux to impose a high heating rate on the target. Recently, thin films of diamond-like carbon (DLC) have been grown on nickel and silicon substrates using methane and hydrogen as precursors. Experiments with silicon substrates have produced thin films of silicon carbide and DLC films, as well as graphic carbon, depending upon the growth conditions. Current conventional technology using microwave plasmas or hot filaments requires large amounts of energy to grow similar films.

An important use for DLC thin films is in electronic materials. Thin coatings of DLC on heat sink materials provide electrical insulation properties approaching that of the commonly used silicon dioxide, combined with a thermal conductivity better than copper. Another use for diamond films is in the area of low-friction (tribological) coatings. Because of their extreme hardness, low coefficient of friction, and high thermal conductivity, diamond or DLC films are viewed as the ultimate coating for many cutting tools and bearing surfaces. These applications account for a large part of the current commercial market in diamond films.

Depositing high-temperature superconducting films is another area SERI is researching. Metalorganic precursors for the yttrium-barium-copper-oxide group of superconductors were spin-coated onto single-crystal yttrium, stabilized zirconia, and magnesium oxide substrates, dried in air, then thermally processed in oxygen using the solar furnace at SERI. Zero resistivity was measured at a temperature of 74.7 K. SERI believes that the higher deposition rates and high heating rates made possible by the solar furnace may not only make it more economical to produce existing superconductivity films but will also enable development of completely new films.

Other experiments at SERI have demonstrated the technical feasibility of conducting self-propagating high-temperature synthesis reactions enabling the deposition of advanced ceramic coatings of nickel aluminide, titanium diboride, and titanium carbonate on a variety of metallic substrates; cladding, such as stainless steel and nickel-chrome alloys on mild steel substrates; phase transformation hardening of steel alloys to obtain various degrees of surface hardness; and finally, radiative joining where very localized, high heating rates enable the local joining of adjacent structures without heating a whole structure.

To determine whether these applications are likely to be economically competitive, two studies, one conducted by Sandia National Laboratory and the other by SERI staff, compared the cost of photons for materials processing using a solar furnace to that using arc lamps and a laser. These studies concluded that better economics existed under most circumstances for the solar furnace for a large area of the United States where insolation is high.

One area of application for SERI's HFSF involves the direct solar pumping of lasers. Researchers have worked on solar-pumped lasers for over 25 years. Because of the relatively low solar flux density available using conventional concentrators, solar pumping of solid-state crystal lasers has achieved low conversion efficiencies of about 1 percent. With high-refractive-index CPCs and concentrations of over 50,000 suns it may be possible to use laser materials with overall conversion efficiencies in the range of 5 percent. Current SERI-sponsored research at the University of Chicago aims to demonstrate this conversion efficiency using a solar-pumped dye laser.

Both the technical feasibility and the resultant conversion efficiency of a solar-pumped dye laser are closely tied to the availability of a high solar concentration, because the concentration has to be high enough to overcome the threshold requirement for lasing and because the laser's overall efficiency increases as the concentration increases. For this reason, attaining concentrations higher than 50,000 suns at SERI's HFSF will be a particularly significant milestone. A solar-pumped dye laser is attractive because it promises to have a higher overall conversion efficiency, tunability, and higher lasing frequencies. In addition, the dye laser promises to be more reliable since it will eliminate the cooling and thermal gradient limitations of solid-state lasers. Thus, SERI believes the technical feasibility of a solar-pumped laser should increase the economic viability of this powerful tool.

Conceptually, applications of a solar-pumped laser include all areas in which current lasers are used. Other categories of applications include the photochemical dissociation of toxic compounds such as polychlorinated biphenyls and the photosynthesis of inorganic high-value substances such as ceramic carbides and borides.

SERI's Advanced Industrial Processes Project

A Presentation Prepared for SOLTECH 91

San Francisco, California
March 26, 1991

by

Meir Carasso
Project Manager

P15-G0717301

Overall Objectives

- To colaborate with industry in moving promising materials processing applications to industrial commercialization
- Conduct R&D necessary to increase the contribution of high solar concentrations to new industrial processes

P15-G0717302

The Advanced Industrial Processes Project Consists of:

- High flux optics
- Applications
- Innovative processes R&D
- Systems and economic assessments

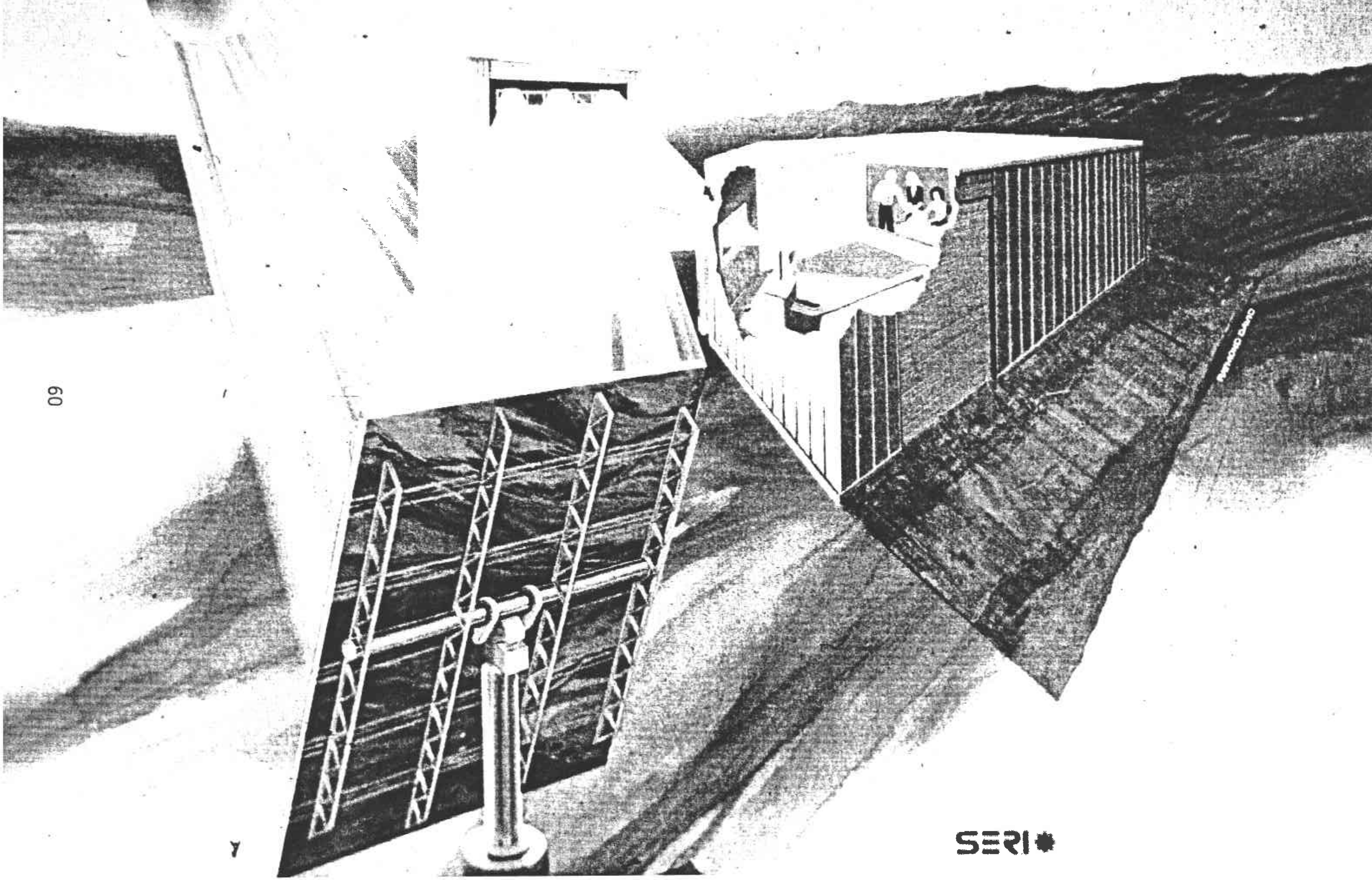
P15-G0717303

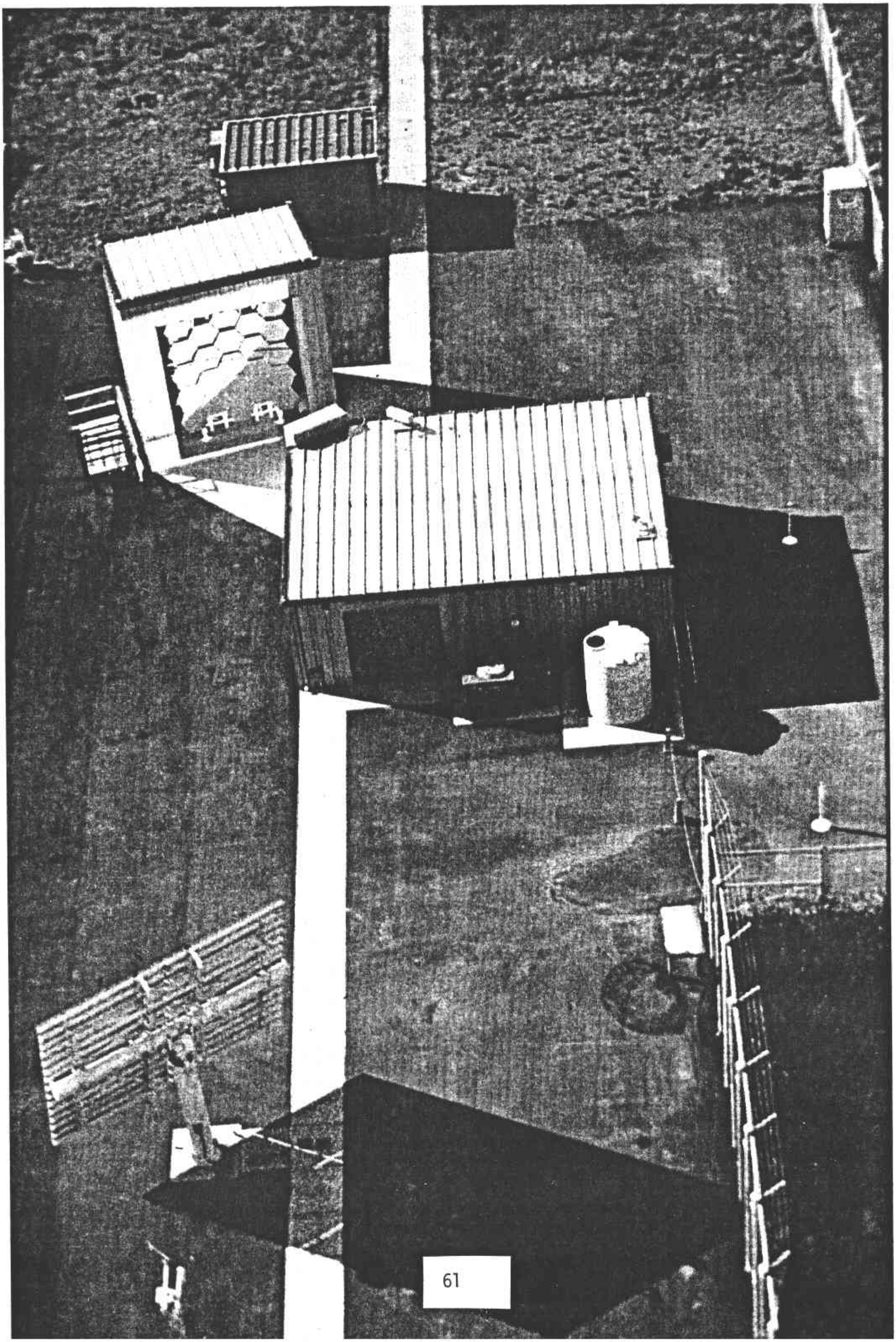
High Flux Optics

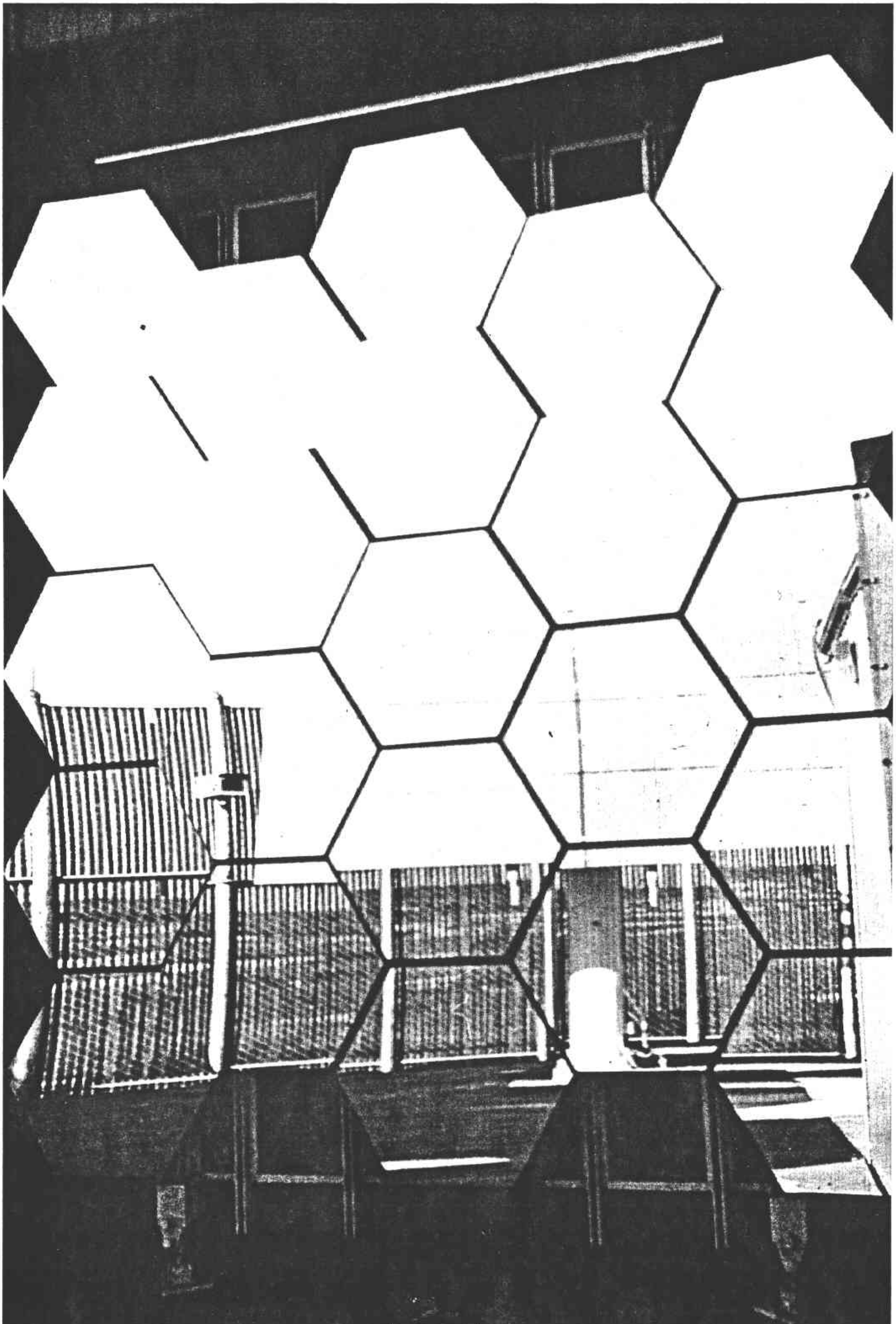
- SERI's high flux solar furnace

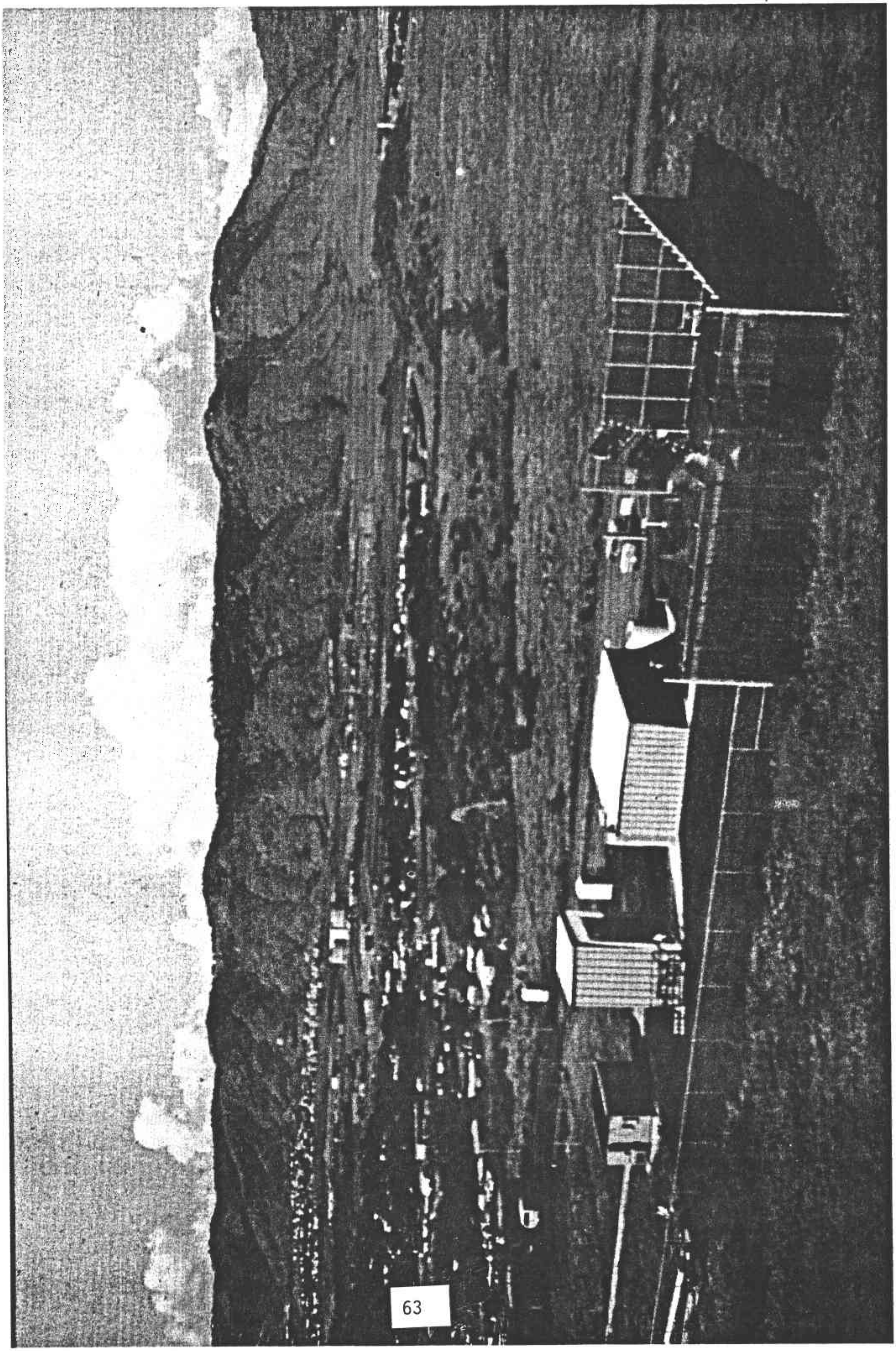
P15-G0717304

High-Flux Solar Furnace









SERI's High Flux Solar Furnace

- Significance: new industrial process conditions
  - Very high temperatures
  - Very high heating rates
  - Very high flux densifier in the 300-2500 nm solar band

P15-G0717305

New Process Conditions Made Possible By Very High Solar Flux Densities

- High total power on the target
- Broad spectrum of photons
- Higher temperatures
- Higher heating rates
- Larger "spot" sizes

- Energy economics competitive with lasers and arc lamps

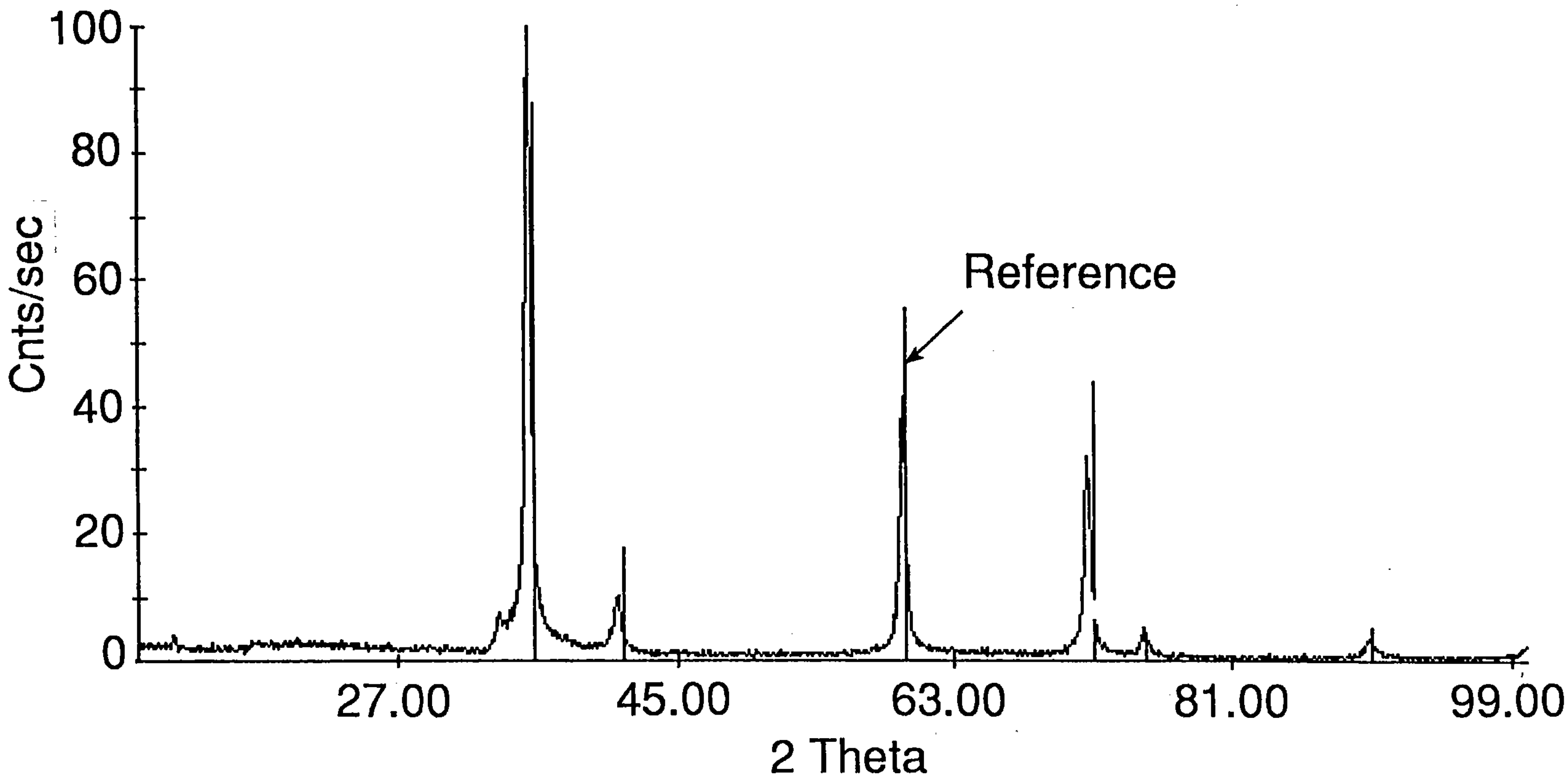
P8-G0671505

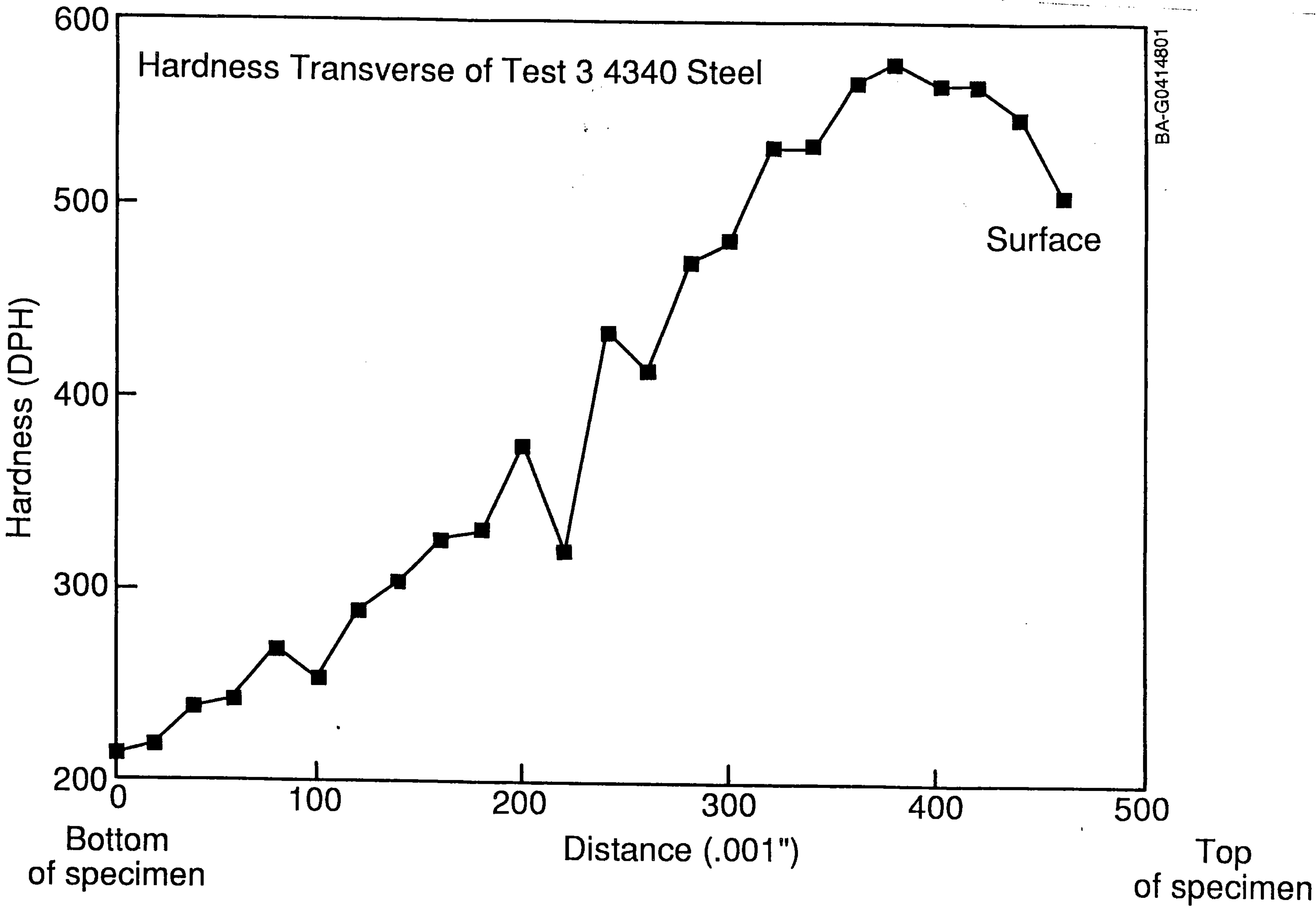
Applications: Materials Processing, Solar Pumped Lasers

- **Synthetic materials**
  - Silicon carbide
  - Fine ceramic powders
- **Surface modification**
  - Phase transformation hardening
  - Cladding
  - Joining
  - Diamond like carbon
  - High temp superconducting film
  - Ceramic coating of alloys (SHS)
- **Solar pumped lasers**

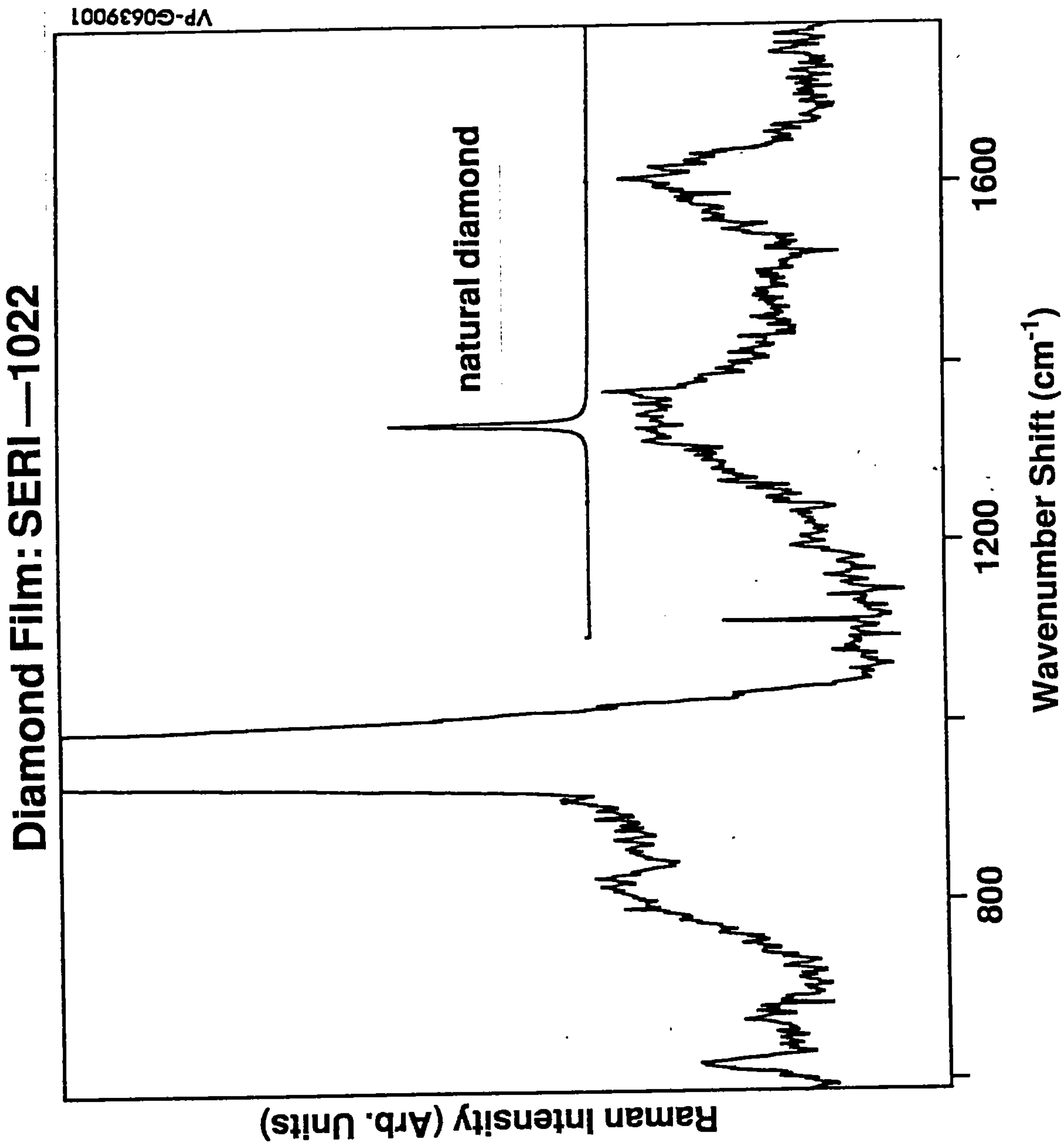
P15-G0717306

X-Ray Diffraction Analysis of Silicon Carbide Sample

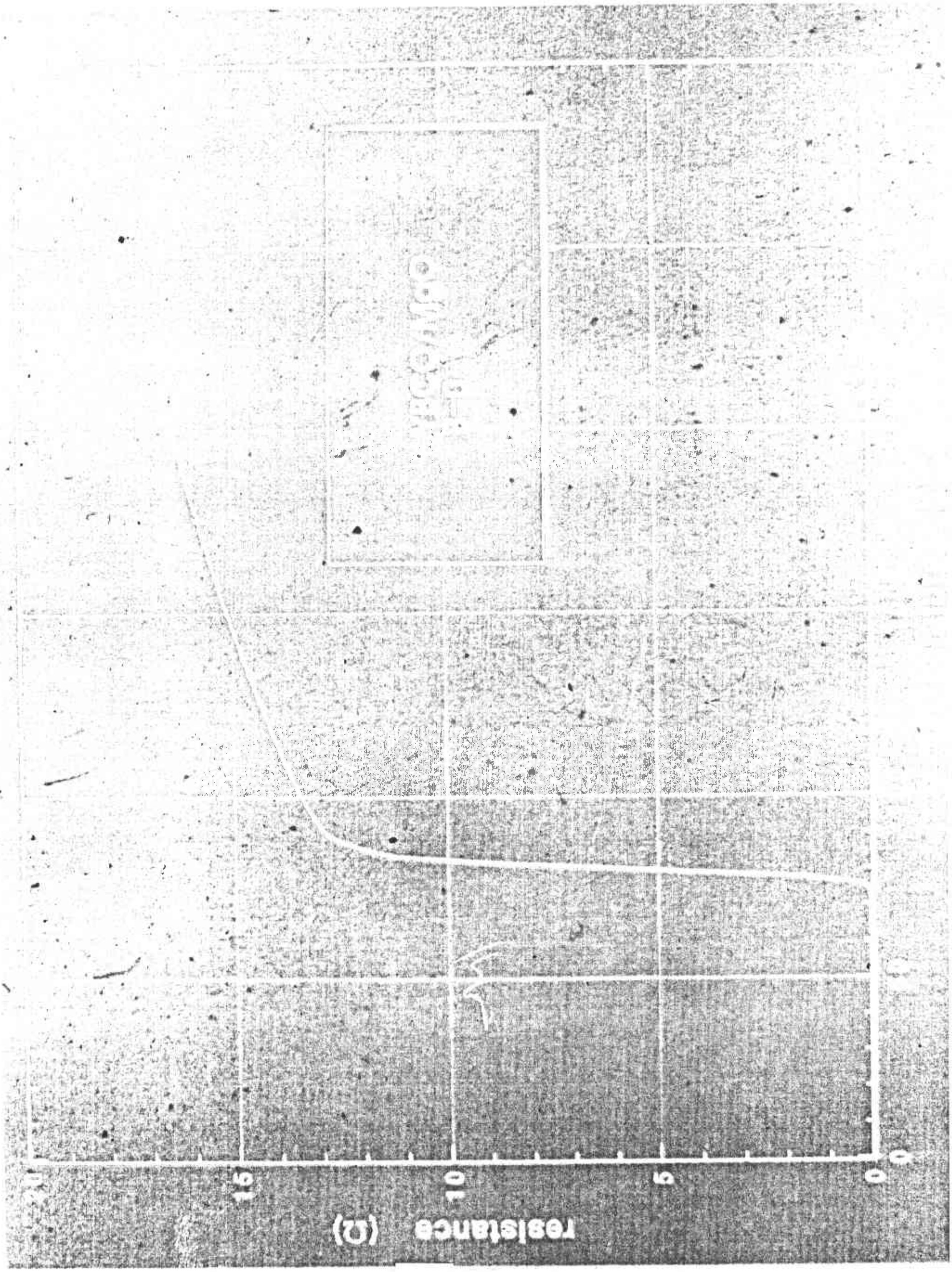




Hardness Transverse of Test 3 4340 Steel
BA-G0414801
Surface
Hardness (DPH)
600
500
400
300
200
0
100
200
300
400
500
Bottom of specimen
Distance (.001")
Top of specimen



Diamond Film: SERI—1022
natural diamond
VP-G063900l
Raman Intensity (Arb. Units)
Wavenumber Shift (cm^{-1})
800
1200
1600


resistance (Ω)
0
5
10
15

Economic Assessments:

- SNLA comparison of solar furnace with arc lamps
- SERI comparison of solar furnace with a CO_2 laser

Both show favorable economics for solar furnace in sun belt locations and batch processes

P15-G0717307

New Applications R&D: Three Current Studies

- National Research Council/Energy Engineering Board
- MIT Energy Lab
- SRI International

P15-G0717308

Solar Pumped Dye Lasers

- High conversion efficiency
- Higher power output
- Larger laser "spot" size
- Improved reliability and economics
- Allows close frequently-coupling with chemical processes

P8-G0671506

SERI SOLAR INDUSTRIAL APPLICATIONS ASSISTANCE PROJECT

Russell Hewett
Solar Energy Research Institute

The SERI Solar Industrial Applications Assistance Project (SIAAP) is a technology transfer/technical assistance/outreach activity in support of the three R&D programs in the SERI Solar Industrial Program:

- Solar Detoxification Program
- Solar Process Heat Program
- Solar Industrial Processes Program.

The goal of SIAAP is to support acceleration of the commercial utilization of the solar technologies for industrial applications by: (i) assisting endusers and identifying and educating potential endusers (government and private); (ii) assisting the solar industry in their commercialization efforts; and (iii) assisting in getting past institutional and infrastructure barriers that impede widespread utilization.

The primary target audiences for SIAAP efforts are:

- Actual endusers of the solar technologies
- Potential endusers and their professional/trade associations
- Solar industry
- Firms interested in becoming involved in specialized areas of the solar industrial technologies
- State/federal energy policymakers
- Local/state/federal environmental protection and regulatory agencies.

SIAAP technical assistance activities make use of existing SERI facilities such as the SERI Solar Detoxification Test Facility, the High Flux Solar Furnace and the Concentrator Research Laboratory.

General activities in FY1991 include:

- Providing direct, hands-on ad hoc technical and systems analysis assistance to industry, etc.
- Educating potential endusers, policymakers and regulatory agencies
- Serving as a focus for collecting and disseminating information and reports about the solar technologies for specific applications
- Participating in the exhibition and technical programs of the annual conferences of professional/trade associations of the target audiences
- Providing feedback to the Solar Industrial Program for use in program planning.

With respect to supporting the Solar Detoxification Program, the emphasis in SIAAP in FY1991 is on the solar detoxification of organics in water. One major effort is serving as the focus for receiving and responding to requests from industry to: (i) conduct solar treatability studies on organics-contaminated water samples; and (ii) perform preliminary systems analysis studies to determine if solar detoxification is an appropriate technology for treating a specific cleanup problem at a specific site.

The SIAAP is also serving as the focus for receiving and responding to requests from industry, universities, government laboratories, etc. to: (i) have materials tested and evaluated in the SERI High-Flux Solar Furnace; or (ii) utilize the furnace for their own RDT&E projects.

MAR(Assistance.RH)

SOLTECH91

SOLAR INDUSTRIAL APPLICATIONS ASSISTANCE PROJECT AT SERI

• R. HEWETT

March 26, 1991

SERI

TECHNOLOGY TRANSFER/TECHNICAL ASSISTANCE/OUTREACH PROJECT

In support of:

- Solar Process Heat Program
- Solar Detoxification Program
- Solar Industrial Processes Program

MISSION STATEMENT

The mission of the Office of Conservation and Renewable Energy is:

> ...to develop and promote the adoption of cost-effective renewable energy and energy efficiency technologies and practices in conjunction with the States and with partners in the building, industrial, transportation, and utility sectors,...

*Strategic Plan for the Office of Conservation and Renewable Energy (January 1, 1991)

GOAL

Support Acceleration of the Commercial Utilization of the Solar Technologies For Industrial Applications By:

- Assisting endusers and identifying and educating potential endusers
- Assisting the Solar Industry
- Assisting in getting past institutional and infrastructure barriers that impede widespread utilization

PRIMARY TARGET AUDIENCES

1. Actual endusers

2. Potential endusers and their professional/trade associations (Government and Nongovernment)

3. Solar industry

4. Firms interested in specialized areas of the solar industrial technologies

5. State/federal energy policymakers

6. Local/state/federal environmental protection/regulatory agencies

SPECIAL FEATURES

1. Broader use of existing SERI resources

   - Scientific, engineering and systems analysis staff and expertise
   - Laboratory facilities
   - Solar field facilities

2. Use of all mechanisms including CRADAs

3. Encouraging solar industry, end users and regulatory agencies to work together for deploying commercial systems

- Emphasis in Process Heat area is on working with industry

- Most activities relating to Process Heat are included in the Solar Process Heat Program.

- Additional technical areas of assistance include:

    - solar detoxification of organics in water
    - materials processing
    - concentrators
    - optical materials

SERI LABORATORY AND TEST FACILITIES AVAILABLE TO THE PROJECT

1. Solar Detoxification of Water
    - Solar Detoxification Laboratory
    - Solar Detoxification Test Facility
    - Basic Photoelectrochemistry Research Laboratory

2. Expected Future Solar Detoxification Facilities
    - Mobile Solar Water Detoxification Unit
    - Pilot Solar Water Treatment System

3. Materials Processing
    - High-Flux Solar Furnace

4. Concentrators
    - Concentrator Research Laboratory

5. Optical Materials
    - Optical Materials Laboratory

FY 1991 ACTIVITIES

General

1. Providing direct hands-on technical and systems analysis support to industry, actual endusers, etc.

2. Increasing the awareness of potential endusers, policy makers and regulatory agencies.

    - Developing educational and promotional materials

3. Serving as a center for collecting and disseminating information about the solar technologies for specific applications.

FY 1991 ACTIVITIES
General (Continued)

4. Participating in the annual conferences of professional/educational/trade associations of target audiences:

    - SOLTECH
    - Society of American Military Engineers
    - Air & Waste Management Association
    - Water Pollution Control Federation

5. Publicizing the Project and the services that can be made available.

6. Providing feedback to the Solar Industrial Program for use in program planning.

FY 1991 ACTIVITIES
Solar Detoxification of Organics in Water

1. Serving as focus for assisting in the following areas:

   - Solar treatability studies on water samples.
   - Preliminary systems analysis studies.

FY 1991 ACTIVITIES
Solar Detoxification of Organics in Water (Continued)

2. Serving as focus for receiving and responding to requests from industry to utilize SERI solar detoxification RDT&E facilities.

3. Developing and maintaining a solar detoxification data base.

4. Responding to requests for information and reports, technical papers, etc. on solar detoxification.

FY 1991 ACTIVITIES
<u>Materials Processing</u>

Responding to requests from industry, universities, government laboratories, etc. to:

- Have materials tested and evaluated in the SERI high-flux solar furnace.

- Utilize the furnace for other research.

EXAMPLES

1. Industrial Solar Technology
   - Refurbishment of the parabolic troughs in the solar water heating system at the Paul Beck Recreation Center with new reflector film (ECP-305)

2. The 3M Company
   - Measured the performance of its new silver/polymer reflector materials
     - Solar testing
     - Laboratory testing

3. United Solar Technologies/Industrial Solar Technology
   - Assisted in evaluating the optical performances of reflector films for the Tehachapi project.
   - Provided sample rolls of reflector film to test production techniques.

EXAMPLES (Continued)

4. Solar Kinetics
   - Did optical testing and evaluation of mirror facets in its multi-facet dish

5. Science Applications International Corporation (SAIC)
   - Did optical testing and evaluation of mirror facets in its multi-facet dish

6. Titanium Dioxide Producer
   - Assessed the suitability of the company's photocatalyst -- in different configurations -- for solar detoxification applications

7. Large Chemical Company "X"
   - Performed treatability studies on groundwater contaminated with trace levels of pesticides

EXAMPLES (Continued)

8. Large Chemical Company "Y"
   - Performed treatability studies on groundwater samples contaminated with di-(2-chloroethyl) ether

9. Chemical Supply and Waste Water Treatment Company "Z"
   - Performed treatability studies on samples of pulp and paper mill process water

10. Cummins/LaJet
    - Planning to do optical testing of the facets in the dish for their dish/Stirling system

11. Arizona Chemical Company
    - Getting ready to do a preliminary assessment of using solar technology for drying copper sulfate solution to make crystals.

ABSTRACT FOR SOLTECH 91

SOLAR THERMAL ELECTRIC TECHNOLOGY STATUS AND THRUST

Martin Scheve
Division of Solar Thermal and Biomass Power
Office of Solar Energy Conversion
U.S. Department of Energy
Washington, D.C. 20585

Most experts agree that a mixture of energy alternatives must be developed for the future. As part of a balanced national energy strategy, the widespread use of solar thermal energy systems could increase domestic energy supplies, reduce dependence on imported oil, help U.S. industry respond to increasing international competition for domestic and overseas markets for solar energy systems, and improve the environment by reducing power plant emissions including SO_x, NO_x, and greenhouse gases.

This paper supports solar thermal electric technology energy cost and performance projections for the National Energy Strategy. This paper reviews the basic principles of solar thermal electric and energy conversion, and the previous contributions of the National Solar Thermal Systems Programs. It discusses the market status for solar thermal electric technology, and identifies user requirements to help establish the future technology path and the historical role of the solar thermal electric industry. It projects trends in the performance and cost of the technology based on input from national laboratories and industry experts.

Significant progress has been made toward generating economically competitive solar thermal energy for electrical applications. Research and development (R&D) efforts in the past years have improved the performance and the reliability of solar thermal systems and reduced both the capital installed costs ($/kW) and energy costs ($/kWh) of solar thermal systems to one-fifth the cost of early systems. This large reduction is a result of lower cost components and increased system efficiency. However, further cost reductions are required to make solar thermal energy cost-competitive with energy generated by fossil fuels. Prime opportunities for solar thermal electricity generation beyond troughs include peaking, intermediate and base load generation for central receivers; and peaking, intermediate, and off-grid applications for dish/engine systems.

The Solar Thermal Systems program is focusing on the development of innovative and economical systems to concentrate and convert solar energy to electricity. This energy source is vast and strategically secure. Its impact upon the environment is minimal. The major impact is land use at less than 15 acres/MWe. In addition, solar thermal systems can be built quickly and in modular units to respond to immediate market needs and to future energy demands. While some solar thermal systems generate heat for industrial processes, the applications closest to the marketplace generate electricity. R&D tasks, leveraged by cost-sharing with industrial partners, are being planned to achieve improvements in the most promising concepts, and to quickly lead to commercial products.

Efforts to bring solar thermal systems to the marketplace are already showing measurable results. Building on the wealth of system experience developed in the DOE program, several companies have made commercial sales of parabolic trough industrial process heat systems. Luz International, for example, projects installation of approximately 700 MWe of power generating stations in the United States by 1994. Today, these parabolic trough systems generate electricity below 10¢/kWh (according to Luz's economic assumptions), with the potential for even lower cost.

In 5 to 7 years, solar thermal systems based on advanced components should find substantially expanded domestic and export market opportunities. These systems will perform better and be available at lower cost than systems at present. One example is central receiver electric power plants that use stretched membrane heliostats and an advanced nitrate-salt receiver. Another is 5 to 25 kWe dish-electric systems, which use low-cost membrane concentrators and advanced focal-mounted engines. Such dish-electric systems can run with solar or fossil fuel for remote and grid-connected markets.

According to the National Energy Strategy Study, the potential market for electric power generation in the southwestern United States alone could be 35,000 MWe in the next decade. Developing export markets for solar thermal systems can further expand this market base. The DOE strategy for moving solar thermal research to the marketplace involves improving cost effectiveness and reliability of solar thermal components and establishing additional early markets with high strategic or economic value to U.S. industry. The strategy also includes establishing cost-shared industrial partnerships that will improve the competitiveness of existing solar thermal electric systems.

SOLAR THERMAL ELECTRIC TECHNOLOGY

STATUS AND THRUST

26 March 1991

Presented at:

Solar Thermal Electric Program Symposium
SOLTECH 91 CONFERENCE
Burlingame, California

Presented by:

Martin Scheve

Division of Solar Thermal and Biomass Power
Office of Solar Energy Conversion
U.S. Department of Energy
Washington, D.C. 20585

SOLAR THERMAL ELECTRIC TECHNOLOGY
STATUS AND THRUST

AGENDA

- Need and Advantages
- Strategy and Options Matching for Future Needs
- Goal and Objectives
- Progress Made in the Past Decade
- Technology Outlook (What Next)
- Base vs Accelerated Scenarios
- Challenges

NEED FOR ALTERNATIVE/RENEWABLE ENERGY OPTIONS

Future energy supply and use poses many challenges:

- Availability of economically viable energy options
  - Energy Security
  - Resource Utilization for High-Payoff Opportunities
- Strengthen Industry Infrastructure
  - Maintain U.S. Industry Leadership
  - Increase International Energy Market Penetration
- Reduce increasing concerns due to environmental problems

A MIXTURE OF ECONOMICAL ENERGY SUPPLY ALTERNATIVES WILL BE REQUIRED TO MEET FUTURE/PROJECTED ELECTRIC ENERGY REQUIREMENTS AND TO OFFSET ANY ENERGY SUPPLY PROBLEMS.

ADVANTAGES OF CONCENTRATED SOLAR ENERGY AS AN EFFECTIVE ENERGY SOURCE

KEY ATTRIBUTES OF CONCENTRATED SOLAR ENERGY:

- Strategically secure source of supply
- Environmentally benign
- Potential for off-grid/remote, peaking and intermediate utility options
- Short construction lead times and modular units.
- POTENTIAL OF LARGE DOMESTIC AND INTERNATIONAL MARKETS

SOLAR THERMAL ELECTRIC TECHNOLOGY STRATEGY

- FOCUSED approach to inform and convince utilities, other users, and decision-makers regarding near-term and future options, and potential of solar thermal electric technologies.

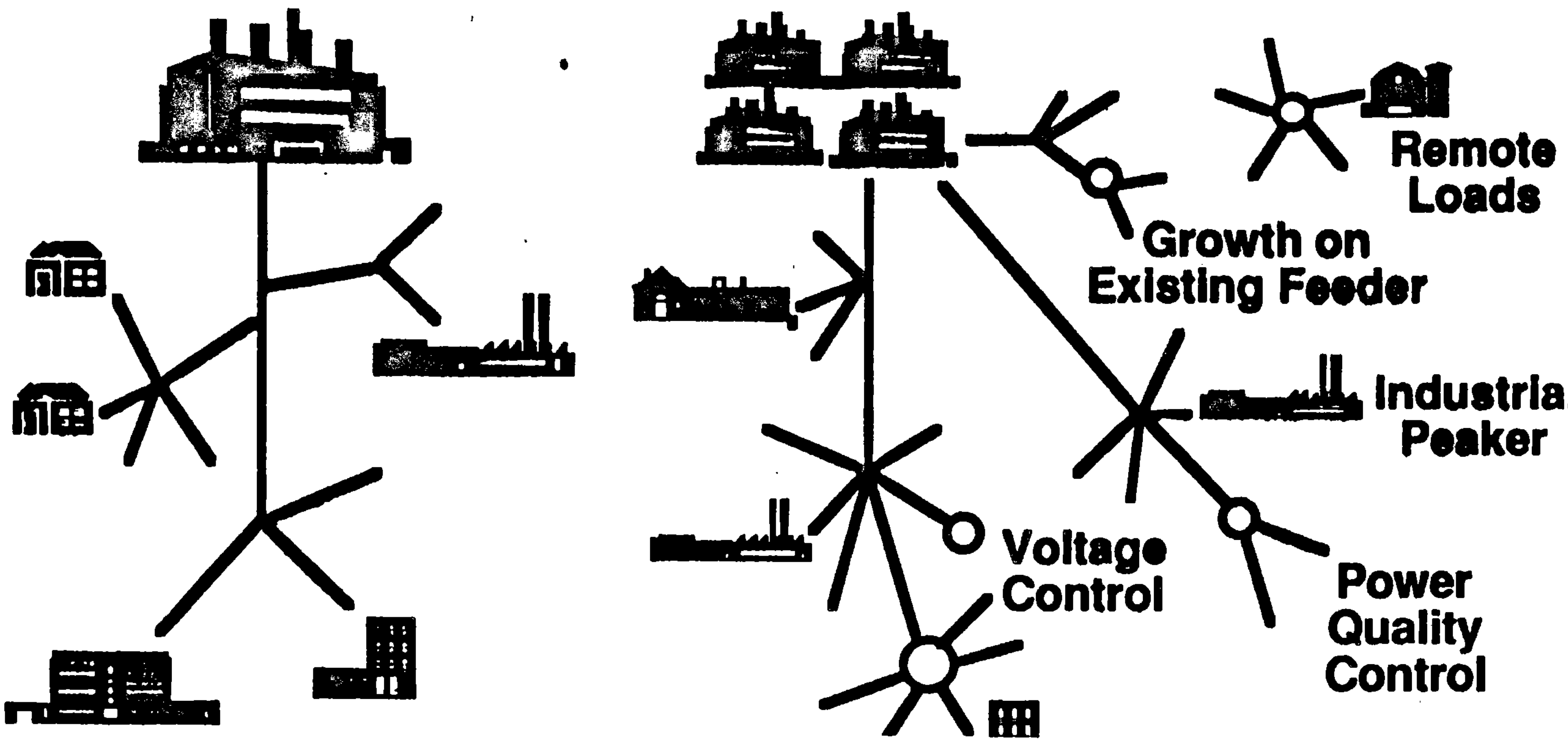
- Strengthen and, where necessary, rebuild ties to industry and other private sector organizations through collaborative activities.

- Focus research and technology development efforts on areas with the potential for major market and energy impacts.

Emerging Electric Supply and Delivery Systems

Utility Today

Utility of Tomorrow?



ADDRESSING FUTURE ENERGY NEED WITH MODULAR PEAKING/INTERMEDIATE PLANTS

- CENTRAL POWER OPTIONS
- REPOWERING OPTIONS
- DISTRIBUTED POWER OPTIONS
- REMOTE/OFF-GRID OPTIONS

SOLAR THERMAL ELECTRIC TECHNOLOGY

PROGRAM GOAL AND OBJECTIVES

GOAL: Establish a technology base from which industry can further commercialize solar thermal power generation options for remote/off-grid, export and utility markets.

OBJECTIVES:

- Develop reliable and competitive solar thermal electric systems and components.

- Assist the private sector to advance the solar thermal electric technology options through system and manufacturing validations.

- Implement market conditions that encourage technology transfer and commercialization, and increase demand for U.S. products domestically and internationally.

PROGRESS MADE IN THE PAST DECADE

- TECHNICAL FEASIBILITY AND PROOF-OF DESIGN PROVEN

- SUBSTANTIAL COST REDUCTION AND PERFORMANCE IMPROVEMENT ACHIEVED

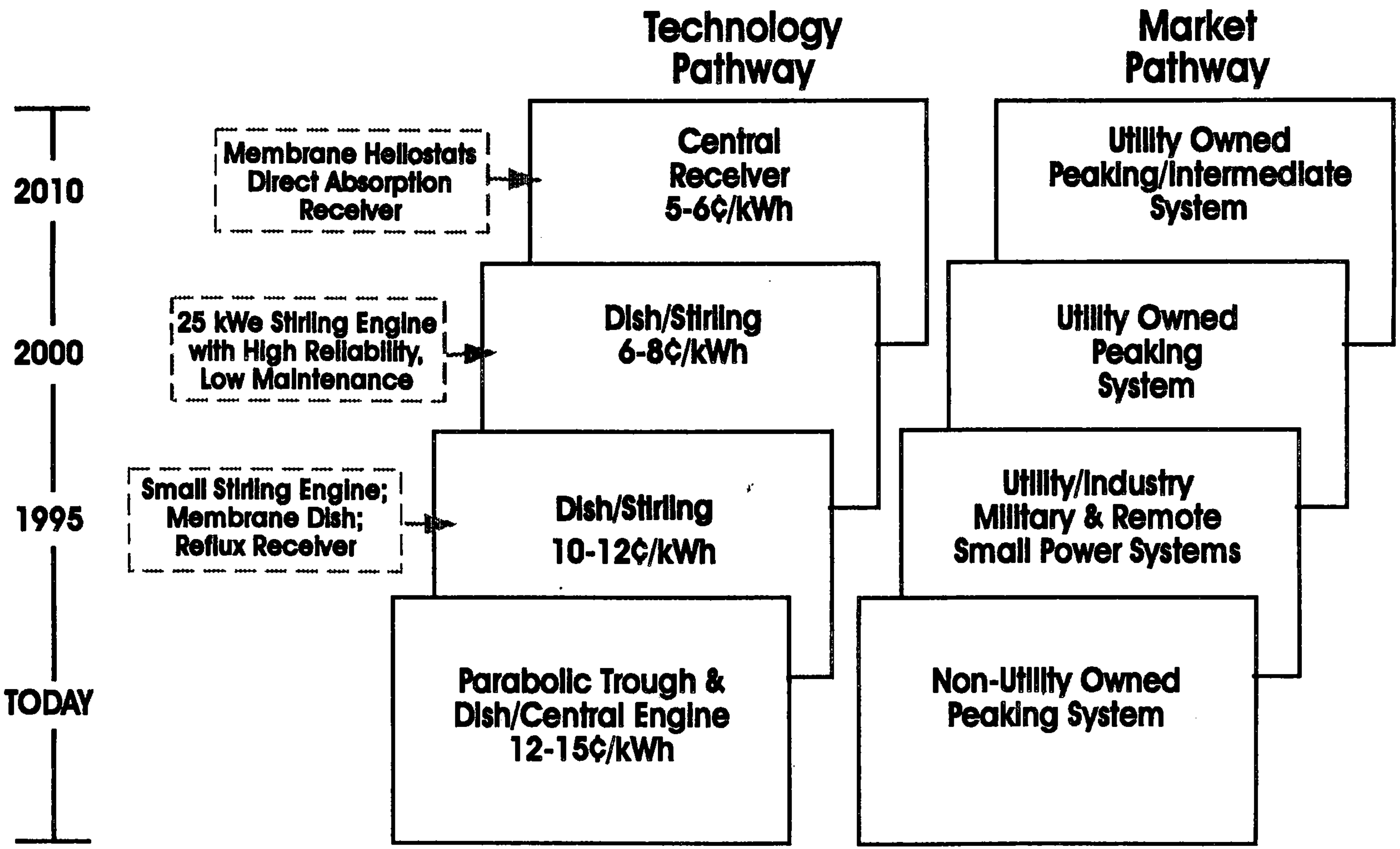
- TECHNICAL AND FINANCIAL RISKS REDUCED

- INITIAL ENERGY MARKET PENETRATED

SOLAR THERMAL ELECTRIC TECHNOLOGY

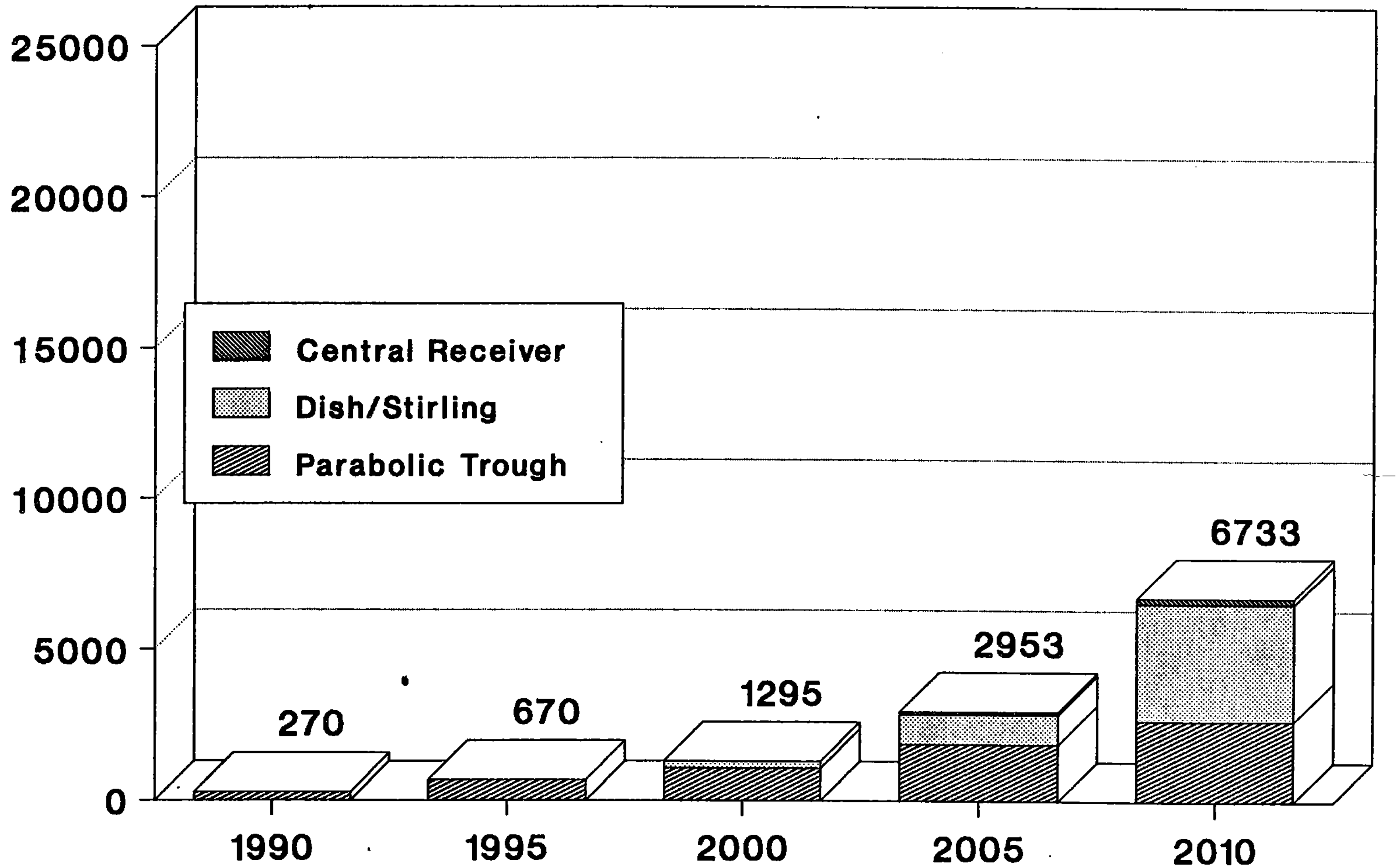
BASE VS ACCELERATED SCENARIOS

SOLAR THERMAL ELECTRIC



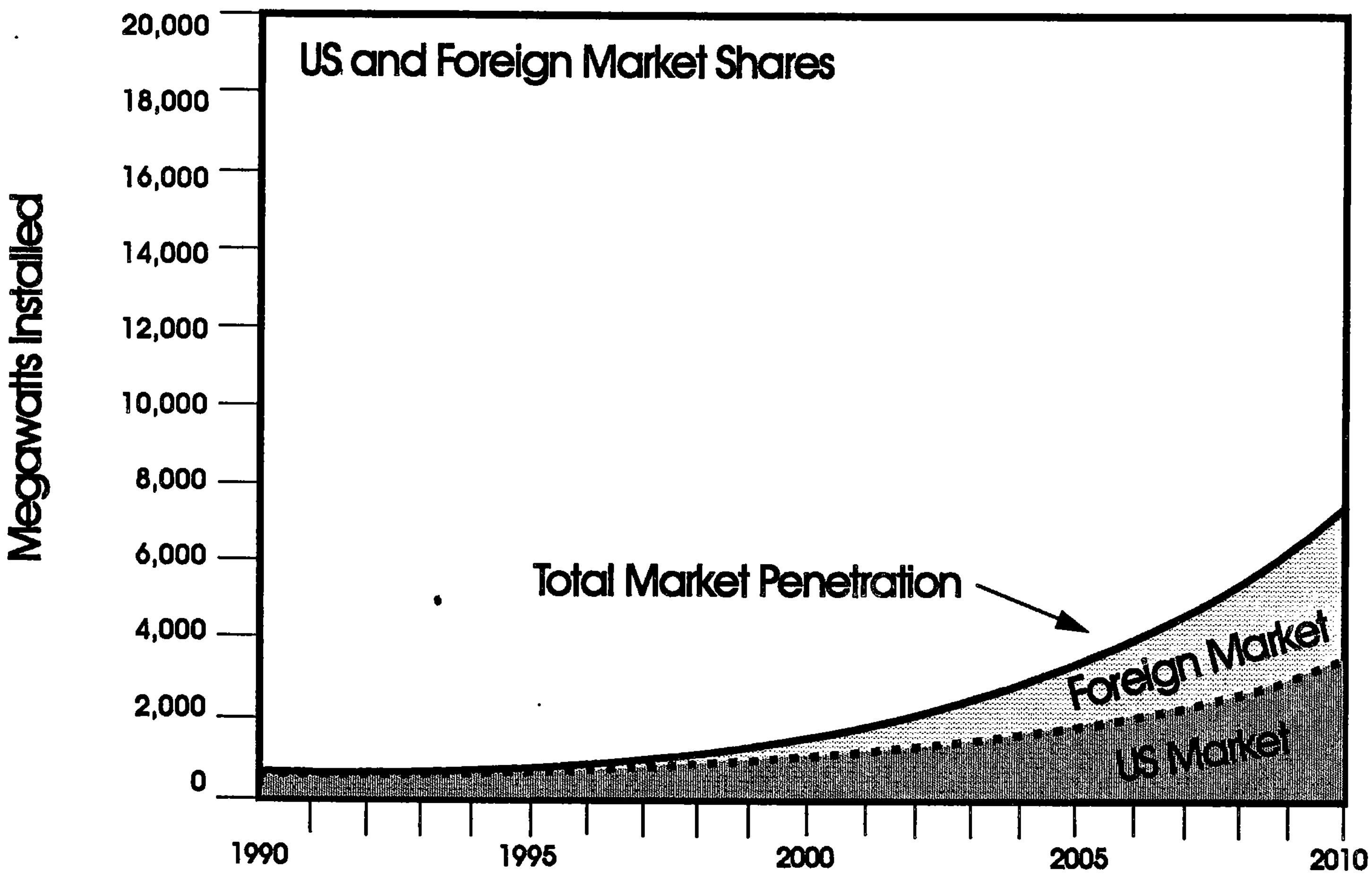
Base Resource Plan

SOLAR THERMAL ELECTRIC POWER
Installed Capacity - Base Case



SOLAR THERMAL ELECTRIC POWER

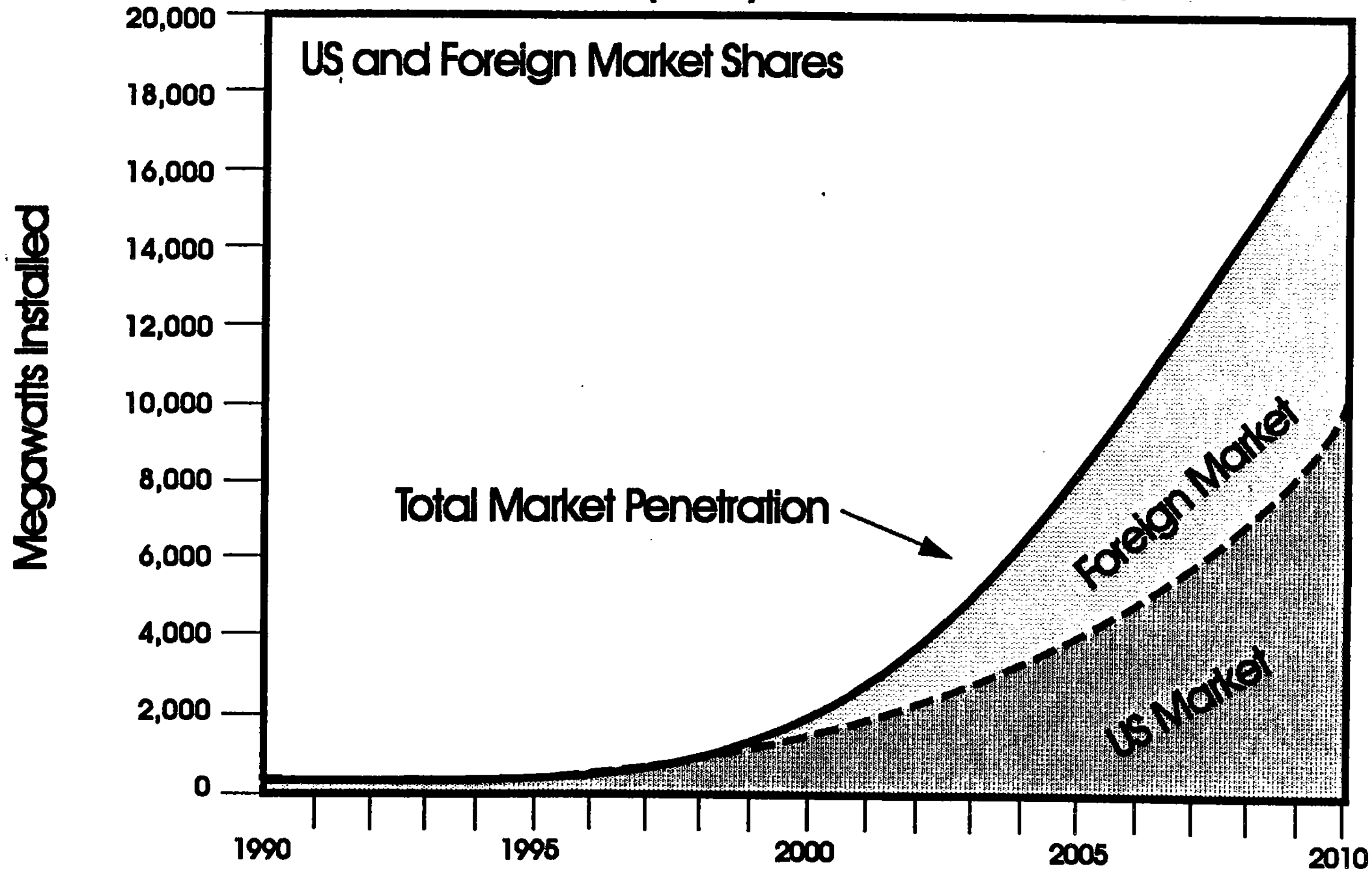
Installed Capacity - Base Case



	1990	1995	2000	2005	2010
US Market	270	670	1,160	1,883	3,515
Foreign Market	0	0	135	1,070	3,128
Total Solar Thermal	270	670	1,295	2,953	6,733

SOLAR THERMAL ELECTRIC POWER

Installed Capacity - Accelerated Case

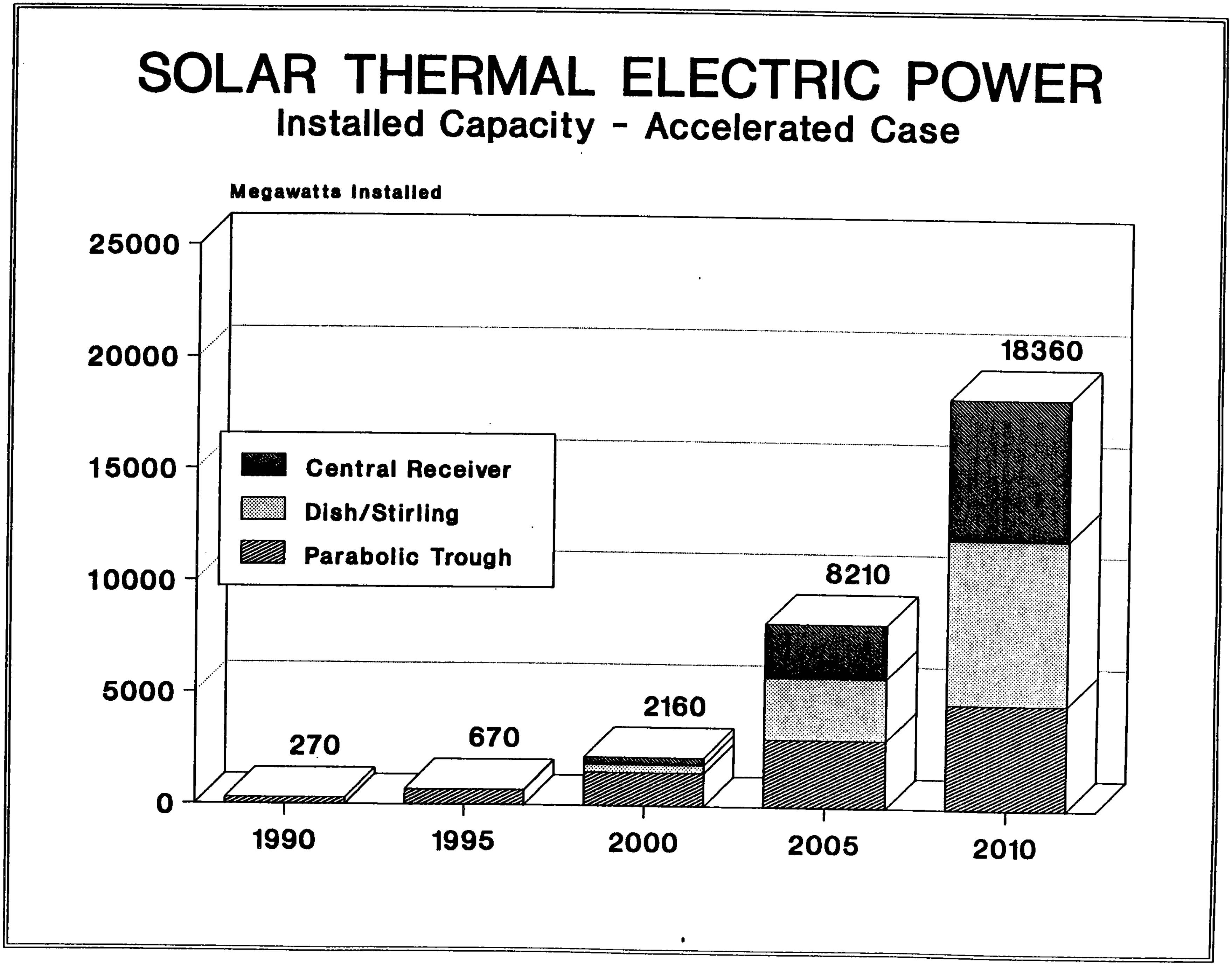


	1990	1995	2000	2005	2010
US Market	270	670	1,680	4,180	9,360
Foreign Market	0	0	480	4,030	9,000
Total Solar Thermal	270	670	2,160	8,210	18,360

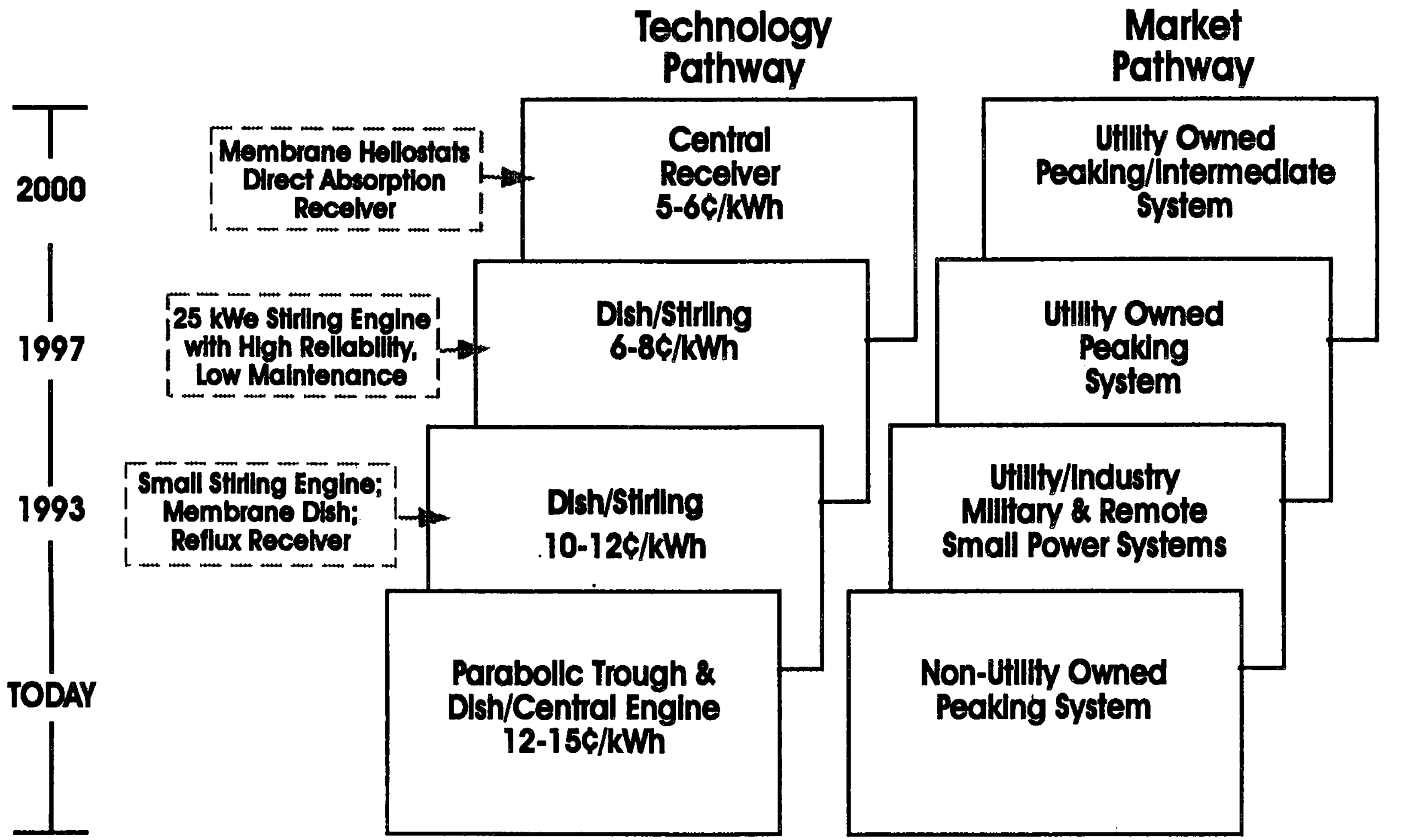
MARKET OPPORTUNITIES - SOLAR THERMAL ELECTRIC

Revised 2/25/91

Time Frame	U.S.	International
Near Term (1991-1995)	Approximately 670 MWe installed. Primarily trough/natural gas hybrid plants of 80 MW. Only in southern California.	Continue industry efforts to penetrate international market by 1995.
Medium Term (1995-2000)	Approximately 1680 MWe installed. Mostly trough/natural gas hybrid plants, with 160 MWe units beginning around 1995. First central receiver plant (100 MW) projected in 1997 followed by second and third 100 MW central receivers by the year 2000. Initial penetration of small dish plants (340 MW total) into niche (and remote) markets in 1995-2000.	Approximately 480 MWe installed. Continued dominance of trough/natural gas hybrid plants, with first plant of 80-160 MW appearing. Initial entry of dishes into remote/off-grid markets.
Long Term (2000-2010)	Approximately 9360 MWe installed. All solar thermal plant types achieve competitiveness with natural gas plants, with dishes and central receiver lower than costs of small coal plants, resulting in extensive use in utility markets.	Approximately 9000 MWe installed. Trough/natural gas hybrid plants show constant growth, but dishes and central receiver plants make significant penetration into utility markets.


SOLAR THERMAL ELECTRIC POWER
Installed Capacity - Accelerated Case
Megawatts Installed
25000
20000
15000
10000
5000
0
Central Receiver
Dish/Stirling
Parabolic Trough
270
670
2160
8210
18360
1990
1995
2000
2005
2010

SOLAR THERMAL ELECTRIC



Enhanced Resource Plan

SOLAR THERMAL ELECTRIC TECHNOLOGY

CHALLENGES

- **Researchers to inform and convince the decisionmakers regarding near- and mid-term potential of solar thermal electric technology options.**

- **Manufacturers and other industry groups to effectively sell solar thermal electric systems for remote/off-grid and utility applications in both domestic and international markets.**

- **Collectively achieve switching from business-as-usual perception to an aggressive strategy that reflects solar thermal's real potential.**

COMMERCIAL APPLICATION ACTIVITIES: DEPARTMENT OF ENERGY SOLAR THERMAL ELECTRIC PROGRAM*

PAUL C. KLIMAS
SANDIA NATIONAL LABORATORIES

SAND91-0606A

1. Introduction

The Department of Energy Solar Thermal Electric Program has shifted its emphasis from research and development to a commercial applications-driven set of cooperative activities with significant industrial involvement in both planning and execution. The purpose of this shift is to accelerate the commercialization of solar thermal electric technology. By closely linking the program to private sector needs, specific activities will support early market penetration of the technology, and program resources will be more highly leveraged. Government/industry partnerships will produce teams uniquely qualified to accomplish this. The partnerships will combine the manufacturing, marketing, and management skills of industry with the solar-specific experience base and analytical and experimental capabilities of the laboratories.

Under this scenario, the program is divided into two main categories: Commercial Applications and Technology Development. Commercial Applications activities determine the overall direction of the program. Technology Development efforts in the concentrator and power conversion tasks support the Commercial Applications task. Relative to earlier years, technology development focuses on nearer timeframes, and far-term research plays a reduced, but continuing, role. The presentation by R. B. Diver in this volume describes this program element. Following is a brief description of the program's Commercial Applications efforts.

2. Utility-Scale Central Receiver System

A presentation entitled "Today's Central Receiver Power Plant Technology" has been made to a number of public utility commissions, industry, utilities and state energy offices in the sun-belt states. The goal of these presentations is to insure utilities consider central receiver power plants in their future plans. The presentation highlights the unique advantages of central receivers: 1) they will produce the lowest cost electricity of any utility-scale solar power plant, 2) they have practical energy storage for dispatchability and high capacity factors--without fossil fuels, and 3) they are environmentally benign. The emphasis of this presentation is on today's central receiver, which uses glass-mirror heliostats and a receiver with salt flowing in tubes. The central message of the presentation is that the technological risk is low and, with today's technology, central receivers are economic, reliable, and ready for commercialization. The presentation also summarizes the plans for the final steps toward commercial central receiver power plants, and enlists support from the utilities in taking these final steps.

3. Dish/Stirling Joint Venture

The objective of the Dish/Stirling Joint Venture is to form one or more industry, user and government consortia which will then begin efforts to field economically competitive prototype Dish/Stirling solar electric systems for remote markets within the next three years. A request for quotation (RFQ) structured using private sector input provided in response to a formal request for information was released in October 1990. Four qualifying proposals were received and evaluated by a technical team consisting of staff members from Sandia, SERI, and NASA. Sandia procurement officials are currently reviewing the results of the evaluation. The quality of the RFQ responses is such that we would expect this joint venture to be successful.

4. Parabolic Trough Cooperative Activity

The program is currently negotiating the beginning of what we hope will be a multi-year cooperative effort with LUZ Engineering Corporation to reduce operation and maintenance (O&M) costs for Solar Electric Generating System (SEGS) power plants. In the first phase of this effort, research and development will be identified that will lead to O&M cost reductions. Currently these expenses account for a significant portion of the SEGS electricity costs. Reductions in O&M costs would enhance the marketability, further development, and widespread use of SEGS technology, as well as other solar power technologies currently being developed by the program. An example of a technology that would benefit is solar central receivers. Central receiver power plants have many of the same subsystems contained within a SEGS power plant and the O&M of these subsystems would be similar.

5. Design Assistance

The Solar Thermal Design Assistance Center accelerates the use of solar thermal systems through cooperative efforts with private industry, by assisting and educating potential users, and by supporting industry and users in the selection, design, characterization, and demonstration of promising solar thermal systems. The center is growing. It typically receives 50 inquiries per month regarding solar thermal technology. Specific cooperative projects are not strictly limited to electric systems. Non-electric projects are often appropriate as they may be viewed as advancing component or subsystem technologies which are part of solar thermal electric systems. Refer to the pesentation in this volume by D. F. Menicucci for details on the Solar Thermal Design Assistance Center.

6. Summary

The Department of Energy's Solar Thermal Electric Program has become more oriented toward commercial applications. This orientation will accelerate the deployment of solar thermal electric technology.

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*This work is supported by the Department of Energy under contract DE-AC04-76DP00789.

COMMERCIAL APPLICATION ACTIVITIES:
DEPARTMENT OF ENERGY SOLAR THERMAL ELECTRIC PROGRAM

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SOLTECH 91
BURLINGAME, CALIFORNIA
MARCH 25 - 28, 1991

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PROGRAM EMPHASIS HAS SHIFTED FROM RESEARCH AND DEVELOPMENT TO A COMMERCIAL APPLICATIONS DRIVEN SET OF COOPERATIVE ACTIVITIES WITH HEAVY PRIVATE SECTOR INVOLVEMENT IN BOTH PLANNING AND EXECUTION

- PRODUCES UNIQUELY QUALIFIED TEAMS
- SUPPORTS EARLIER MARKET PENETRATION OF TECHNOLOGY
- RESOURCES ARE MORE HIGHLY LEVERAGED

PCK-2
3/26/91

FY91 SOLAR THERMAL ELECTRIC PROGRAM

I. COMMERCIAL APPLICATIONS

A. CENTRAL RECEIVER COOPERATIVE PROJECT

B. DISH/ENGINE COOPERATIVE PROJECTS

C. PARABOLIC TROUGH COOPERATIVE PROJECTS

D. DESIGN ASSISTANCE

II. TECHNOLOGY DEVELOPMENT

A. CONCENTRATOR TECHNOLOGY

1. HELIOSTATS
2. PARABOLIC DISHES
3. OPTICAL MATERIALS

B. POWER CONVERSION

1. CENTRAL RECEIVER TECHNOLOGY
2. DISH RECEIVER TECHNOLOGY
3. DISH CONVERTER SOLARIZATION TECHNOLOGY

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CENTRAL RECEIVER COOPERATIVE PROJECTS

OBJECTIVES: DEVELOP AND SUPPORT AN IMPLEMENTATION PLAN FOR A UTILITY-SCALE SOLAR CENTRAL RECEIVER ELECTRICITY GENERATING FACILITY.

APPROACH:

- PREPARE AND MAKE A TECHNICAL PRESENTATION TO A REVIEW COMMITTEE WHOSE MEMBERS INCLUDE PUBLIC UTILITIES AND INDUSTRIAL CONCERNS FAMILIAR WITH SOLAR ELECTRIC TECHNOLOGY.
- MAKE CONTACT WITH CANDIDATE ORGANIZATIONS (UTILITIES, IPPs, PUCs, STATE ENERGY COMMISSIONS, ETC.) AND ESTABLISH INTEREST LEVEL REGARDING A VISIT BY THE LABORATORIES.
- UPDATE TECHNICAL PRESENTATION REFLECTING INPUT FROM THE REVIEW COMMITTEE AND CONTACTS WITH CANDIDATE ORGANIZATIONS.
- MAKE PRESENTATIONS TO THE MOST STRONGLY INTERESTED ORGANIZATIONS CONCLUDING WITH DESCRIPTIONS OF CURRENTLY PLANNED CENTRAL RECEIVER JOINT VENTURE PROJECTS.
- ENTER INTO COST-SHARED AGREEMENTS WITH INDUSTRY TO SUPPORT SITE-SPECIFIC EVALUATION OR DESIGN ACTIVITIES FOR A UTILITY SCALE DEMONSTRATION.

PCK-3A
3/26/91

"TODAY'S CENTRAL RECEIVER POWER PLANT TECHNOLOGY"

PRESENTATION HIGHLIGHTS THE UNIQUE ADVANTAGES OF CENTRAL RECEIVERS:

1. THEY WILL PRODUCE THE LOWEST COST ELECTRICITY OF ANY UTILITY-SCALE SOLAR POWER PLANT,

2. THEY HAVE PRACTICAL ENERGY STORAGE FOR DISPATCHABILITY AND HIGH CAPACITY FACTORS--WITHOUT FOSSIL FUELS,

3. THEY ARE ENVIRONMENTALLY BENIGN.

EMPHASIS IS ON TODAY'S CENTRAL RECEIVER, I.E., GLASS-MIRROR HELIOSTATS AND A SALT-IN-TUBE RECEIVER, IMPLYING LOW TECHNOLOGICAL RISK.

SUMMARIZES CANDIDATE PLANS FOR COMMERCIALIZATION AND ENLISTS UTILITY SUPPORT AND PARTICIPATION.

PCK-3B
3/26/91

TO DATE:

COMPLETED REVIEW PHASE PRESENTATIONS (BECHTEL, PG&E, EPRI, CALIFORNIA ENERGY COMMISSION, LUZ)

BEGAN PRESENTATIONS TO INTERESTED POTENTIAL PLAYERS IN A UTILITY-SCALE DEMONSTRATION. INCLUDED WERE:

- ARIZONA CORPORATION COMMISSION
- ARIZONA PUBLIC SERVICE
- BUREAU OF RECLAMATION
- CITY OF AUSTIN UTILITY
- GOVERNOR'S ENERGY MANAGEMENT COUNCIL (TEXAS)
- HADSON INCORPORATED
- LOS ANGELES DEPARTMENT OF POWER & WATER
- LOWER COLORADO RIVER AUTHORITY
- LUZ INTERNATIONAL
- NEVADA POWER
- NEVADA PUBLIC UTILITY COMMISSION
- SACRAMENTO MUNICIPAL UTILITY DISTRICT
- SALT RIVER PROJECT
- SAN DIEGO GAS & ELECTRIC
- SIERRA PACIFIC
- SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT
- SOUTHERN CALIFORNIA EDISON
- TEXAS PUBLIC UTILITY COMMISSION
- TEXAS UTILITIES
- TUCSON GAS & ELECTRIC
- WESTERN AREA POWER AUTHORITY

EARLY RESPONSE SUMMARY:

- POSITIVELY RECEIVED, GENERATING MUCH FOLLOW-ON DISCUSSION

- GENERALLY NEW INFORMATION TO MOST ATTENDEES

- MUCH INTEREST IN FORMING A UTILITY STEERING COMMITTEE

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3/26/91

THE DISH/STIRLING JOINT VENTURE SEEKS TO FORM INDUSTRY/USER/GOVERNMENT CONSORTIA TO FIELD ECONOMICALLY COMPETITIVE DISH/STIRLING SOLAR ELECTRIC SYSTEMS FOR REMOTE APPLICATIONS WITHIN THREE YEARS.

- REQUEST FOR QUOTATION STRUCTURED USING INDUSTRIAL INPUT
- FOUR QUALIFYING PROPOSALS RECEIVED
- RESULTS OF TECHNICAL EVALUATION GIVEN TO SANDIA PROCUREMENT OFFICIALS

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PARABOLIC TROUGH COOPERATIVE PROJECTS

OBJECTIVE: WORK CLOSELY WITH INDUSTRY TO REDUCE THE COST ASSOCIATED WITH OPERATING AND MAINTAINING PARABOLIC TROUGH BASED SOLAR ELECTRIC GENERATING PLANTS THROUGH RESEARCH AND DEVELOPMENT BASED ON THE EXTENSIVE OPERATING EXPERIENCE OF LUZ ENGINEERING CORPORATION.

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OPERATION AND MAINTENANCE (O&M) COSTS ACCOUNT FOR A SIGNIFICANT PORTION OF ELECTRICITY COSTS IN SEGS PLANTS

GOAL OF THIS PLANNED MULTI-YEAR COST-SHARED EFFORT (50/50) IS TO REDUCE O&M COSTS BY 50% THROUGH DESIGN ENHANCEMENTS AND CHANGES IN OPERATING PROCEDURES AFFECTING THE

1. SOLAR FIELD

2. BALANCE OF PLANT

3. ENTIRE PLANT

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3/21/91

AREAS WHERE PROGRAM CAPABILITIES ARE EXPECTED TO CONTRIBUTE:

- CONTROLS
- MECHANICAL DESIGN
- PREVENTATIVE MAINTENANCE, INCLUDING ADVANCED DIAGNOSTICS
- RELIABILITY ANALYSIS
- OVERHAUL FREQUENCY DETERMINATION
- SYSTEMS ANALYSIS

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DESIGN ASSISTANCE

OBJECTIVE: ACCELERATE THE USE OF SOLAR THERMAL SYSTEMS THROUGH COOPERATIVE EFFORTS WITH PRIVATE INDUSTRY, BY ASSISTING AND EDUCATING POTENTIAL USERS, AND BY SUPPORTING INDUSTRY AND USERS IN THE SELECTION, DESIGN, CHARACTERIZATION, AND DEMONSTRATION OF PROMISING SOLAR THERMAL SYSTEMS.

ACTIVITIES: RECENT PROGRAM DESIGN ASSISTANCE/TECHNOLOGY TRANSFER ACTIVITIES INCLUDE:

- SANDIA AND SERI SUPPORT THE CUMMINS POWER GENERATION 5KW DISH/STIRLING SYSTEM.
- PUBLIC SERVICE OF COLORADO FT. ST. VRAIN NUCLEAR POWER PLANT: DISCUSSIONS/INFORMATION EXCHANGE REGARDING PARTIAL SOLAR REPOWERING.

DESIGN ASSISTANCE (cont'd)

ACTIVITIES: (cont'd)

- UNITED SOLAR TECHNOLOGIES/INDUSTRIAL SOLAR TECHNOLOGY PROCESS HEAT SYSTEM OPERATIONAL AT TEHACHAPI, CALIFORNIA.
- CONSTRUCTION WAS BEGUN ON SOLAR PROCESS WATER SYSTEM AT LBJ HOSPITAL, AMERICAN SAMOA.
- GOULD EVALUATION OF STDAC-SUPPLIED FLEXHOSES COMPLETED.
- ASSISTANCE CONTINUES TO CALIFORNIA ENERGY COMMISSION FOR SOLAR THERMAL WATER HEATING AT TWO CORRECTIONAL FACILITIES.
- CONSULTATION PROVIDED TO PLAINS ELECTRIC.
- PHOTOVOLTAIC CENTRAL RECEIVER TESTING DISCUSSED WITH SUNPOWER CORPORATION.
- 3M BEGINS FRESNEL LENS IPH COLLECTOR SYSTEM PROJECT.

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DESIGN ASSISTANCE (Concluded)

A NUMBER OF INFORMATIONAL ACTIVITIES TOOK PLACE:

- STDAC CONTRIBUTED TO SOLTECH PLANNING.
- EDUCATIONAL OUTREACH MATERIAL PROOF-TESTED.
- STDAC PARTICIPATED IN INTERREGIONAL TRAINING COURSE SPONSORED BY THE INTERNATIONAL ATOMIC ENERGY AGENCY.
- PLANNING WAS BEGUN FOR RENEWABLES WORKSHOP IN GUAM.
- STDAC PARTICIPATED IN DEPARTMENT OF DEFENSE ENERGY AWARENESS MONTH ACTIVITIES.

IN ADDITION, THE STDAC RESPONDS TO ~ 50 CONTACTS (TELEPHONE AND MAIL INQUIRIES) MONTHLY.

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3/26/91

SUMMARY:

THE DOE PROGRAM HAS BECOME A COMMERCIAL APPLICATIONS-DRIVEN SET OF ACTIVITIES INTENDED TO ACCELERATE THE DEPLOYMENT OF SOLAR THERMAL ELECTRIC TECHNOLOGY.

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3/26/91

SOLAR THERMAL ELECTRIC PROGRAM*
POWER CONVERSION TECHNOLOGY DEVELOPMENT

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Abstract

Solar Thermal Electric Technology has made significant progress over the past 15 years. Central receiver technology was successfully demonstrated at the Solar One power plant where during the last year of power production over 95% availability was demonstrated. The world's record for solar-to-electric conversion efficiency is currently held by the Advanco parabolic dish-Stirling system. Over 350 megawatts of generating capacity from LUZ International parabolic trough systems is operational today in California. The near-term evolution of these technologies holds great promise for pandemic application of solar thermal electric systems.

The DOE Solar Thermal Electric Program has continued to narrow the focus of its efforts. Systems integration and component development activities are being concentrated in those areas where near-term commercialization appears most likely. As cooperative ventures with industry become an increasingly important strategy, technology development priorities are strongly influenced by industry. The role of the national laboratories is to conduct basic research and development in key technical areas to support the direction suggested by industry and the marketplace.

Systems based on distributed receiver technology are well on their way to commercialization. In an ambitious program, Cummins Engine Company (CEC) was able to successfully demonstrate the operation of a 4-kW_e system using a stretched-membrane multi-faceted concentrator (LaJet), a sintered-metal wick sodium heat-pipe reflux receiver (Thermacore), and free-piston Stirling engine converter modules (Sunpower). Sandia National Laboratories (SNL) was pleased to have been an active contributor to this effort. On-sun testing of a full-scale (75 kW_t) proof-of-concept reflux pool-boiler receiver was completed at SNL and design of a next-generation design was initiated. Plans call for mating a reflux solar receiver based on either the SNL next-generation pool-boiler design or a screen-wick heat-pipe receiver under development by SNL and Stirling Thermal Motors (STM) to a STM4-120 kinematic Stirling engine for on-sun testing at SNL. Tools, both analytical and empirical, for characterizing flux distributions, analyzing performance, and for designing and testing heat-pipe receivers of varying wick constructions have been used to support the SNL development efforts and the efforts of several commercial developers of dish-Stirling systems.

Dynamometer testing of the STM4-120 Stirling engine has been under way for the past two years at SNL. Total testing time (182 hours) has been less than expected, but overall experience with the engine continues to be positive. The STM4-120 addresses traditional Stirling reliability issues

by employing heat-pipe energy input (versus direct insolation), hydraulically actuated swashplate control (instead of working fluid exchange) and a crankcase pressurized to cycle mean pressure (to reduce seal requirements). Measured engine output powers and efficiencies agree closely with theoretical predictions. The difficulties to date have been associated with the gas-fired sodium heat pipes. Lessons learned on gas-fired heat pipes will be applied to hybridization (combining solar energy input with a fossil fuel such as natural gas) which is the next major step in dish-Stirling solar receiver development.

Design of two 25-kW_e free-piston Stirling engine (FPSE) systems continues under technical management by NASA Lewis Research Center. The Stirling Technologies Company (STC) design features a hydraulic-output free-piston Stirling engine and a reflux pool-boiler receiver. The STC detailed design review was completed in March, 1991. Westinghouse has provided technical support during the design and will continue to support STC during the fabrication portion of this program. The Cummins design utilizes a Sunpower FPSE with a linear alternator to provide electrical output directly to the grid and a sintered-powder wick reflux heat-pipe receiver. The Cummins preliminary design review is scheduled for April, 1991. Indications are that the DOE cost, performance, and reliability goals can be met with either of these designs.

Central receiver technology development, because of high total system capital costs, has been directed at components and subsystems. The direct absorption receiver 3-MW_t panel research experiment, following a water-flow checkout phase, completed low-power molten-salt tests with encouraging results. Testing of large-scale molten salt pumps and valves was also completed, with over 6700 operational hours having been accumulated on the high-temperature (565°C) molten salt transport loop. Over 2400 hours were completed on the higher pressure cold loop. Knowledge regarding packing materials, pump construction, and loop fabrication techniques has been documented. With the completion of molten salt pump and valve testing, all of the technical prerequisites to construct a large-scale (>30 MW_e) central receiver power plant have been completed. In accordance with the new strategy, efforts have been directed towards building a DOE/utility/industry consortium to take this technology to the next step -- a large scale demonstration.

By focusing Sandia's hardware development activities, entering into formal cooperative ventures with industry, providing flexible quick-response design assistance, and joining in selected international agreements, we believe that DOE can contribute to significant marketplace penetration of U.S. solar thermal electric technology.

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* This work is supported by the Department of Energy under contract DE-AC04-76DP00789.

SOLAR THERMAL ELECTRIC PROGRAM
POWER CONVERSION TECHNOLOGY DEVELOPMENT

R. B. Diver

Solar Thermal Electric Technology Division
Sandia National Laboratories

March 26, 1991

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THE DOE SOLAR THERMAL ELECTRIC PROGRAM CAN POINT TO SEVERAL MAJOR SUCCESSES

- HIGH RELIABILITY OPERATION OF THE SOLAR ONE CENTRAL RECEIVER POWER PLANT (OVER 95% AVAILABILITY IN LAST YEAR OF OPERATION)

- OVER 350 MW_E OF COMMERCIAL GENERATING CAPACITY BASED ON DOE-DEVELOPED TROUGH TECHNOLOGY (LUZ, IST)

- ESTABLISHMENT OF WORLD'S RECORD SOLAR-TO-ELECTRICITY CONVERSION EFFICIENCY (29.4% NET, ADVANCO)

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SANDIA IS ATTEMPTING TO BUILD ON THESE SUCCESSES BY ESTABLISHING MORE AND CLOSER RELATIONSHIPS WITH INDUSTRY THROUGH:

- DESIGN ASSISTANCE CENTER ACTIVITIES
- COOPERATIVE JOINT VENTURE PROGRAMS
- REDIRECTING CORE TECHNOLOGY DEVELOPMENT TO SUPPORT INDUSTRY
- CONTINUALLY EVALUATING THE RELEVANCE OF OUR ON-GOING TECHNOLOGY DEVELOPMENT

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POWER CONVERSION TECHNOLOGY DEVELOPMENT

- REFLUX RECEIVERS
- STIRLING ENGINE SOLARIZATION
- CENTRAL RECEIVER TECHNOLOGY

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DISH/STIRLING INDUSTRY INVOLVEMENT

- STIRLING THERMAL MOTORS (ANN ARBOR, MI)
  - SANDIA CONTRACTS FOR REFLUX RECEIVER & ENGINE DEVELOPMENT
  - TEAMED WITH DETROIT DIESEL
- STIRLING TECHNOLOGY CO. (RICHLAND, WA)
  - COST SHARING WITH SANDIA & NASA TO DEVELOP A 25 kW_E SYSTEM
  - TEAMED WITH WESTINGHOUSE
- CUMMINS ENGINE CO. (COLUMBUS, IN)
  - COST SHARING WITH SANDIA & NASA TO DEVELOP A 25 kW_E SYSTEM
  - DEVELOPING A 5 kW_E SYSTEM WITH THEIR OWN RESOURCES

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CURRENT DISH/STIRLING TECHNOLOGY DEVELOPMENT

- REFLUX RECEIVERS
  - Reflux Heat-Pipe Receivers
  - Reflux Pool-Boiler Receivers
- STIRLING ENGINE SOLARIZATION
  - STM4-120 Kinematic Stirling Engine
  - Free-Piston Stirling Engines

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REFLUX SOLAR RECEIVER TECHNOLOGY

- ADAPTATION OF LIQUID METAL HEAT-PIPE AND POOL BOILING TECHNOLOGY TO SOLAR RECEIVERS
  - SPHERICAL ABSORBER TO EFFICIENTLY COLLECT SOLAR ENERGY
  - CONDENSER IS THE HEATER TUBES OF A STIRLING ENGINE
- LIQUID METAL IS PASSIVELY RECIRCULATED
  - GRAVITY (REFLUXING)
  - CAPILLARY FORCES IN A WICK
- INTERMEDIATE HEAT TRANSFER FLUID
  - ISOTHERMAL BEHAVIOR
  - HIGH FLUX CAPABILITY
  - INDEPENDENT OPTIMIZATION OF RECEIVER AND ENGINE
  - READILY HYBRIDIZED

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COMPLETED ON-SUN TESTING OF SANDIA POOL-BOILER RECEIVER

- DEMONSTRATED EFFICIENT OPERATION OVER AN EXTENSIVE RANGE OF SOLAR TRANSIENT CONDITIONS
  - STARTUP FROM AMBIENT (SODIUM PREHEATED TO >100oC)
  - SATISFACTORY RESPONSE TO CLOUD TRANSIENTS
  - STEADY STATE EFFICIENCY >90% AND ALL DAY EFFICIENCY APPROX. 89%.

- COMPLETED TESTS TO ASSESS DESIGN CRITERIA FOR POOL-BOILER RECEIVERS
  - ON-SUN X-RAY MEASUREMENTS TO ASSESS VOID FRACTIONS
  - ON-SUN INFRARED THERMOGRAPHY

- TESTING TERMINATED DUE TO FAILURE OF THE ABSORBER
  - APPROX. 50 HOURS OVER 605oC, HUNDREDS OF CLOUD TRANSIENTS

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REFLUX RECEIVER LIFE ASSESSMENT

- BENCH-SCALE POOL-BOILER DURABILITY TEST AT THERMACORE
- REFLUXING CAPSULE TESTS AT STIRLING TECHNOLOGY CO.
- MATERIALS CHARACTERIZATION AT SANDIA
- CUMMINS DURABILITY HEAT-PIPE TEST IN ABILENE, TEXAS

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STATUS OF THE STM KINEMATIC STIRLING ENGINE

- THE STM4-120 HAS OPERATED IN SNL'S ENGINE TEST FACILITY 182 HOURS WITH CYCLE PRESSURES UP TO 100 BAR (1450 PSI) AT 780°C AND 1800 RPM. SHAFT POWER OF 14.5 kW AND THERMAL EFFICIENCY OF 40% HAVE BEEN DEMONSTRATED.

- CYCLE PRESSURE IN ENGINE WILL BE INCREASED INCREMENTALLY TO 120 BAR (1760 PSI) FOR FULL POWER OF 25 kW. PERFORMANCE CHARACTERISTICS WILL CONTINUE TO BE GATHERED DURING FY91.

- A SECOND STM4-120 IS IN TEST AT STIRLING THERMAL MOTORS AND WILL BE DELIVERED TO SANDIA FOR ON-SUN TESTING.

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STATUS OF FREE-PISTON STIRLING ENGINE DEVELOPMENT ACTIVITIES (DOE/NASA/SNL)

- Cummins Power Generation w/Sunpower and Thermacore have completed preliminary design of their 25 kW_E Advanced Stirling Conversion Systems (ASCS). Design Review scheduled for April 1990.

- Stirling Technology Co. and Thermacore (STC) completing detailed design of their 25 kW_E ASCS. Design Review held in February 1991.

- Fabrication of the STC ASCS will begin soon.

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CENTRAL RECEIVER TECHNOLOGY DEVELOPMENT

- MOLTEN SALT PUMPS AND VALVES
- DIRECT ABSORPTION RECEIVER (DAR)
- MOLTEN SALT/AIR CENTRAL RECEIVER COMPARISON STUDIES
- VOLUMETRIC RECEIVERS

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3/91

MOLTEN NITRATE SALT DIRECT ABSORPTION RECEIVER

- HIGH SOLAR FLUX ABSORBED DIRECTLY IN A BLACKENED FLOWING MOLTEN SALT FILM

- DIRECT ABSORPTION RECEIVER ADVANTAGES

  - HIGH EFFICIENCY
  - LOW COST
  - SIMPLE & RELIABLE
  - NO TUBE LIFE CONSIDERATIONS

- POTENTIAL DIRECT ABSORPTION RECEIVER PROBLEMS

  - FLOW STABILITY
  - PANEL DEFORMATION
  - WIND
  - SALT BLACKENER STABILITY

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DIRECT ABSORPTION RECEIVER PANEL RESEARCH EXPERIMENT

- DEMONSTRATE ENGINEERING FEASIBILITY

- REALISTIC SCALE
  - 3 MW_T
  - 1 M WIDE X 6 M LONG PANEL
  - SALT INLET (285°C), SALT OUTLET (565°C)
  - FLOW RATE 120 GPM

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DIRECT ABSORPTION RECEIVER PANEL RESEARCH EXPERIMENT STATUS

- COMPLETED WATER FLOW TEST
  - VERIFIED INTERMEDIATE MANIFOLD OPERATION
  - MEASURED FILM THICKNESS
- SALT FLOW TEST
  - DEMONSTRATED SYSTEM OPERATION WITH SALT
  - OPTIMIZE INLET MANIFOLD
  - EVALUATED FLUID LOSS
  - LOW SOLAR FLUX TEST
- FULL POWER SOLAR TESTING DELAYED INDEFINITELY

MOLTEN SALT PUMP AND VALVE STATUS

HOT LOOP

- TOTAL OF 6700 HOURS OF OPERATION
- 4300 HOURS OF TROUBLE FREE PUMP OPERATION SINCE SHAFT REPLACED
- NEW VALVE PACKING MATERIAL WORKING SATISFACTORILY

COLD LOOP

- OVER 2400 HOURS OF OPERATION

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3/91

SUMMARY

- SOLAR THERMAL PROGRAM HAS A FOUNDATION OF SUCCESS
- SOLAR THERMAL POWER CONVERSION TECHNOLOGY DEVELOPMENT IS GUIDED BY INDUSTRY
  - JOINT VENTURE PROGRAM
  - DESIGN ASSISTANCE
- DISH/STIRLING IS CURRENTLY THE PRIMARY FOCUS OF TECHNOLOGY DEVELOPMENT

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3/91

THE DOE SOLAR THERMAL ELECTRIC PROGRAM CONCENTRATOR TECHNOLOGY PROJECT

SOLTECH91

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SAND 91-0570C

March 26, 1991

ABSTRACT

The Department of Energy's Solar Thermal Program Concentrator Technology Project comprises the development of concentrating solar collectors, heliostats and dishes, and the development of optical materials. Because the solar concentrator represents from 40 to 60% of the cost of a solar thermal electric system, the continued development of high-performance concentrators that cost less than current heliostats and dishes is very important to the commercial viability of these systems.

Heliostats are long-focal-length concentrators used in central receiver power systems to reflect the sun's energy onto a centrally located receiver. The receiver absorbs the thermal energy that is then used in a conventional power plant cycle to generate electrical power. Glass heliostat technology is commercially viable today. In the concentrator technology project, we are currently testing two large area heliostats, the SPECO 200 m^2 heliostat and the ATS 150 m^2 heliostat. We are also trying to reduce the cost of the heliostats through the development of stretched-membrane heliostats.

Stretched-membrane heliostats are made by attaching thin metal membranes to the two sides of a circular, metal ring. A slight vacuum in the plenum

between the two membranes is used to focus the heliostat. The optical surface is provided by a silver-acrylic film, ECP 305. The measured performance of prototype stretched-membrane heliostats is comparable to the glass heliostats and, because of their utilization of fewer, less expensive materials, the potential cost of stretched-membrane heliostats is substantially less than the glass heliostats. A prototype 100 m^2 commercial unit has been built and is currently being tested.

Parabolic dish concentrators are under development for use on dish-Stirling electric systems. The state-of-the-art dish is the McDAC/SCE faceted glass concentrator. Because of the success of stretched-membrane technology for heliostats, we also started the application of the technology to parabolic dish development. We are currently designing a near-term, faceted, stretched-membrane dish in whose development Science Applications International Corporation, Solar Kinetics Incorporated, WGAssociates, SERI, and Sandia are cooperating. This dish should be available for integration with a 25 kW_e Stirling engine in about 18 months. We are also developing a longer-term, single-element, stretched-membrane dish that holds promise for higher performance and reduced cost over both the glass and faceted SM concentrators.

Concentrator Technology

The third element of the Concentrator Technology Project is optical materials development. The current thrust of the program is the development of a low-cost, high-performance, silver-acrylic film. 3M's ECP 305, the current generation of this film, has demonstrated substantial improvement over previous films in its resistance to corrosion, longer life. An experimental film, developed at SERI, has promise for further improving the lifetime of the ECP 305. We are currently investigating solutions to the problem of separation between the silver and acrylic layers of the film in the presence of water, referred to as delamination or tunneling. Some potential solutions have been identified including: improved methods for cutting the film, edge taping with Tedlar tape, and "baking" of the laminated film-substrate structure. Because the film has a life somewhat shorter than the concentrator, we are also examining various approaches to making a replaceable film. This includes the use of a low-tack adhesive on the back of the film.

CONCENTRATOR TECHNOLOGY (C. Tyner)

Purpose: To establish the commercial readiness of concentrating solar collectors for solar thermal electric systems.

- Heliostat Development (D. Alpert, R. Houser)
- Parabolic Dish Development (T. Mancini, J. Grossman, W. Erdmann)
- Optical Materials Development (G. Jorgensen, P. Schissel, T. Wendelin)

CONCENTRATOR TECHNOLOGY (C. Tyner)

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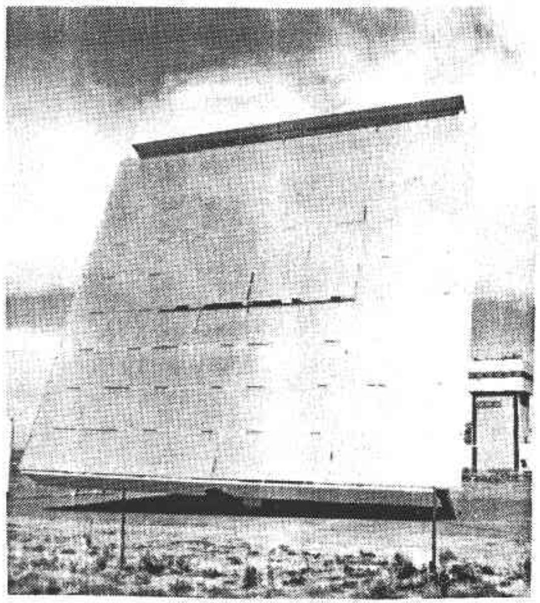
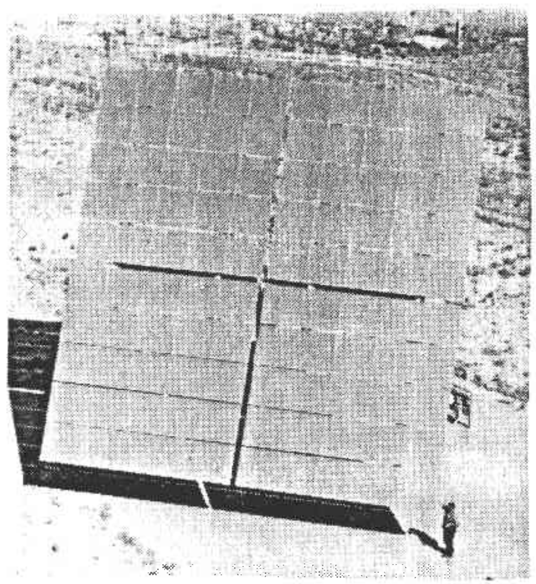
- **Parabolic Dish Development (T. Mancini, J. Grossman, W. Erdmann)**
- **Optical Materials Development (G. Jorgensen, P. Schissel, T. Wendelin)**

Concentrator Technology

- **Glass-Mirror Heliostats are ready for Central Receiver Power Plants.**



SPECO Heliostat
200 m2



ATS Heliostat
150 m2

Heliostat Testing

Low-Cost Drive
- **Heliostats**
- **Photovoltaics**
- **Dishes**

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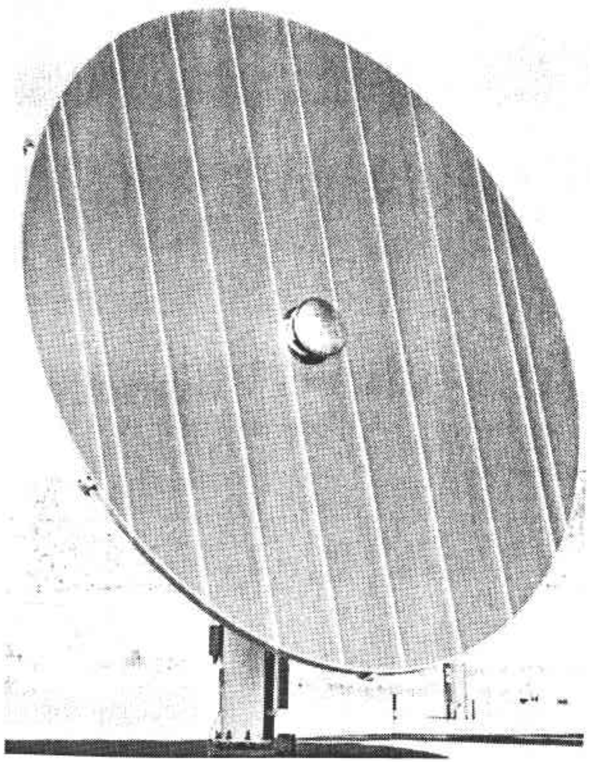
trm:SOLTECH91:3/26/91 3/13

Concentrator Technology

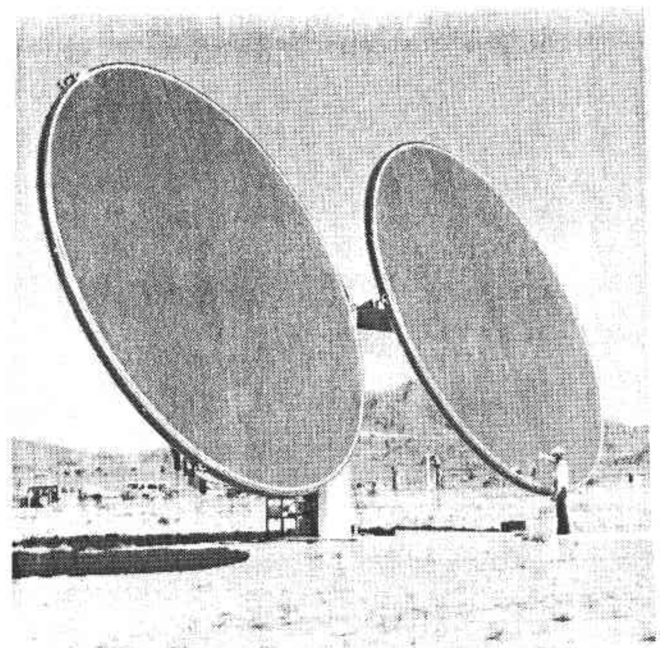
- **Stretched-Membrane Heliostats offer the potential for cost reductions.**



SKI Heliostat
(50 m2)

- Metal Membranes
- Membranes Welded to Ring
- Vacuum Focused
- Need Film Development

SAIC Heliostat
(100 m2)



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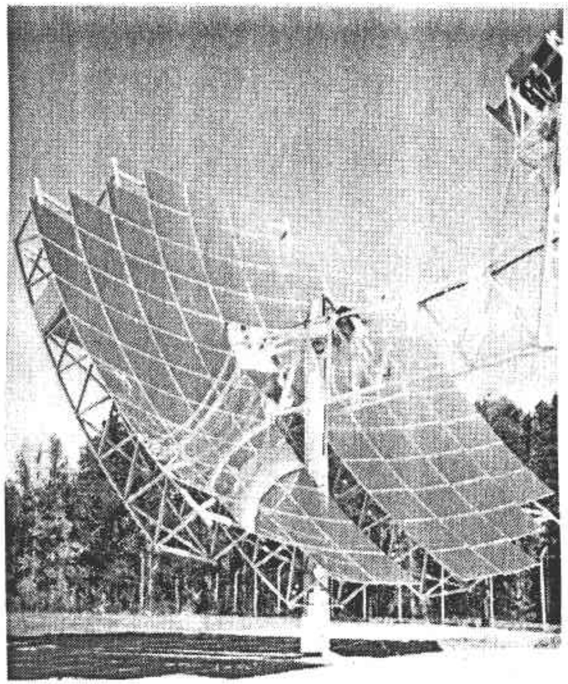
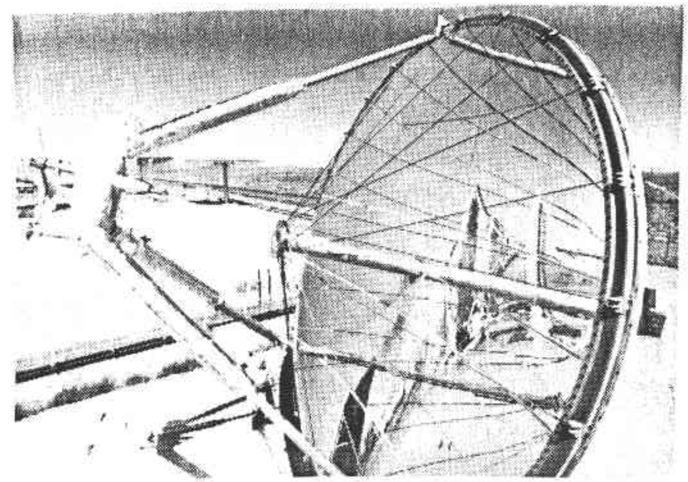
Concentrator Technology

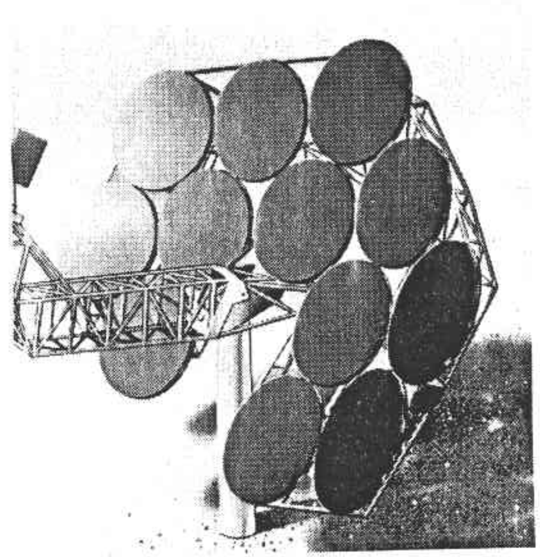
- **Parabolic Dish Development**



State-of-the-Art Glass-Metal Dish

Near-Term Faceted SM Dish





Future Single-Element Stretched-Membrane Dish

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Concentrator Technology

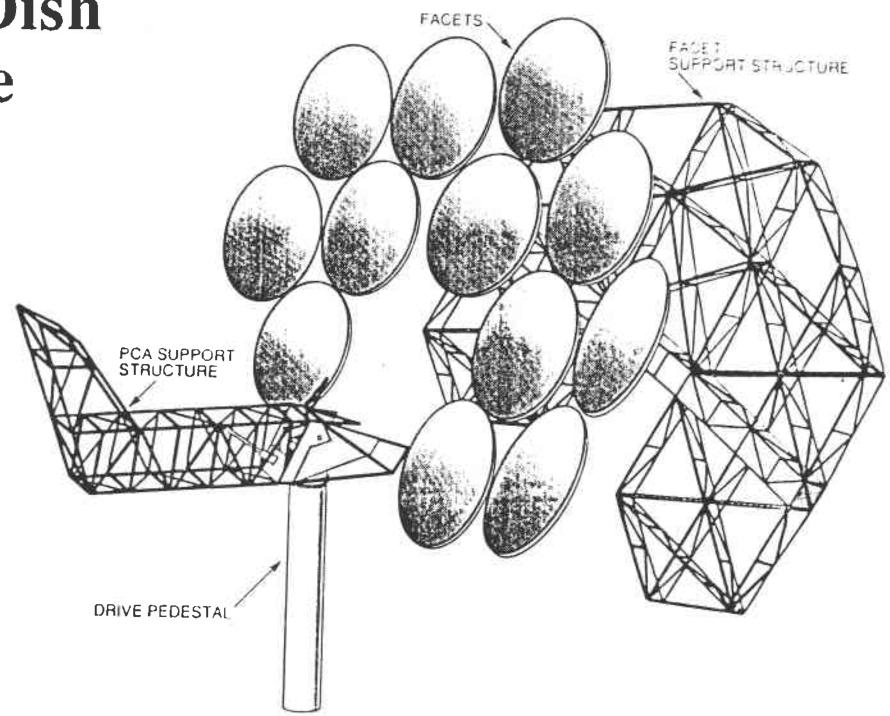
- **Faceted Stretched-Membrane Dish Development**

Near-Term (18 Months) Dish for 25 kW_e Stirling Engine

- 12 SM Facets
- Focal Length = 10.5 m
- Facet Diameter ~ 3.5 m
- Total Power ~ 75 kW_T
- Weight ~ 15.2 lbs/ft^2

Participants:

- SKI: Facets
- SAIC: Facets
- WGA: Structure
- SERI: Measurements
- SNL: Program Direction, Management, and Testing



Faceted Stretched-Membrane Dish

Sandia National Laboratories

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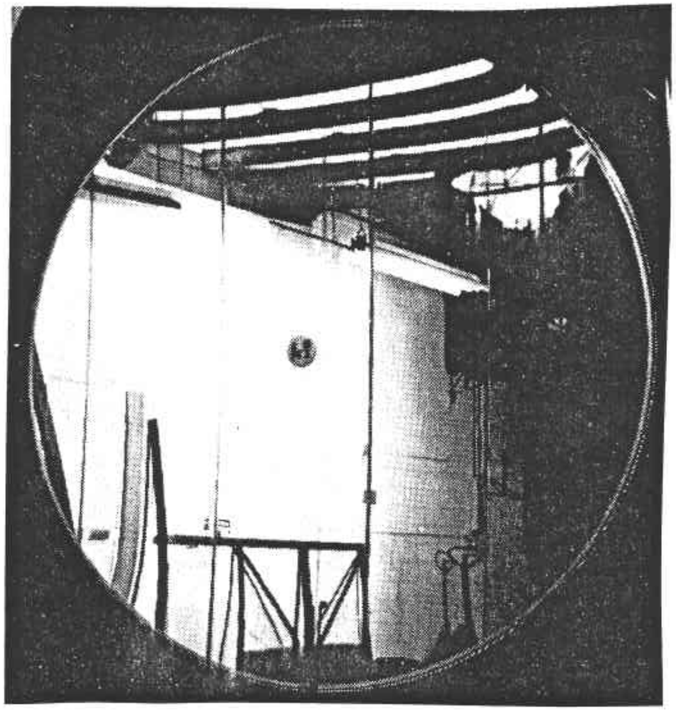
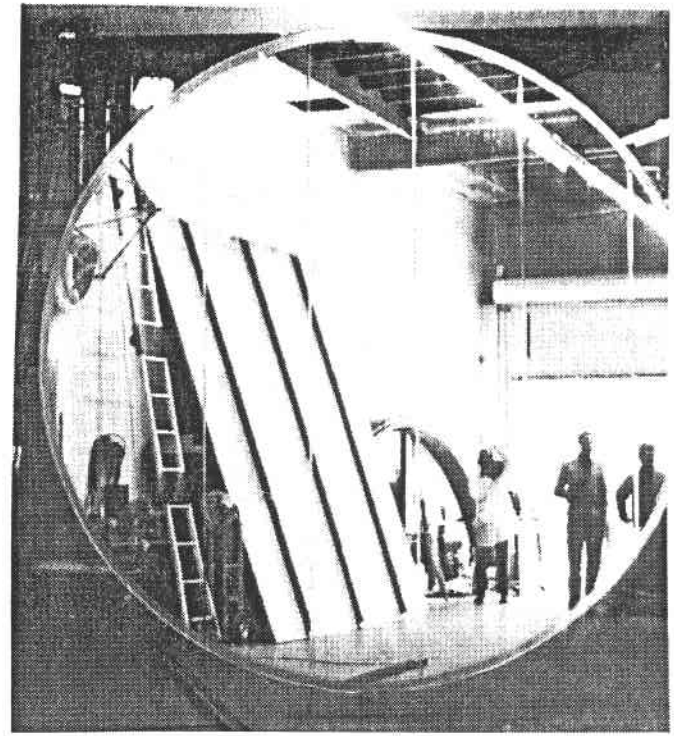
Concentrator Technology

- **Faceted Stretched-Membrane Dish facets.**





SKI Facet Design

- Slope Error ~ 1.2-1.5mr
- Peak Flux 798-1163 suns
- Facet Weight = 260 lbs.

SAIC Facet Design

- Slope Error ~ 2.5-2.6mr
- Peak Flux 359-425 suns
- Facet Weight = 291 lbs.

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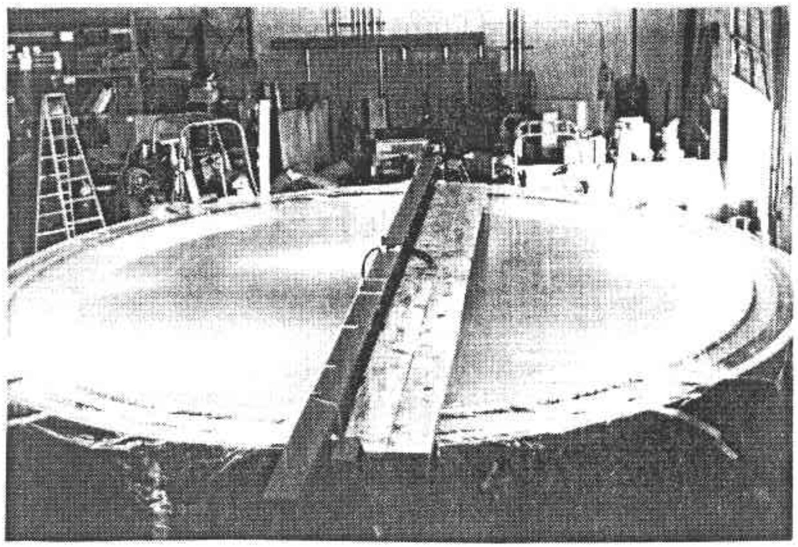
Concentrator Technology

- **SKI Single-Element Stretched-Membrane Dish.**

Unique Membrane Forming Technique



- Combination of uniform and nonuniform loading
- Established repeatability in small-scale tests
- Proceeded to design and build a 7-m diameter optical element

Membrane Forming

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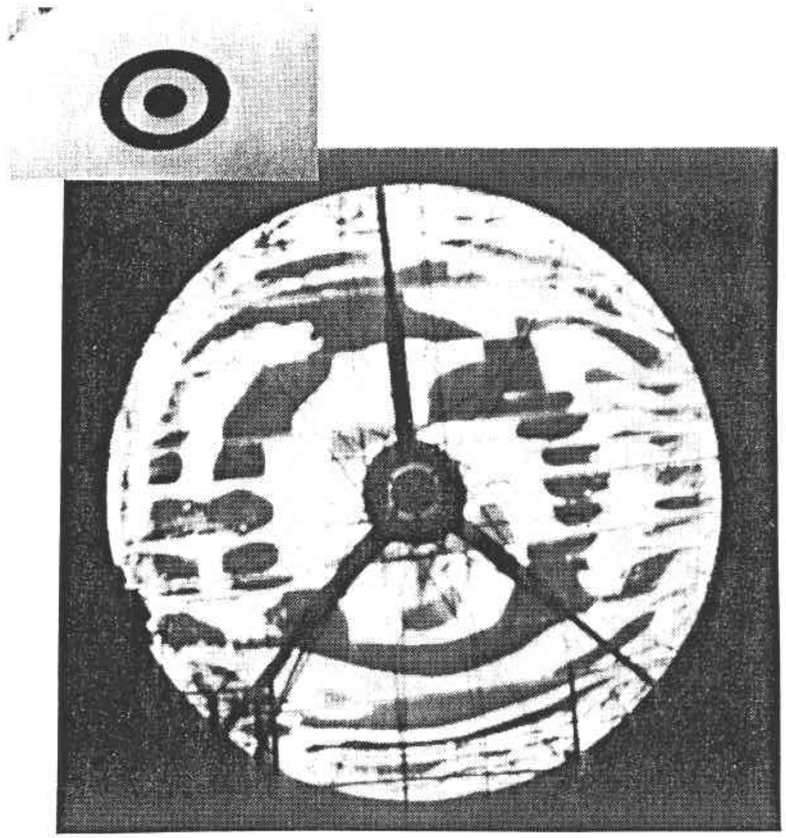
Concentrator Technology

- 7-Meter Diameter dish tested at Sandia.

Testing included:
- Reverse Imaging
- Video Flux Mapping
- Cold-Water-Cavity Calorimetry

Results showed:
- Peak Flux 5200 suns
- 21 kW_T Total Power in a 15 cm aperture
- Efficiency ~ 67%



Reverse Imaging

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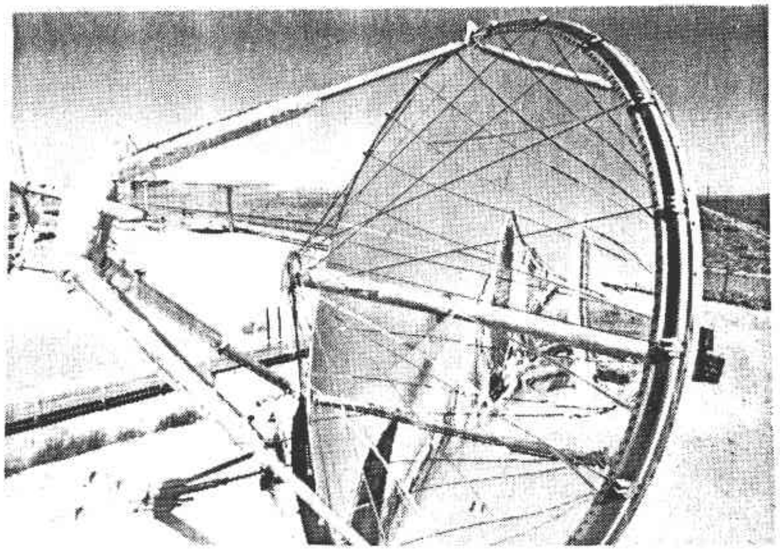
- **Single-Element Stretched-Membrane Dish.**



7-M Single-Element Stretched-Membrane Dish

Need a 75 kW_T dish for operation with a 25 kW_e Stirling engine

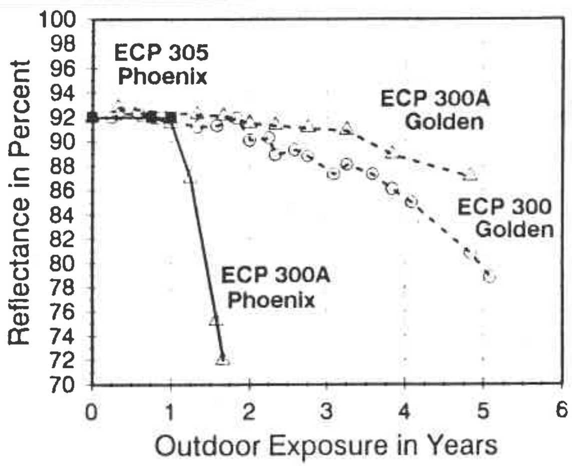
Completed the conceptual design of a full-scale dish

Started the detailed design of the full-scale stretched-membrane dish

Prototype ~ 30 Months

- **Optical Materials Development**

SOLAR REFLECTANCE OF SILVER FILMS: OUTDOOR TESTS

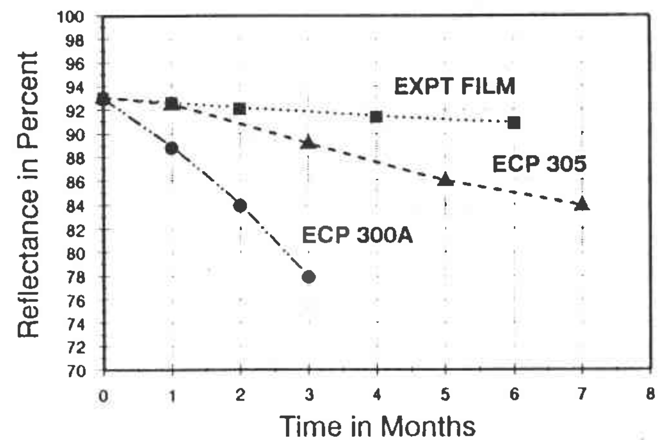


EXPT Film Promises Improvements over ECP 305

Silver-Acrylic Films

ECP 305 Demonstrates Improved Performance

WEATHER-OMETER TESTS OF SILVER FILMS



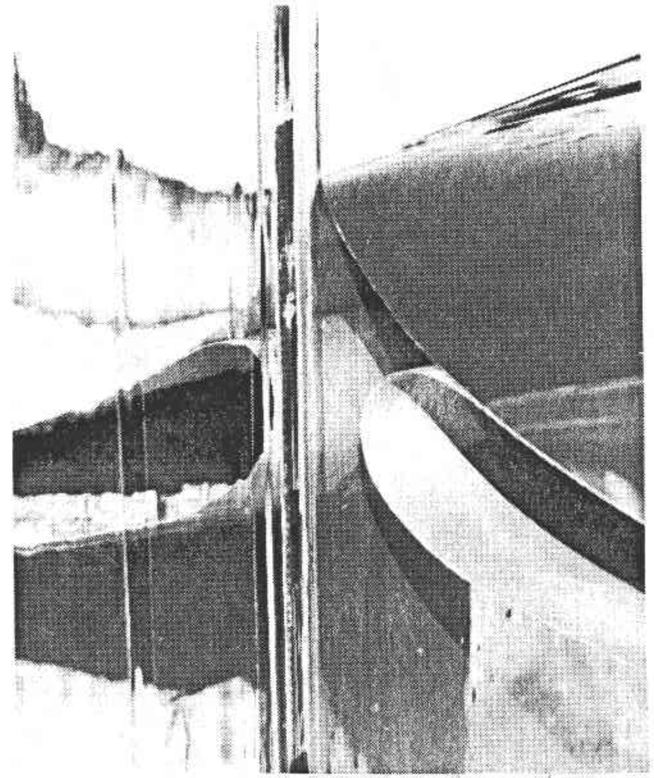
Concentrator Technology

- **Optical Materials Development**

- **Inhibition of Delamination at Silver-Acrylic Interface**
  - Heat Treatment of edges
  - Use of Tedlar Tape
  - "Baking" of Laminate

- **Replaceable Films**
  - "Post-It-Note" Adhesive

- **Soiling and Cleaning**



Replaceable Film

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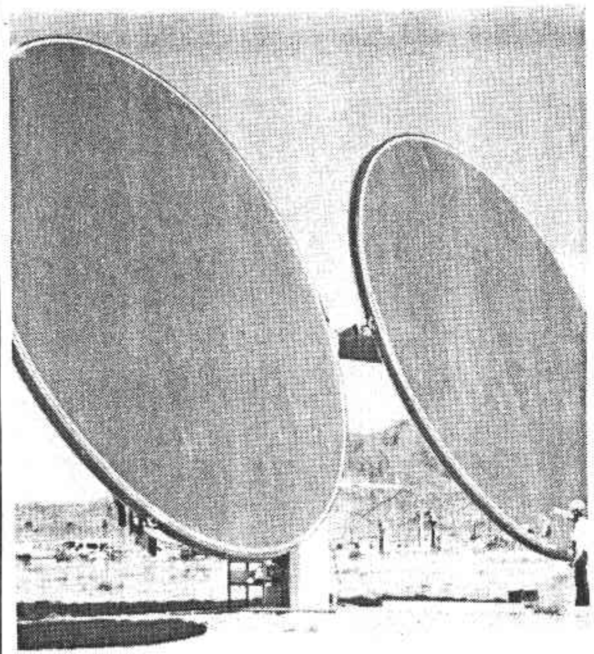
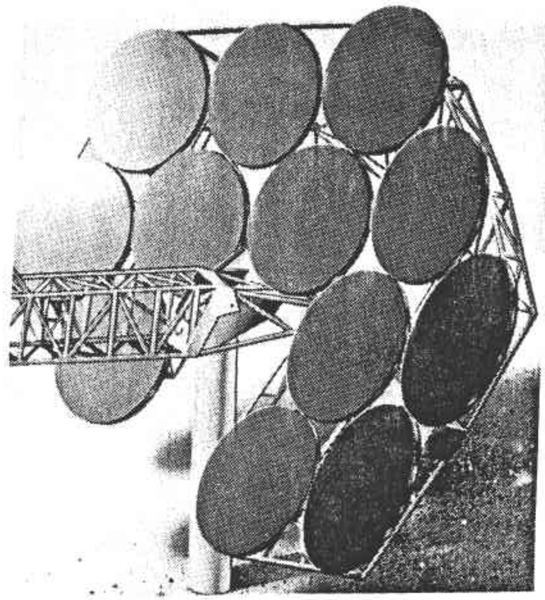
Concentrator Technology

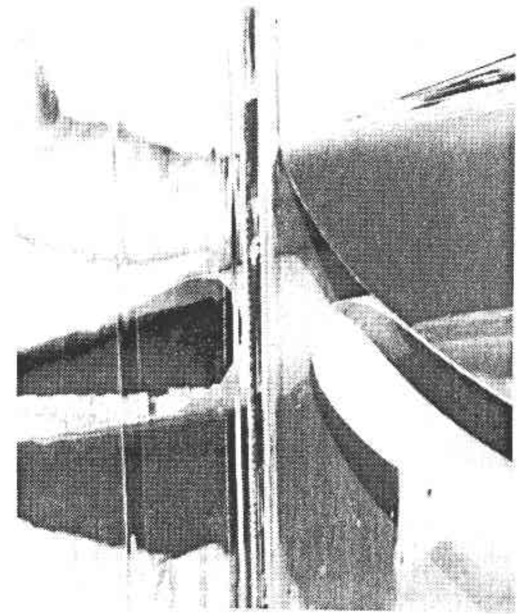
- **Summary of Concentrator Technology**



Heliostat Testing

Faceted and Single Element SM Dishes





Silver-Acrylic Film Development

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THE SOLAR THERMAL DESIGN ASSISTANCE CENTER -AN OVERVIEW OF ITS SUCCESSFUL TECHNOLOGY TRANSFER EFFORTS*

David Menicucci
Sandia National Laboratories

SAND91-0234A

The Solar Thermal Design Assistance Center at Sandia National Laboratories is a resource provided by the U.S. Department of Energy's Solar Thermal Program. Its major objectives are to accelerate the use of solar thermal systems through cooperative efforts with private industry, technology transfer activities, and direct technical assistance.

The Solar Thermal Design Assistance Center recently published a brochure outlining its operation. The text of this brochure exemplifies the tech-transfer publications the center distributes and outlines its activities. It is included here as a preview of the conference presentation:

Does a solar energy system make sense for you?

Maybe. Solar energy systems make sense when the savings from not having to buy fuel exceed the cost to install and maintain the system. Thus, in assessing whether solar energy is appropriate for a given use, it is important to have an accurate idea of how well a given solar system might perform and how much it will cost.

Who can help you decide?

Although the process of evaluating a possible solar application is not complex, it can be confusing to those who are not accustomed to the technology. For this reason the Department of Energy created the Solar Thermal Design Assistance Center to provide professional technical assistance in applying and/or developing solar thermal technology.

Located at Sandia National Laboratories, the center couples the technical expertise gained from over 15 years of research in solar thermal technology with the maturity and resources of a major national laboratory. The operation of the center is funded by the Department of Energy and its major objectives are to

- provide direct technical assistance to suppliers and users of solar thermal technologies;
- collaborate with development, testing, and evaluation of new and promising solar thermal technologies;

- write and distribute technical information about how solar thermal technology works, where it can be applied, and its potential benefits;
- transfer details of government-sponsored solar thermal technology developments by contributing to technical conferences, meetings, and journals.

What will these services cost?

These services are free through Sandia's technology transfer programs. Interested parties can obtain STDAC services through:

- Informal agreements, which are the easiest to form and often involve information exchanges between Sandia solar research engineers and an individual or organization. However, they provide no formal protection for proprietary information and/or the rights of ownership for technology for projects that may involve technology development.

- Semi-formal agreements that involve a written agreement between the two parties. Depending on the circumstances, this agreement can protect proprietary information, and set out the terms of joint development projects. They are often used when the project involves the application of existing technology and little new development.

- Formal agreements, which can be somewhat more time consuming to develop, but provide complete protection for all parties in a technology development effort. Most important, these agreements clearly define the rights of ownership for any new technology developed in a Sandia/private sector development effort. An example of this agreement is a Cooperative Research and Development Agreement between Sandia and a private party.

The conference presentation describes the center's activities in more detail. The structure and operation of the center are outlined, and examples are presented to show the type of assistance and services that are provided. The presentation at this conference features some of the most successful projects of recent years and discusses the center's plans for the future.

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*This work is supported by the Department of Energy under contract DE-AC04-76DP00789.

A Review of the Solar Thermal Design Assistance Center

David Menicucci
Sandia National Laboratories

THE STDAC'S PRINCIPAL MISSION

To promote and assist the commercialization of solar thermal technology

WHAT IS THE STDAC?

- It is a method of operating in which the laboratory staff's highest priority is to respond quickly and effectively to the needs of the solar community

- It involves a commitment of all levels of management, staff, and support personnel

SANDIA MANAGEMENT AND THE STDAC

1) Sandia's matrix organization allows appropriate personnel to assist as needed (e.g., PVDAC, technical specialists)

2) Sandia management guides but does not interfere with STDAC efforts

3) STDAC decisions are made at the lowest levels

THE SANDIA MANAGEMENT STRUCTURE PROMOTES:

- Timely and relevant responses to the customer (i.e., the solar community)
- Flexibility to meet new challenges
- Ability to grow and adapt to changing environment (e.g., collaboration with PVDAC and SERI)

MAJOR STDAC ACTIVITIES

1) Direct technical assistance

2) Education

3) Testing and evaluation

4) Joint-venture developments

WHAT IS THE FORM OF THE DIRECT TECHNICAL ASSISTANCE?

- Consulting with users about selecting and applying solar thermal technology
- Responding to questions and requests for information. (Over 500 requests were answered last year)
- Working with SEIA, CORECT, and industry to identify and develop new markets for solar thermal technology

EXAMPLES OF SOME OF THE STDAC'S CONSULTING EFFORTS

1) Tehachapi, CA Correctional Facility
2) Cummins Power Generation
3) Gould Electronics
4) LBJ Hospital in Samoa
5) San Luis Obispo Correctional Facility
6) Tonto National Forest
7) U.S. Federal Weatherization Assistance Program

WHAT CONSTITUTES THE STDAC'S EDUCATIONAL EFFORTS?

- Technical briefings about solar thermal technology to industry, utilities, energy managers, and other potential end users

- Educational videos that explain the fundamentals of solar thermal technology to elementary, mid-, and high-school students

- Documents and exhibits that inform about solar thermal technology

SELECTED EXAMPLES OF STDAC EDUCATIONAL EFFORTS OVER THE LAST YEAR

1) Central receiver "road show" has reached over 200 individuals within 50 companies

2) "Solar fundamentals" video along with classroom demonstration models are ready for release to the nation

3) STDAC/PVDAC exhibits have been displayed at about 10 major events reaching several thousand visitors

4) STDAC/PVDAC workshops have involved over 100 participants

5) Over 5,000 copies of STDAC publications have been released

SOME OF THE STDAC'S TESTING AND EVALUATION EFFORTS AT THE NSTTF

- Energy Concepts solar icemaker
- BSAR distiller
- Gould system component upgrades
- PVCR/PVDISH testing and evaluation
- Refinement of the SOLIPH computerized performance model

JOINT-VENTURE DEVELOPMENTS

A major joint-venture program to commercialize dish/Stirling systems is now underway

WHERE IS THE STDAC GOING?

1) Maintaining timely and relevant responsiveness to solar thermal community through direct assistance and educational activities

2) Expanding involvement with CORECT to increase potential applications for solar thermal technology in foreign markets

3) Increasing interaction with SEIA for industrial/solar project information throughout the world

4) Continuing to develop the STDAC as a national resource through collaborations with the PVDAC and SERI

SOLTECH91

Solar Industrial Program/Solar Thermal Electric Program Symposia

- Symposium No: 2
- Symposium Title: Current & Near-Term Solar Industrial Applications
- Date: Wednesday, March 27, 1991 • Time: 8:30 - Noon
- Chairperson(s): Richard Kelly (United Solar Technology)

Time Slots	Presentations	Proposed Speakers (Name/Affiliation)
8:30 - 8:45	Introduction	Session Chairperson
8:45 - 9:00	Changing Directions: New Proposed DOE Thrusts	Clifton Carwile (Department of Energy/Headquarters)
9:00 - 9:20	What Is Needed from DOE's Solar Heat Program -- An Industry View	Pascal DeLaquil (Bechtel)
9:20 - 9:40	Applications of Parabolic Trough Technology	Ken May Randy Gee (Industrial Solar Technology)
9:40 - 10:00	Isaac™ Solar Absorption Icemaker	Donald Erickson (Energy Concepts)
10:00 - 10:20	BREAK	

SOLTECH91

Solar Industrial Program/Solar Thermal Electric Program Symposia

- Symposium No: 2 (Concluded)
- Symposium Title: Current & Near-Term Solar Industrial Applications
- Date: Wednesday, March 27, 1991 • Time: 8:30 - Noon
- Chairperson(s): Richard Kelly (United Solar Technology)

Time Slots	Presentations	Proposed Speakers (Name/Affiliation)
10:20 - 10:40	Solar Heat Applications in California: Status and Prospects	Pramod Kulkarni (CA Energy Commission)
10:40 - 11:00	Gould's Solar Industrial Heat Process System: An Update on Its Performance and Plans for Upgrade	David Knipfer (Gould, Inc.)
11:00 - 11:20	Stretched Membrane Parabolic Trough System for Process Hot Water/Air Conditioning System	Allen Bronstein (Sun Steam)
11:20 - 11:40	Low and Medium Flat Plate Technology for Industrial Process Heating	Arthur Brooks (Sun Earth)
11:40 - Noon	Solar Heat Applications: Products and National/International Market Opportunities	Ken Sheinkopf (Solar Energy Industires Association)

CHANGING DIRECTIONS: NEW PROPOSED DOE THRUSTS

by Clifton Carwile
Department of Energy

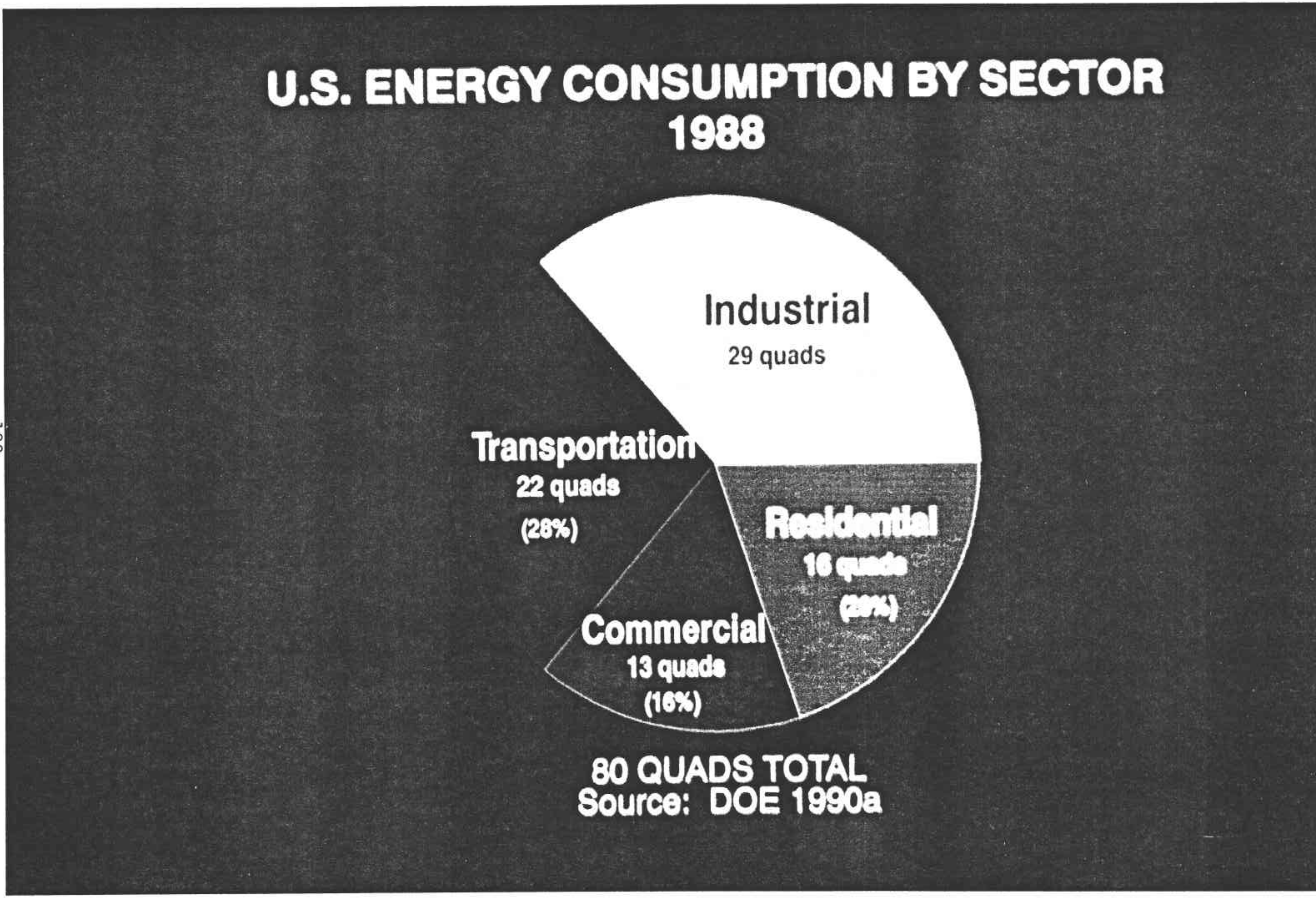
In the late 1970s and early 80s, there were 17 large, DOE sponsored, industrial process heat (IPH) demos built. In 1985, seven of the experiments were operating upon transfer to their owners. None of them are operating today and there is no industrial process heat industry, because of many negative factors including neglect, low energy prices and cogeneration. In the early demo programs, an aggressive push by government was not followed up with support during the critical product improvement period. And because it was part technology push, rather than simply market pull; the loss of continued government support and low energy prices were fatal to a promising new industry.

But solar IMP did not die completely. With the emphasis on developing a national energy strategy, along with heightened interest in energy supply because of the Persian Gulf crisis; a fresh look at solar IPH is appropriate. Accordingly, in the Fall of 1990, DOE and E.A. Mueller conduct a short study, using available information on solar technology and industrial energy use, on the potential of solar process heat in the industrial sector. One of the first things that became evident was that the databases were out of date and incomplete. We really don't know on a national basis what has been happening to energy use in the industrial sector although overall energy efficiency has improved significantly. There is also a reasonable match between the areas where solar is best and where industrial energy demand has increased the most.

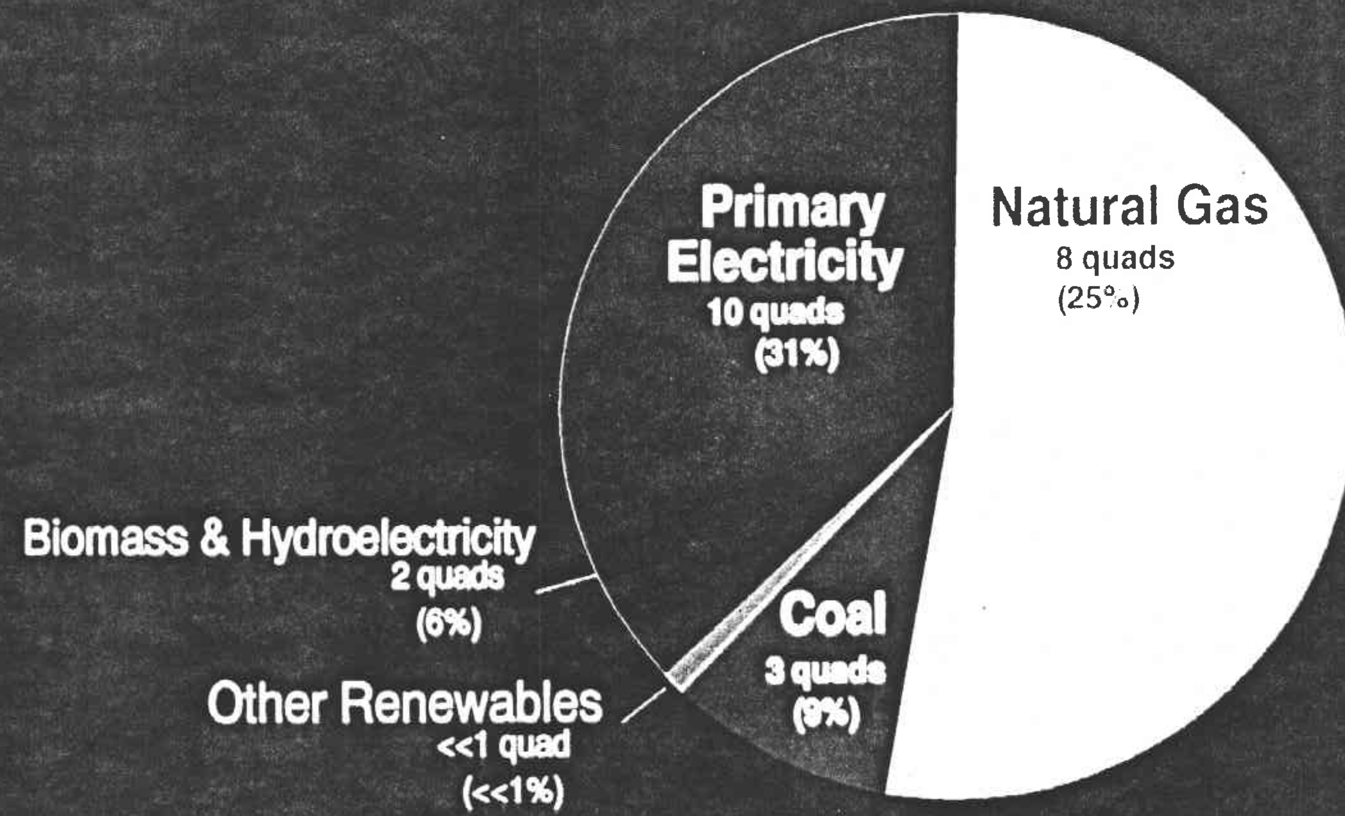
The results discussed here are from that initial study, completed in November, 1990. The primary conclusion is that there is a significant potential for solar IPH - as much as 5 Quads of thermal energy out of a projected total of 12.6 Quads for manufacturing activities alone in the industrial sector. But improvements in technology, or rather reductions in the cost of energy (even beyond that estimated for the United Solar installation at Tehachapi), will be required for significant penetration to occur by the year 2030. (Or rapidly rising energy prices). Otherwise, the penetration model predicts early introduction in niche markets, some growth, and finally a roll off. Hopefully, we learn from experience, but not the wrong things, and can structure an appropriate role for DOE in solar IPH. If you are looking for Quads. (and who isn't), the name of the game is parabolic troughs and dishes. Troughs are here and now for low and medium temperature process heat, but the higher temperature applications will require further development of dishes and receivers. For dishes, we are depending on the Solar Thermal Electric Program to continue and meet its planned developmental schedules. Other types of solar thermal technology such as flat plate collectors and CPC collectors also have a role in industrial process heat.

DOE sees a significant opportunity for solar IPH. It also appears that it won't just happen. Thus the question, is there an appropriate role for the Federal government and if so, what is it? There are a few examples of how DOE can help without being part of the problem or becoming the problem. The solar Thermal Design Assistance Center at Sandia, under Dave Menicucci, has been providing limited assistance to industry if and when industry comes and asks. With limited resources, Sandia has helped United Solar and Gould, provided engineering assistance to the LBJ Hospital refurbishment project on American Samoa, and provided support to the California Energy commission in developing an RFP for process heat systems for the California Department of Corrections. Institutional process heat applications like the Tehachapi Correctional Facility may be the early market niche for solar process heat. DOE will continue to react and provide assistance to clearly defined solar industry needs, limited only by our ability to get funds and the needs of the solar industry.

In addition there is a need for more studies and efforts directed toward improving the database on industrial energy use and the potential markets for solar IPH. Seminars and workshops also appear to be needed to acquaint potential users with the technology. DOE may also be effective in representing solar technology to state and local governments and other Federal agencies. The DOE will continue to work with the solar thermal industry and potential users to define additional areas of cooperation including cost-shared research and development and joint projects where they can be justified.

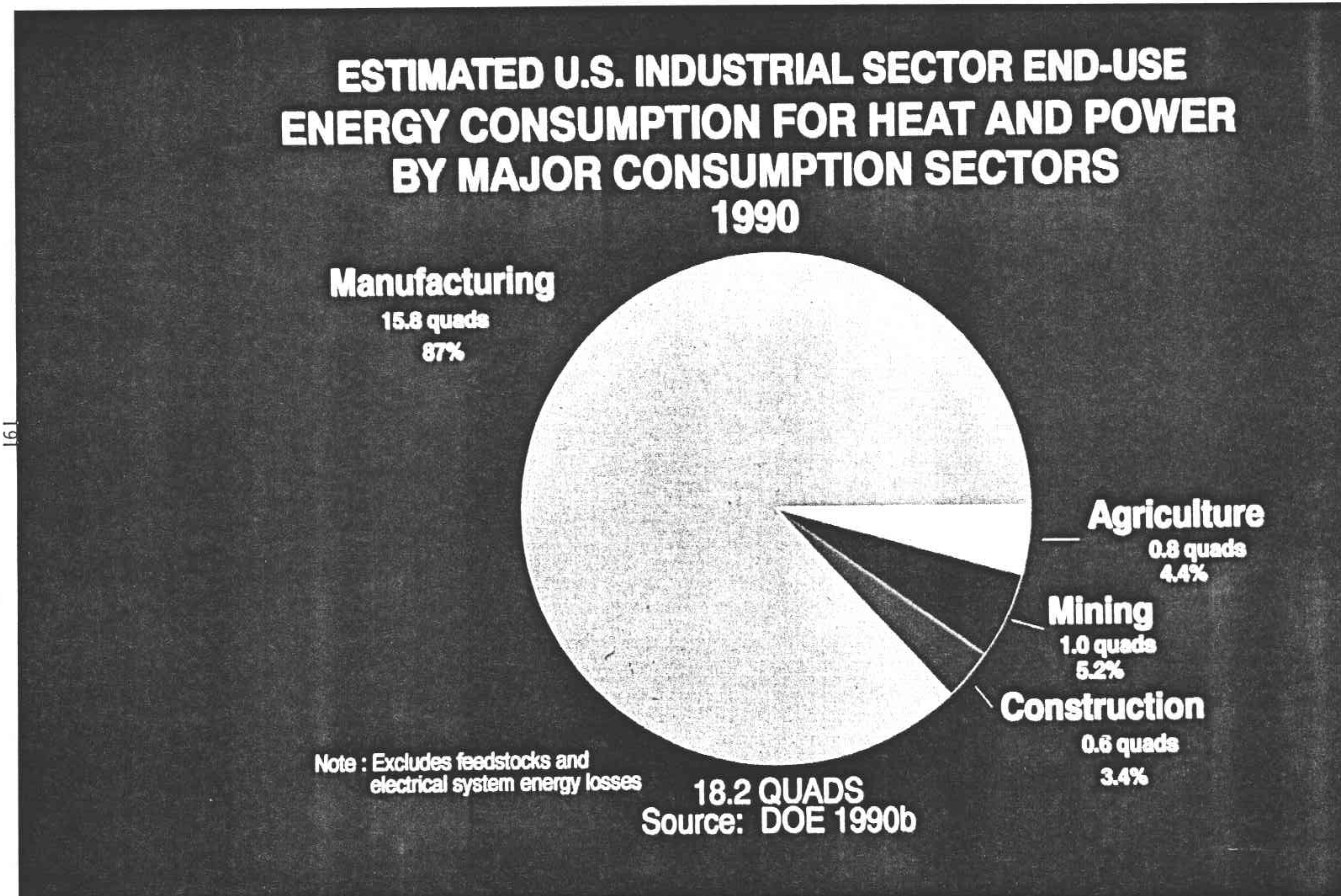

U.S. ENERGY CONSUMPTION BY SECTOR
1988
Industrial
29 quads
Transportation
22 quads
(28%)
Residential
16 quads
Commercial
13 quads
(16%)
80 QUADS TOTAL
Source: DOE 1990a

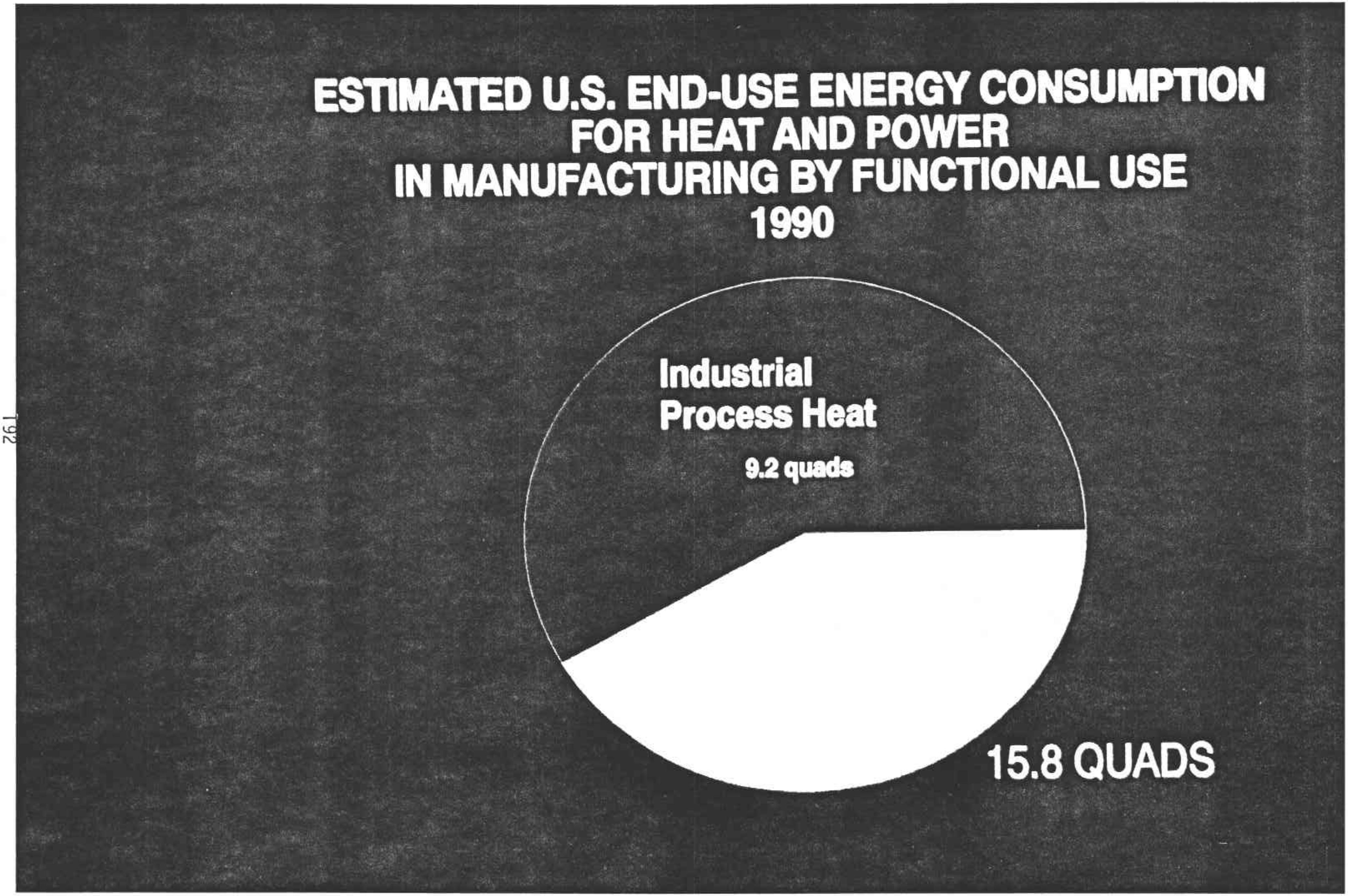
ESTIMATED U.S. INDUSTRIAL SECTOR END-USE CONSUMPTION BY ENERGY SOURCE 1990

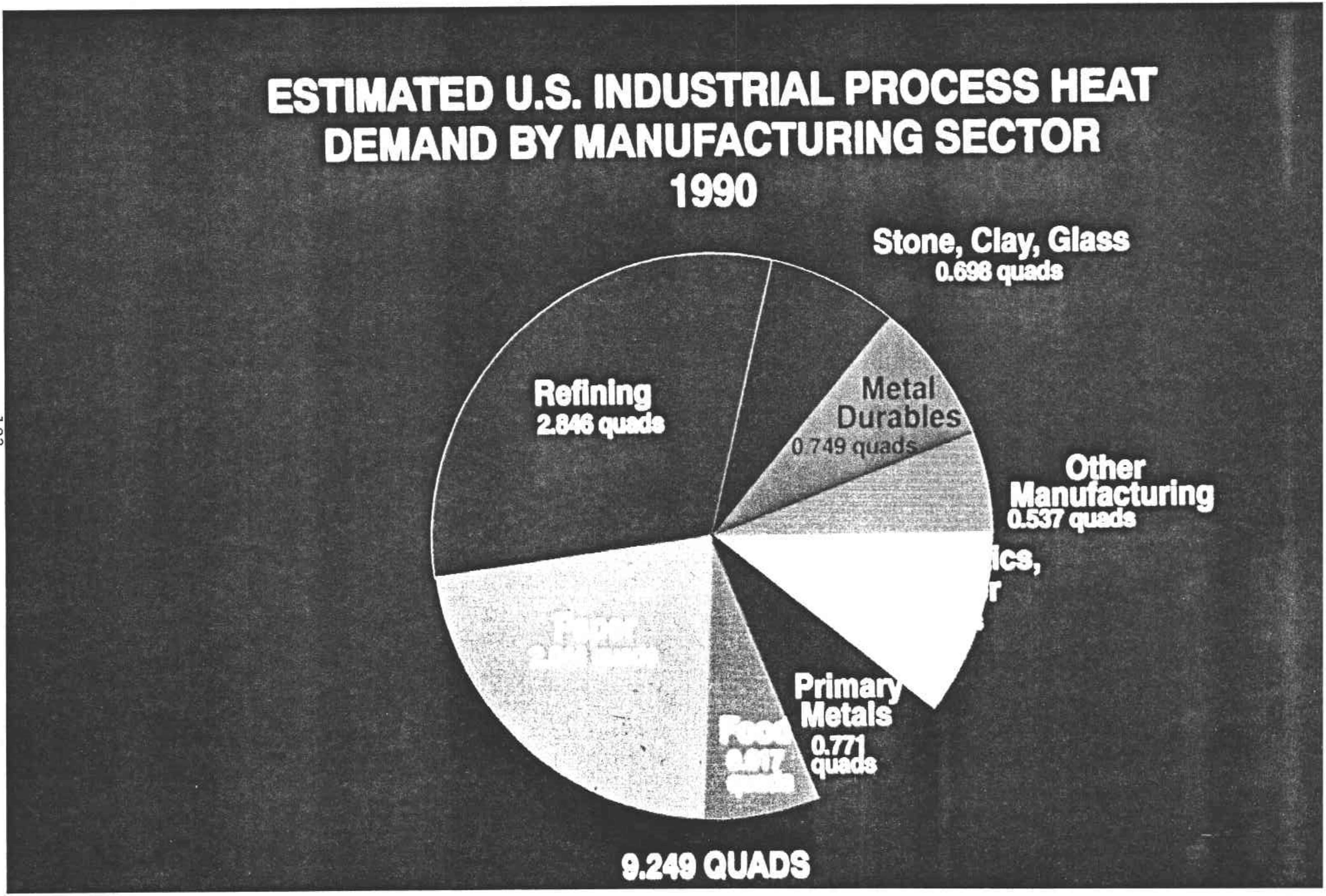


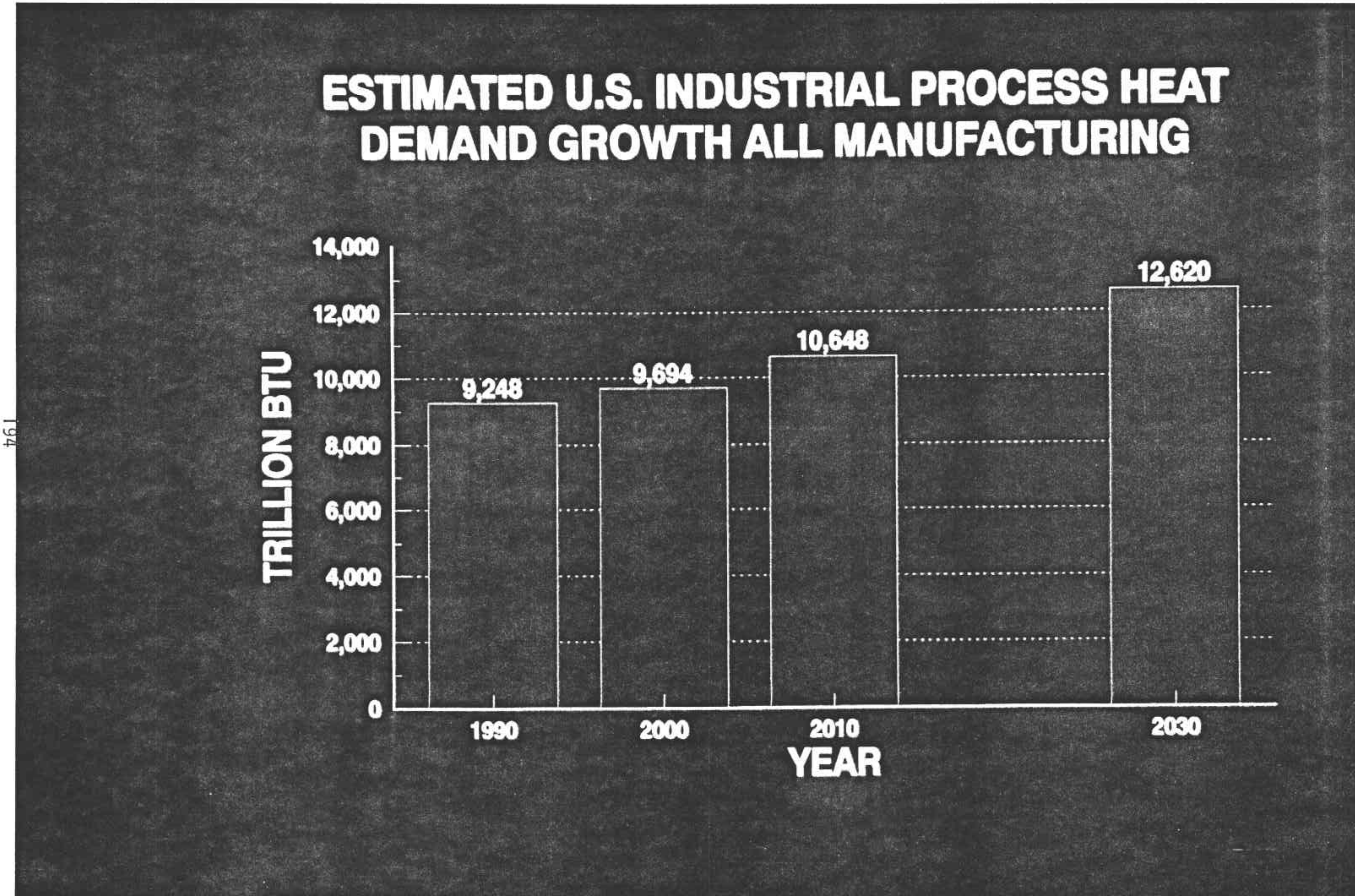
32 QUADS TOTAL
Source: DOE 1990b

Note : Includes feedstocks and electrical system energy losses and biomass and others renewables

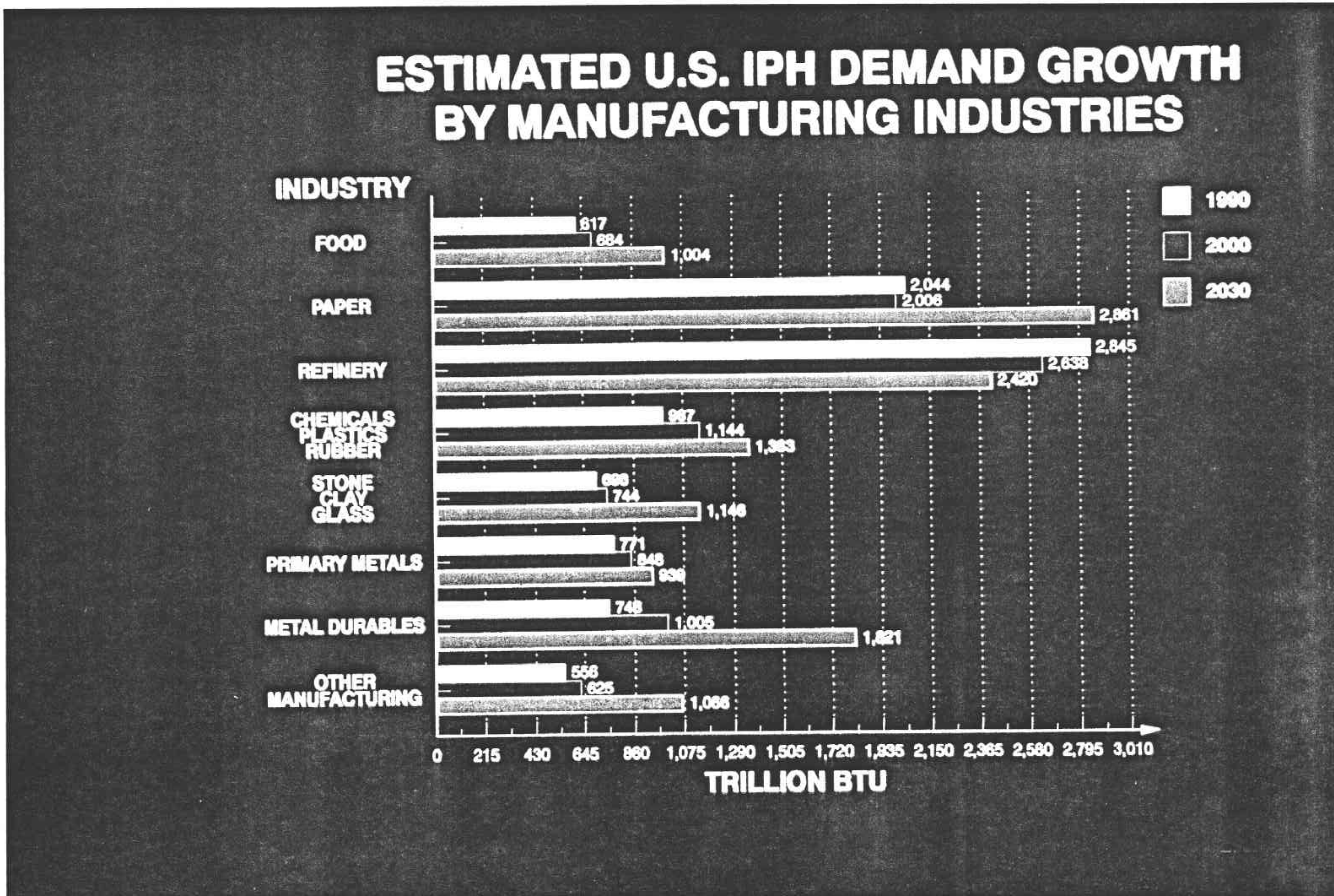

ESTIMATED U.S. INDUSTRIAL SECTOR END-USE
ENERGY CONSUMPTION FOR HEAT AND POWER
BY MAJOR CONSUMPTION SECTORS
1990
Manufacturing
15.8 quads
87%
Agriculture
0.8 quads
4.4%
Mining
1.0 quads
5.2%
Construction
0.6 quads
3.4%
Note : Excludes feedstocks and electrical system energy losses
18.2 QUADS
Source: DOE 1990b

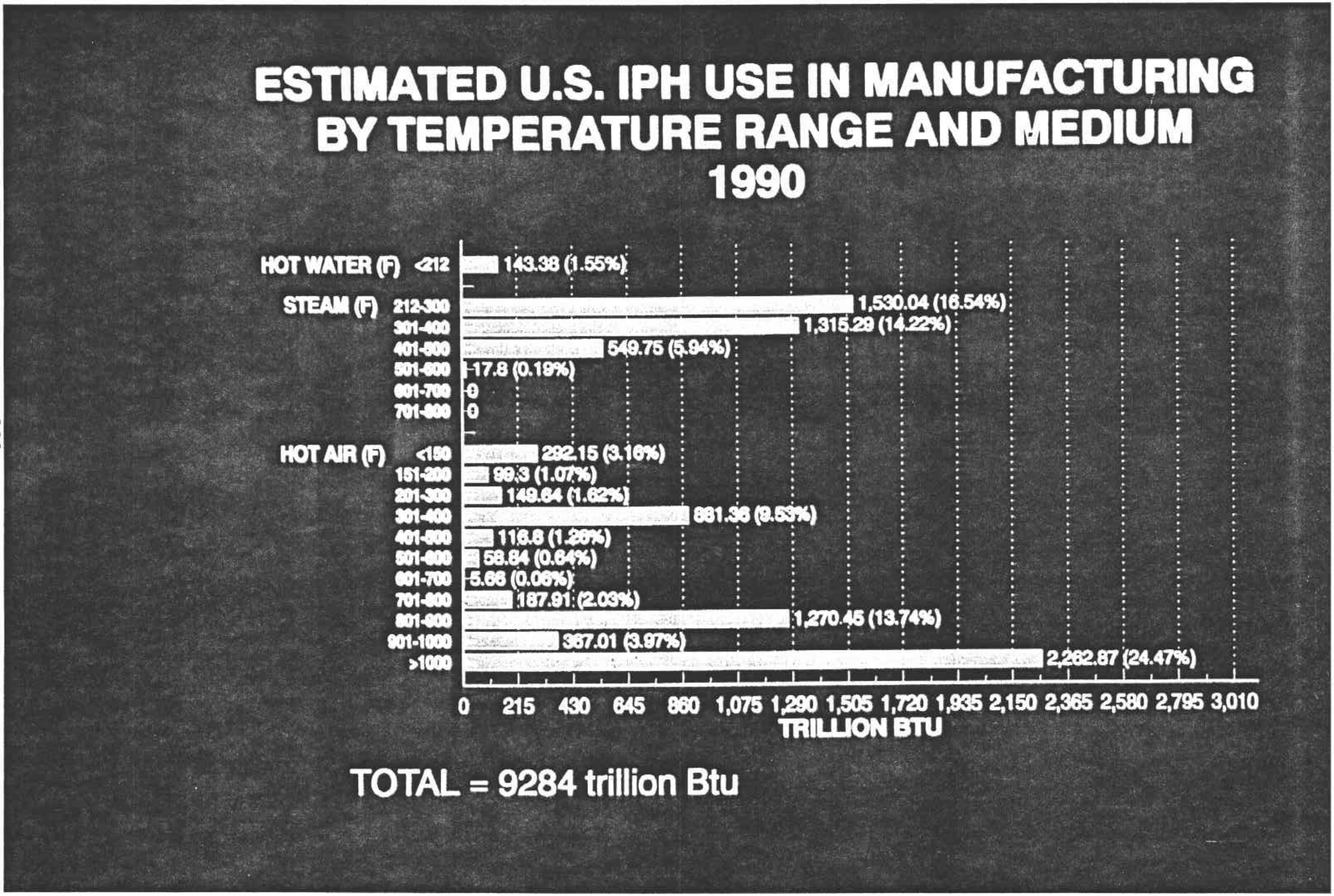

ESTIMATED U.S. END-USE ENERGY CONSUMPTION
FOR HEAT AND POWER
IN MANUFACTURING BY FUNCTIONAL USE
1990
Industrial
Process Heat
9.2 quads
15.8 QUADS

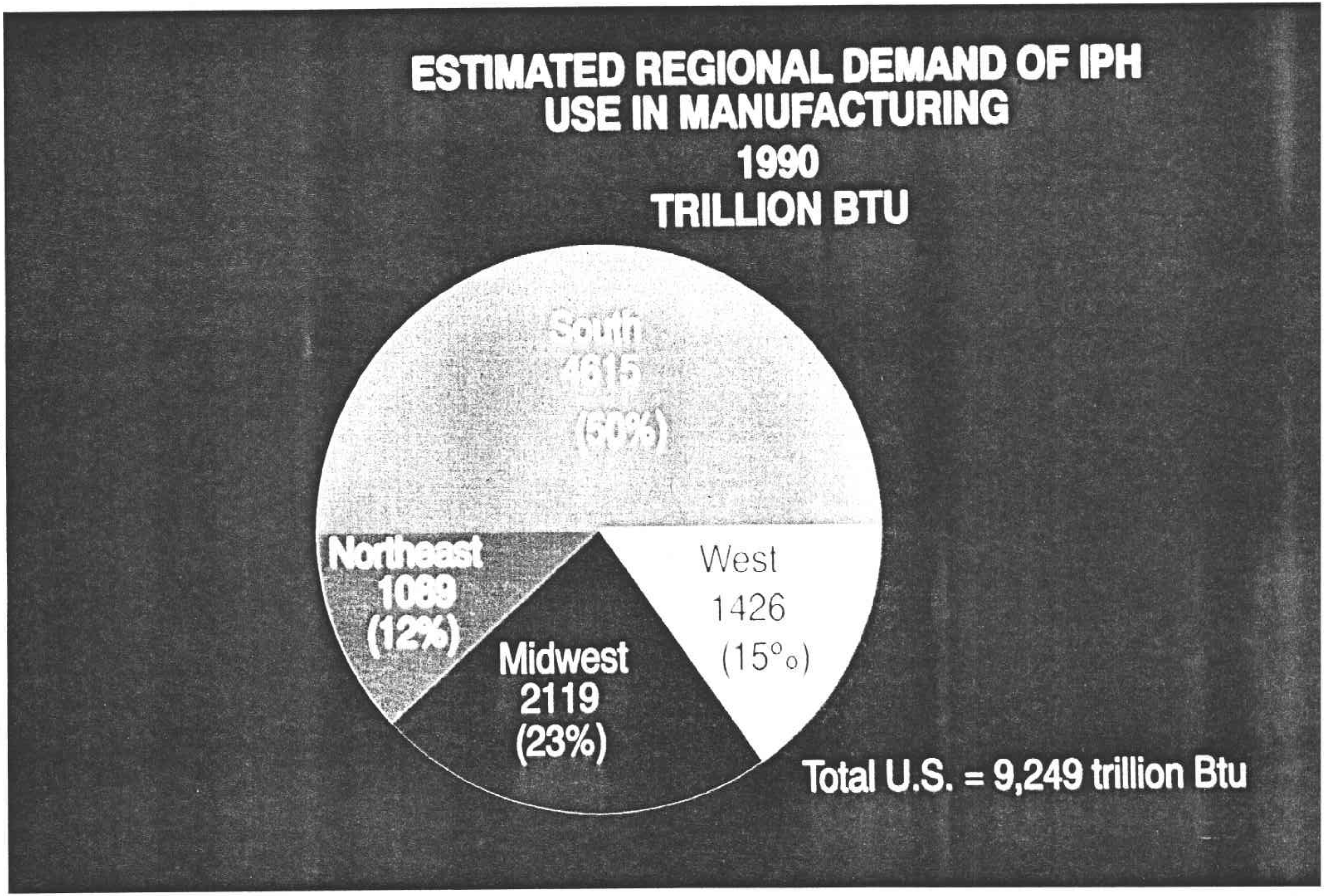

ESTIMATED U.S. INDUSTRIAL PROCESS HEAT
DEMAND BY MANUFACTURING SECTOR
1990
Stone, Clay, Glass
0.698 quads
Refining
2.846 quads
Metal
Durables
0.749 quads
Other
Manufacturing
0.537 quads
Primary
Metals
0.771
quads
9.249 QUADS



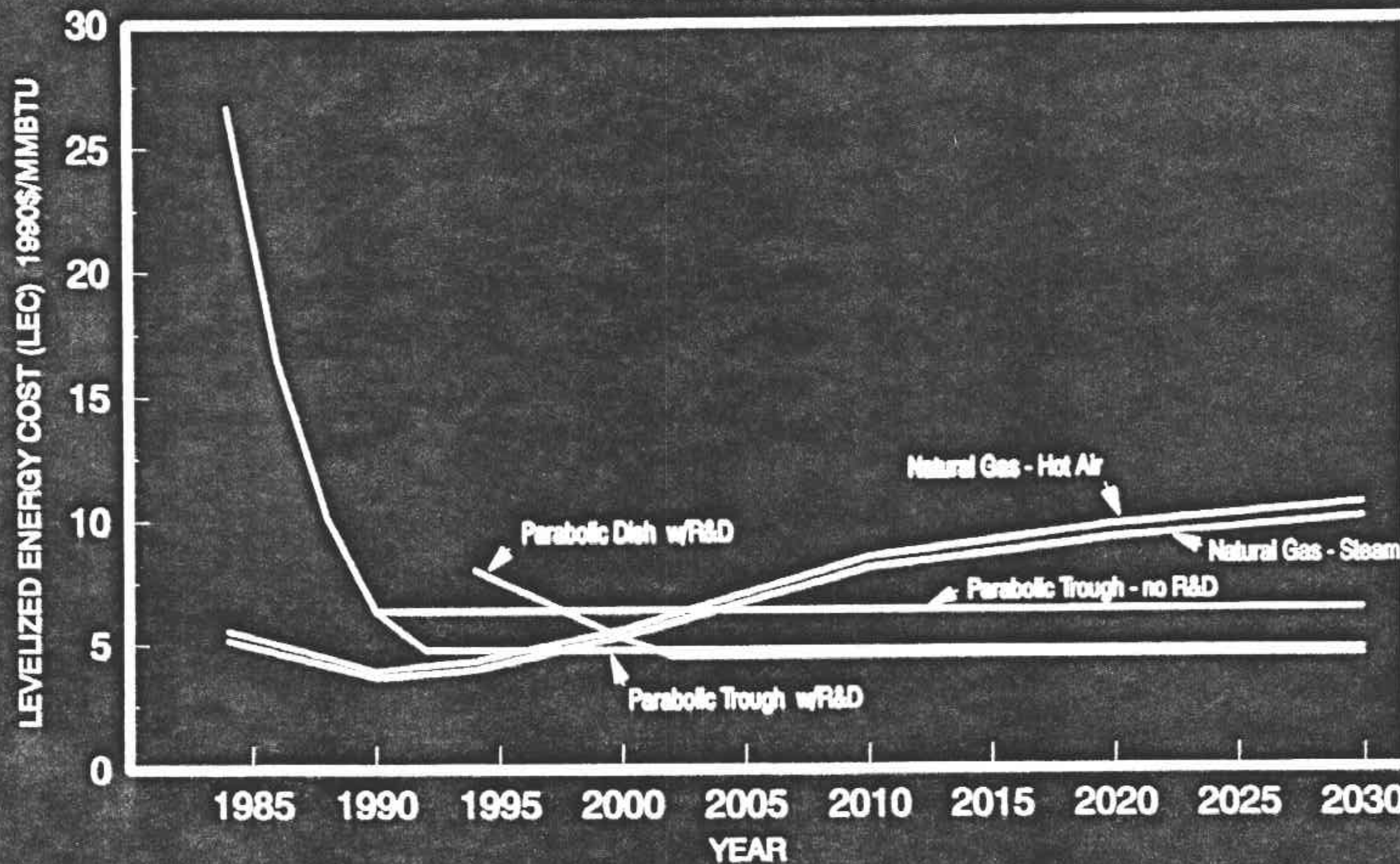
ESTIMATED U.S. INDUSTRIAL PROCESS HEAT
DEMAND GROWTH ALL MANUFACTURING
TRILLION BTU
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
9,248
9,694
10,648
12,620
1990
2000
2010
2030
YEAR


ESTIMATED U.S. IPH DEMAND GROWTH
BY MANUFACTURING INDUSTRIES
INDUSTRY
FOOD
617
684
1,004
PAPER
2,044
2,006
2,861
REFINERY
2,845
2,638
2,420
CHEMICALS
PLASTICS
RUBBER
987
1,144
1,383
STONE
CLAY
GLASS
744
1,146
PRIMARY METALS
771
848
939
METAL DURABLES
748
1,005
1,821
OTHER
MANUFACTURING
556
625
1,066
1990
2000
2030
0
215
430
645
860
1,075
1,290
1,505
1,720
1,935
2,150
2,365
2,580
2,795
3,010
TRILLION BTU

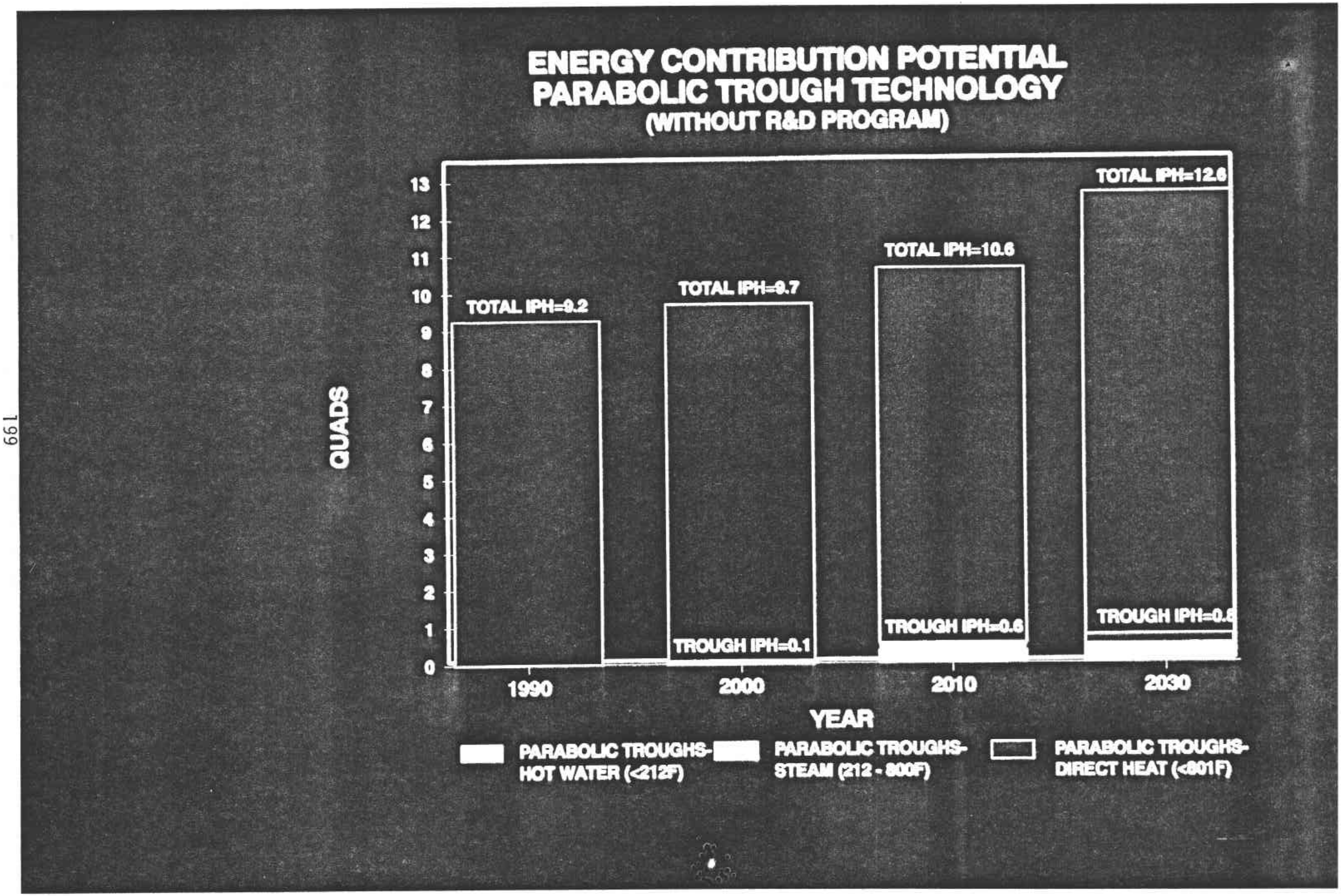

ESTIMATED U.S. IPH USE IN MANUFACTURING
BY TEMPERATURE RANGE AND MEDIUM
1990
HOT WATER (F) <212
143.38 (1.55%)
STEAM (F) 212-300
1,530.04 (16.54%)
301-400
1,315.29 (14.22%)
401-500
549.75 (5.94%)
501-600
17.8 (0.19%)
601-700
0
701-800
0
HOT AIR (F) <150
292.15 (3.16%)
151-200
99.3 (1.07%)
201-300
149.64 (1.62%)
301-400
881.36 (9.53%)
401-500
116.8 (1.26%)
501-600
58.84 (0.64%)
601-700
5.66 (0.06%)
701-800
187.91 (2.03%)
801-900
1,270.45 (13.74%)
901-1000
367.01 (3.97%)
>1000
2,262.87 (24.47%)
0 215 430 645 860 1,075 1,290 1,505 1,720 1,935 2,150 2,365 2,580 2,795 3,010
TRILLION BTU
TOTAL = 9284 trillion Btu

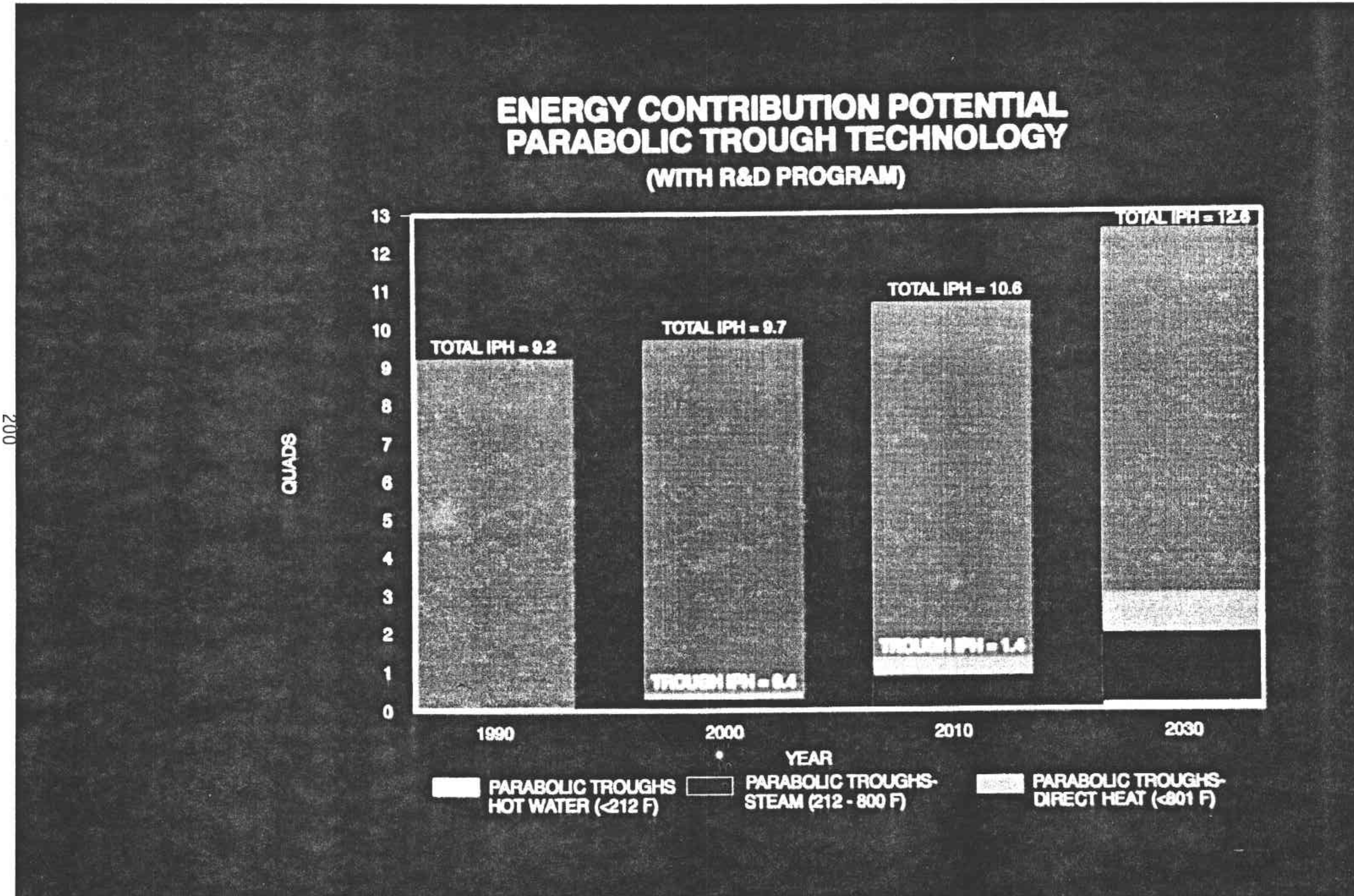

ESTIMATED REGIONAL DEMAND OF IPH
USE IN MANUFACTURING
1990
TRILLION BTU
South
4615
(50%)
Northeast
1089
(12%)
Midwest
2119
(23%)
West
1426
(15%)
Total U.S. = 9,249 trillion Btu

LEVELIZED ENERGY COST
NATURAL GAS vs SOLAR TECHNOLOGIES[1]
WESTERN REGION

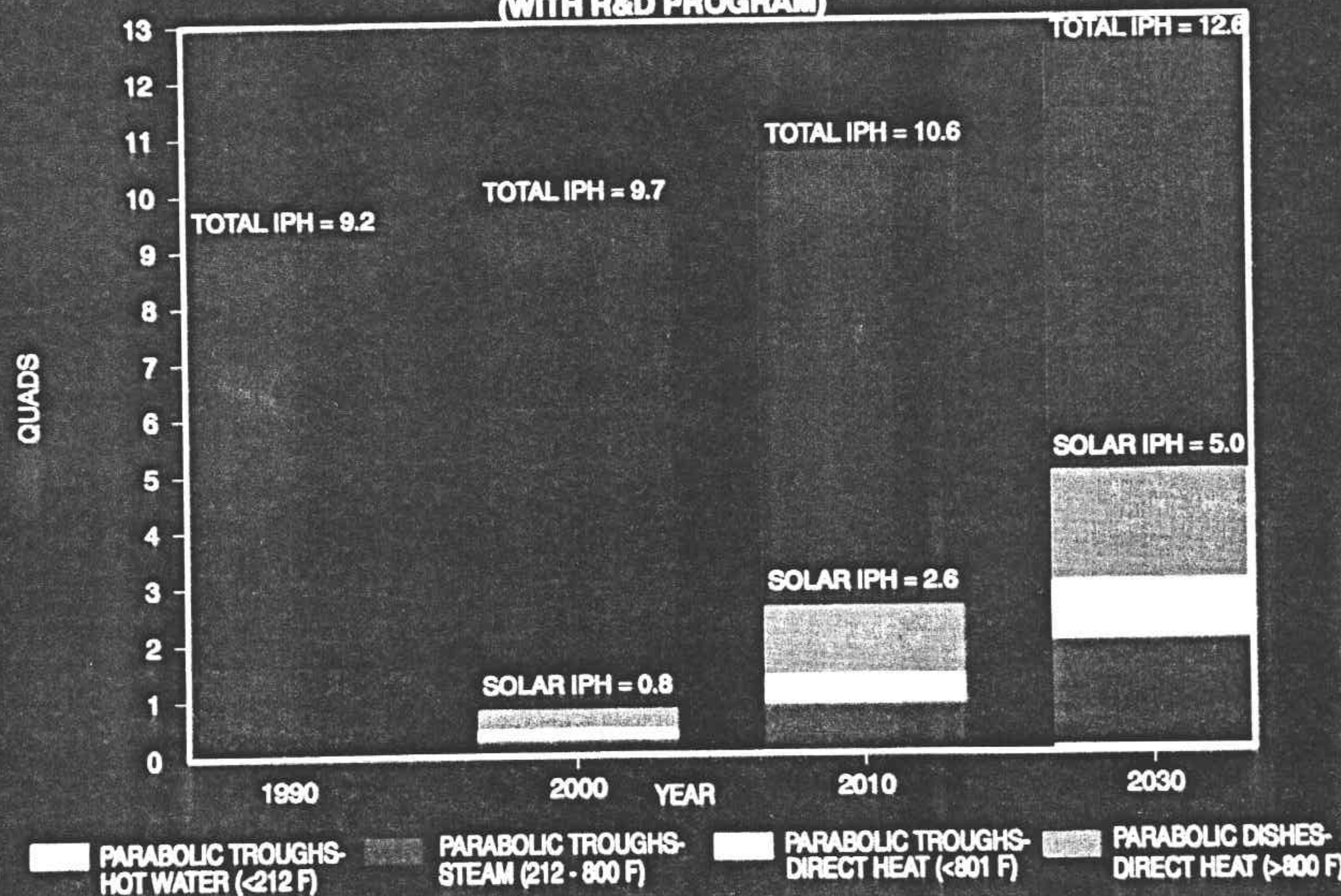


1) Natural gas fuel prices rise above the rate of inflation while there are (above the inflation rate) in the capital cost of solar technological increases


ENERGY CONTRIBUTION POTENTIAL
PARABOLIC TROUGH TECHNOLOGY
(WITHOUT R&D PROGRAM)
QUADS
TOTAL IPH=9.2
TOTAL IPH=9.7
TOTAL IPH=10.6
TOTAL IPH=12.6
TROUGH IPH=0.1
TROUGH IPH=0.6
TROUGH IPH=0.8
1990
2000
2010
2030
YEAR
PARABOLIC TROUGHS-
HOT WATER (<212F)
PARABOLIC TROUGHS-
STEAM (212 - 800F)
PARABOLIC TROUGHS-
DIRECT HEAT (<801F)


ENERGY CONTRIBUTION POTENTIAL
PARABOLIC TROUGH TECHNOLOGY
(WITH R&D PROGRAM)
QUADS
13
12
11
10
9
8
7
6
5
4
3
2
1
0
TOTAL IPH = 9.2
TOTAL IPH = 9.7
TROUGH IPH = 0.4
TOTAL IPH = 10.6
TROUGH IPH = 1.4
TOTAL IPH = 12.8
1990
2000
2010
2030
YEAR
PARABOLIC TROUGHS HOT WATER (<212 F)
PARABOLIC TROUGHS- STEAM (212 - 800 F)
PARABOLIC TROUGHS- DIRECT HEAT (<801 F)

ENERGY CONTRIBUTION POTENTIAL
PARABOLIC TROUGH AND PARABOLIC DISH TECHNOLOGY
(WITH R&D PROGRAM)



WHAT IS NEEDED FROM DOE'S SOLAR HEAT PROGRAM AN INDUSTRY PERSPECTIVE

by Dr. Pat De Laquil
Vice Chairman, SEIA Solar Thermal Power Division and
Renewable Energy Manager
Research and Development
Bechtel Group, Inc.

The Department of Energy is now in a position to structure a new program which could stimulate and support significant growth in the solar process heat market. The U.S. consumes about 15% of its primary energy to deliver industrial process heat, and a large fraction of this potential market is in the temperature range achievable using today's solar thermal technology. However, over the 1980's, solar thermal technologies were not able to make any significant penetration of this market due to: 1) the economic climate of low fuel prices, 2) the insensitivity of the energy market, as well as the financial community, to the social and environmental benefits of solar energy sources, 3) the societal emphasis on short-term profits, in which solar energy technologies having a high capital cost (with very low annual costs) are not as financially attractive as low capital cost technologies (even those with high, or highly uncertain, annual costs), 4) declining federal R&D support which has delayed many possible improvements in the technologies, and 5) continued government subsidies to conventional energy sources.

Growing environmental concerns, especially at the local level, renewed interest in energy security, and emerging mechanisms to introduce environmental benefits into the market place are creating the opening for a reemergence of the solar process heat industry. The three categories of activities which DOE can and should support to stimulate this budding U.S. solar process heat industry are 1) Regional Market Assessments, 2) Market Impact Analyses, and 3) Funded Research.

Regional Market Assessments. Industry and DOE must better understand the specific needs and constraints of the process heat market. This involves more than determining the size and location of process heat users. A series of market assessment studies should be conducted which are regional in nature. A regional analysis should make it easier to identify needs and constraints common to particular process heat users. It would also allow better matching of the capabilities and limitations of solar thermal systems to meet these needs or alleviate the constraints. The studies should involve interviews and on-site surveys of potential process heat applications with the intent of identifying attractive market-entry systems and applications.

Market Impact Analyses. Effective market incentives are perhaps the most important factors in stimulating solar process heat applications in the U.S. The effectiveness of alternate policy options should be investigated and analyzed by DOE to allow informed debate and decisions by government policy makers. Possible policy options which have been suggested include:

- Mandated use of solar heating for federal facilities
- Standardized 30-year contracts for energy purchases by federal facilities
- Income tax exemption on revenue generated from the sale of solar heat energy
- Buy-downs for early application systems
- O&M credits to encourage better system maintenance
- Long-term low interest loans

Many of these suggested market incentives are based upon the performance of the installed systems and not on their capital cost. Performance incentives are favored by the industry as a way to avoid the abuses of the past and as a way to stimulate improvements in system performance.

Funded Research. The industry values the support of the Sandia Design Assistance Center and wishes DOE to maintain this activity. While the technology for early applications is largely proven, there were many suggestions for system improvements. These included:

- A reliable silver film, or a thin (micro-glass) mirror laminate
- A cermet selective-surface coatings available in the U.S.
- Materials and techniques for in-situ boiling
- Better flexhoses and/or swivel joints
- Cooperative demonstrations for new technologies and applications
- Monitoring of long-term system performance

The intent of these funded R&D activities is to support industry and not to perform exploratory research. Generic issues, such as silver films or cermet coatings, can be directed by the laboratories. However, system specific technology developments should result from industry-initiated proposals that meet minimum requirements for cost-sharing. Cooperative demonstrations should be carried out at significant levels of industry cost-sharing.

WHAT IS NEEDED FROM DOE'S SOLAR HEAT PROGRAM

AN INDUSTRY PERSPECTIVE

DR. PAT De LAQUIL

VICE CHAIRMAN, SEIA SOLAR THERMAL POWER DIVISION AND

RENEWABLE ENERGY MANAGER
RESEARCH & DEVELOPMENT
BECHTEL GROUP, INC.

SAN FRANCISCO, CALIFORNIA

SOLAR EQUIPMENT CAN DELIVER THERMAL ENERGY TO INDUSTRIAL USERS OVER A WIDE RANGE OF TEMPERATURES

- SOLAR HEAT MARKET STALLED DURING 1980's
  - LOW FUEL PRICES
  - NO RECOGNITION OF ENVIRONMENTAL BENEFITS
  - DECLINING FEDERAL SUPPORT

- REEMERGENCE DURING 1990's
  - ENERGY SECURITY
  - ENVIRONMENTAL BENEFITS

POSSIBLE DOE SOLAR HEAT PROGRAM ACTIVITIES

1. REGIONAL MARKET ASSESSMENTS

2. COOPERATIVE IMPLEMENTATION PROGRAMS

3. MARKET IMPACT ANALYSES

4. FUNDED RESEARCH

REGIONAL MARKET ASSESSMENTS

PURPOSE: SUPPORT INDUSTRY-DRIVEN MARKET STRATEGIES

- MORE THAN SIZE AND LOCATION OF PROCESS HEAT USER
- IDENTIFY NEEDS AND CONSTRAINTS COMMON TO REGIONAL USERS
- CONDUCT INTERVIEWS AND SITE SURVEYS TO IDENTIFY ATTRACTIVE MARKET-ENTRY SYSTEMS

COOPERATIVE IMPLEMENTATION PROGRAMS

PURPOSE: COMBINE AVAILABLE LEVERAGE FOR MARKET-ENTRY SYSTEMS

- FEDERAL SUPPORT PROGRAMS
  - WEATHERIZATION
  - LOW INCOME HOUSING
- STATE INSTITUTIONAL NEEDS
- UTILITY REBATE PROGRAMS

MARKET IMPACT ANALYSES

PURPOSE: INVESTIGATE LONGER-TERM MARKET INCENTIVES

- EMPHASIZE PERFORMANCE INCENTIVES TO AVOID PAST ABUSES

- POSSIBLE OPTIONS INCLUDE:
  - MANDATED USE IN FEDERAL FACILITIES
  - INCOME TAX EXEMPTIONS
  - BUY-DOWNS FOR EARLY INSTALLATIONS
  - O&M CREDITS
  - LONG TERM, LOW INTEREST RATE LOANS

FUNDED RESEARCH

PURPOSE: SUPPORT INDUSTRY NEEDS; NOT BASIC RESEARCH

- SPECIFIC PROGRAMS INITIATED BY INDUSTRY
  - COOPERATIVE TECHNOLOGY DEVELOPMENT
  - COST-SHARED DEMONSTRATION SYSTEMS

- POSSIBLE AREAS FOR SYSTEM IMPROVEMENT
  - RELIABLE POLYMER REFLECTORS OR MICROSHEET GLASS
  - CERMET SELECTIVE SURFACE COATING
  - BOILING IN RECEIVER TUBES
  - IMPROVED FLEX HOSES AND SWIVEL JOINTS

APPLICATIONS OF PARABOLIC TROUGH TECHNOLOGY

KEN MAY
RANDY GEE

INDUSTRIAL SOLAR TECHNOLOGY

Industrial Solar Technology Corporation is actively marketing parabolic trough solar energy systems for large-scale commercial and industrial applications. The company offers turn-key system capability through system manufacture, installation, start-up and maintenance.

IST systems are based upon the use of a lightweight parabolic trough concentrator of high accuracy. The concentrators are factory fabricated close to the system site. Field installation onto accurately-aligned steel pylons supported on reinforced concrete caissons is very rapid. Though lightweight, the concentrators have proven to be extremely rugged and durable in field applications. They are constructed entirely of aluminum, which reduces maintenance costs, and the reflective surface is an acrylic film manufactured by 3M Co.

A multi-row system is used to focus up to 3,600 ft^2 of collectors on the sun using a single drive and controller. Such a system is simpler and has fewer parts than conventional designs that drive each row individually. The drive system is unaffected by snow, ice or temperatures down to -32°C (-25°F).

The solar system is controlled by the Honeywell Fluxline control system, now manufactured by IST under an exclusive license. This microprocessor-based system has demonstrated outstanding reliability in field applications over more than 10 years. Each system has a master controller that monitors sunlight intensity, wind speed, flow and other safety parameters, such as system temperature, pressure and level in the expansion tank. If all parameters are within acceptable bounds, the master controller sends an authorization signal to the local controllers that control the actual tracking of the collectors to maintain focus on the sun. The local controllers have their own internal logic. On receiving the authorization signal and if no unsafe conditions exist, the local controllers instruct the collectors to drive from the face-down stow position to focus on the sun. The local controllers maintain the collectors in focus as long as the authorization signal is provided by the master controller. The collectors return to the stow position at night or when any unsafe condition is detected. In stow, the collectors minimize exposure to wind, and soiling of the collector surface is retarded.

After several years of research, development and testing on a smaller scale, IST installed the company's first commercial system at the Paul Beck Recreation Center in Aurora, Colorado, in December 1985. This system was privately financed through third party investors, and comprises 223 m^2 (2,400 ft^2) of collectors, arranged in four rows rotated by a single drive. The system provides heat to the domestic hot water supply and to an indoor swimming pool. Peak output temperature of the collectors is about 71°C (160°F). In sunny summer months, the system provides essentially 100% of the energy needed to heat the pool. The system has operated very reliably. The main maintenance task is to wash the system every two to three months, using deionized water pumped through a pressure washer. The performance data shown are based on the output of a BTU metering system. Changes in thermal output year to year are relatively small. However, performance in 1990 was down somewhat, due largely to the deterioration of the ECP-300 silver reflective film. In November 1990, under a cost sharing arrangement with SERI, the collectors were retrofit with new ECP-305 reflective film. This restored system performance to its original output.

In December 1986, IST started up a second system at the Adams County Detention Facility in Brighton, Colorado. The system was financed equally by private investors and the Colorado Office of Energy Conservation using Exxon overcharge funds. After being expanded in 1988, this system comprises 725 m^2 (7,800 ft^2) of collectors. For two years, this system was operated in a cogeneration mode, producing both heat and electricity through the use of an ORC turbine driving a 55 kW induction generator. Under such conditions, the collector outlet temperature reached 158°C (316°F) compared to 127°C (260°F) in the thermal only mode of operation. Domestic hot water is delivered to six different load centers within the Facility. A 19 m^3 (5,000 gallon) storage tank allows energy to be delivered on a 24 hour-per-day basis. A Btu metering system measures energy delivery for billing purposes. In addition, system performance was measured by the Joint Center for Energy Management at the University of Colorado for 14 months, and for another 11 months by IST under contract to the Office of Energy Conservation. Under peak operating conditions, the system delivered about 65% of the solar radiation incident on the collectors. Silver reflective film and anti-reflective glass on the receiver annulus contributed to this level of performance. On an annual basis the system provides nearly 50% of the hot water needed.

The major maintenance activity has been to wash the reflective surface to maintain system performance. Under a cost-shared contract with SERI, IST monitored soiling rates of the ECP-300 silver reflective film, and investigated washing techniques and frequency.

IST started up a 2,677 m^2 (28,800 ft^2) system at the California Correctional Institution (CCI) in Tehachapi, California during the fall of 1990. This system provides heat to a pressurized high-temperature water loop that distributes energy throughout the Institution for showers, kitchens, a laundry and space heat. A secondary thermal load is a separate domestic hot water loop. At peak conditions, the system is designed to meet about 80% of the summertime thermal load. No thermal storage is provided. Collector outlet temperature at design conditions is 147°C (296°F). The collector field is divided into 16 rows arranged in 8 U-loops. Tracking is provided through 8 drive/controllers. Like IST's previous installations, this system was a retrofit requiring that interface equipment be located within a crowded area among existing equipment. Thus, the main heat exchanger is mounted on the boiler room wall 5.5 m (18 ft) above the floor. From the solar field to the boiler room there is a 122 m (400 ft) piping run of which 76 m (250 ft) is overhead. Using funds provided by the Design Assistance Center at SNLA, a weather station was installed adjacent to the CCI solar field and the system was instrumented to measure system performance. Data gathering on a regular basis started in February 1991. SNLA also provided assistance related to the design of the piping system, and the mounting of the heat exchanger. Both SNLA and SERI provided property data on the black chrome selective surface, and using material supplied by SERI, one row of collectors was installed with ECP-305, so that this latest generation of silver reflective surface can be evaluated in a realistic field setting.

All three of IST's systems have been financed by private investors. Energy is sold to the energy users at rates below what they pay for natural gas, on the basis of long-term energy purchase agreements. In addition to designing and constructing the first two systems that IST installed in Colorado, IST formulated energy purchase agreements that allowed for ownership of the systems by investors in the Colorado area. Revenues from the sale of the solar-produced energy flow back to the investors to repay their investment. The recently installed system in Tehachapi, California was developed by United Solar Technologies. This company also provided bridge financing to build the system with the help of a small business loan from the State of California.

Applications of Parabolic Trough Solar Technology

INDUSTRIAL SOLAR TECHNOLOGY

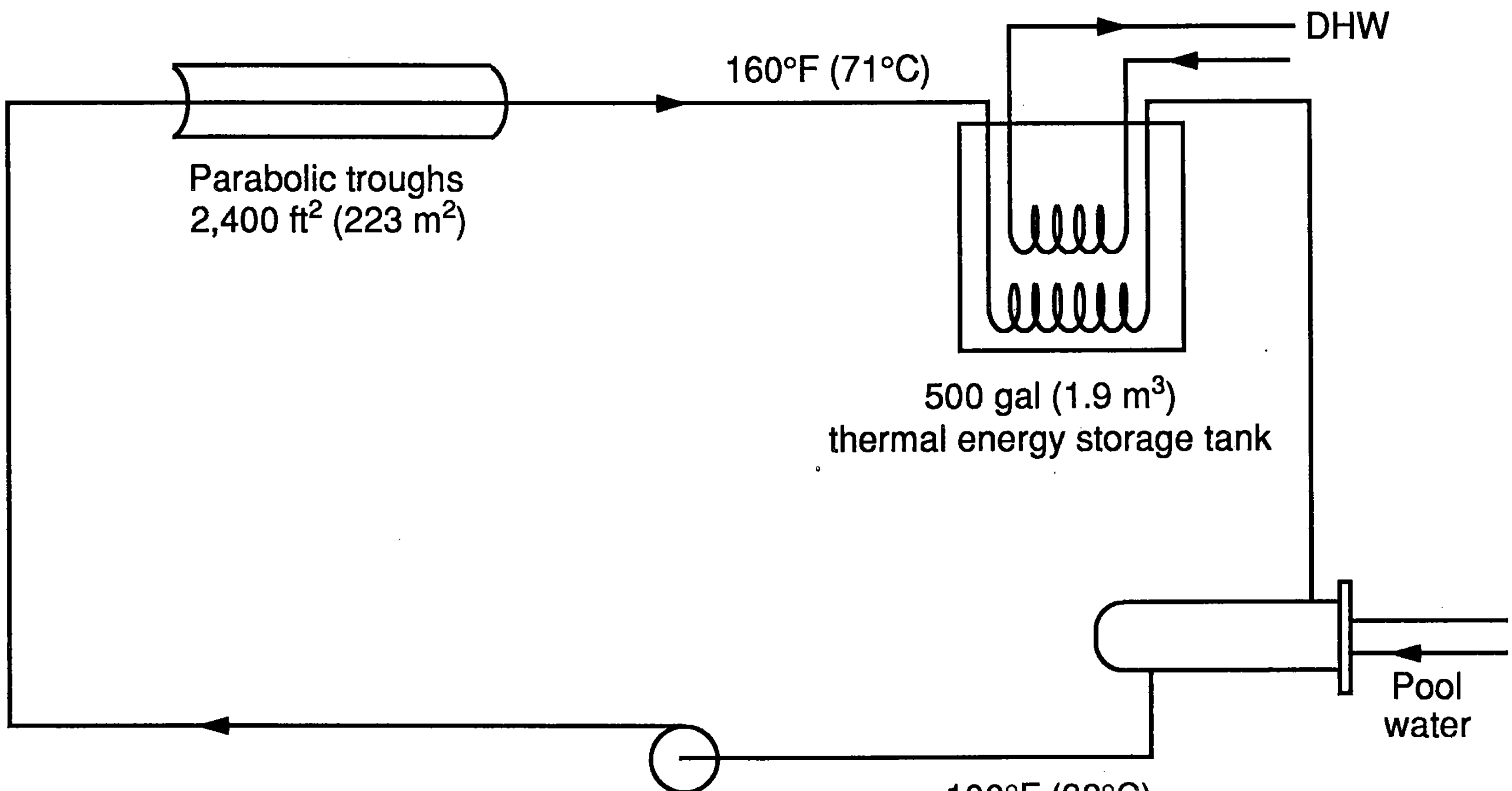
Ken May

Paul Beck Recreation Center

Location	Aurora, Colorado
Start-up	December 1985
Solar system area	2400 ft^2 (223 m^2)
Solar loads	Swimming pool and DHW
Peak thermal output	480,000 Btu/h (140 kW)

P13-G0711203

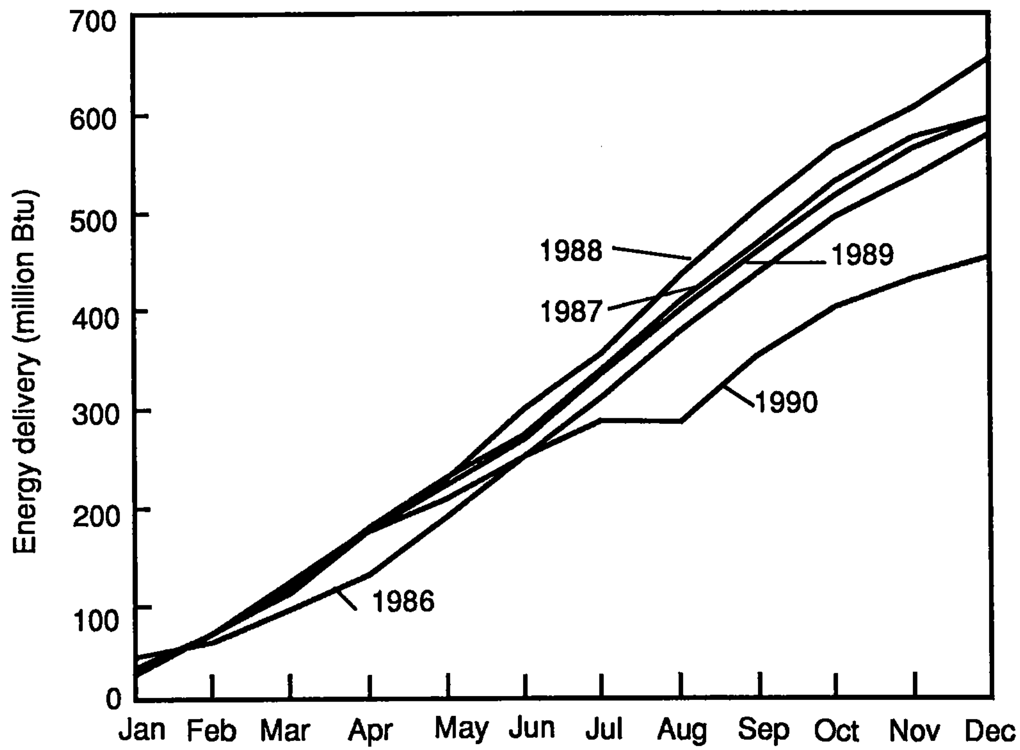
Paul Beck Recreation Center



P13-G0711210

Paul Beck Center, Aurora, CO

Cumulative Energy Delivery



P13-G0711216

219

Adams County Detention Facility

Location	Brighton, Colorado
Size	485 inmate capacity
Domestic hot water load	10 million Btu/day average (2930 kWh) (19,200 GPD)

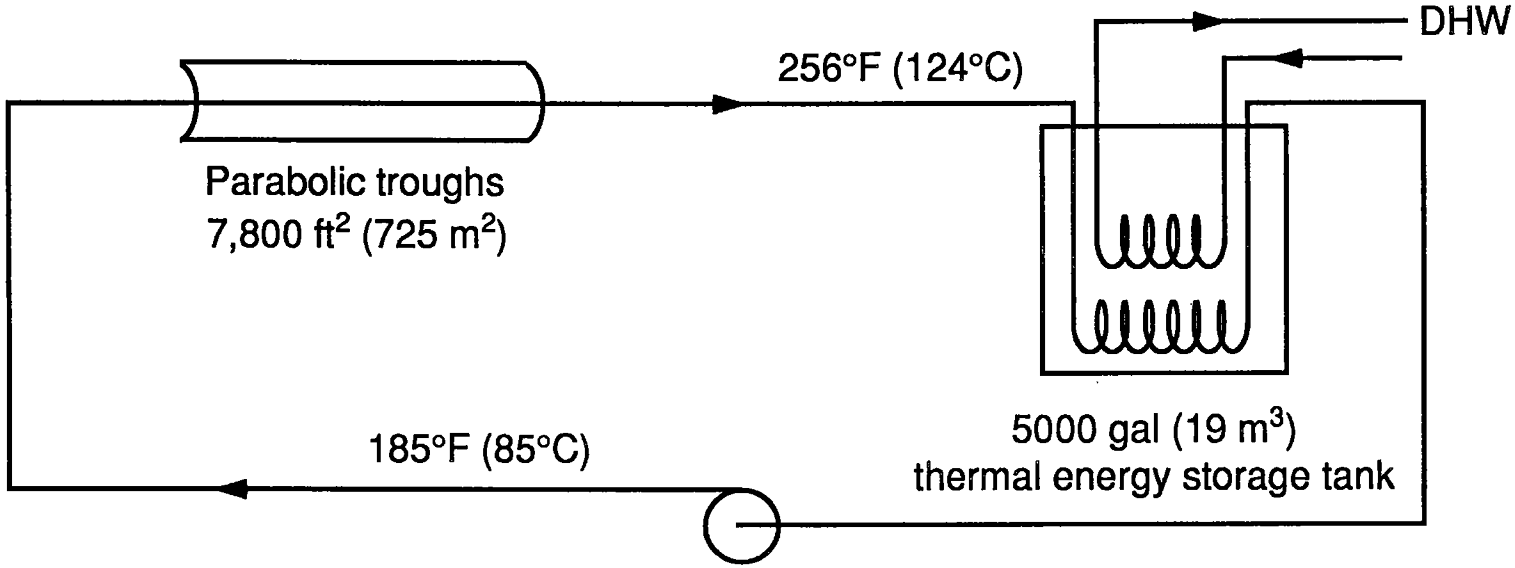
P13-G0711204

Solar System Characteristics

System area	7800 ft^2 (725 m^2)
Peak thermal output	1.4 million Btu/h (400 kW)
Thermal storage tank volume	5000 gallons (19m^3)

P13-G0711205

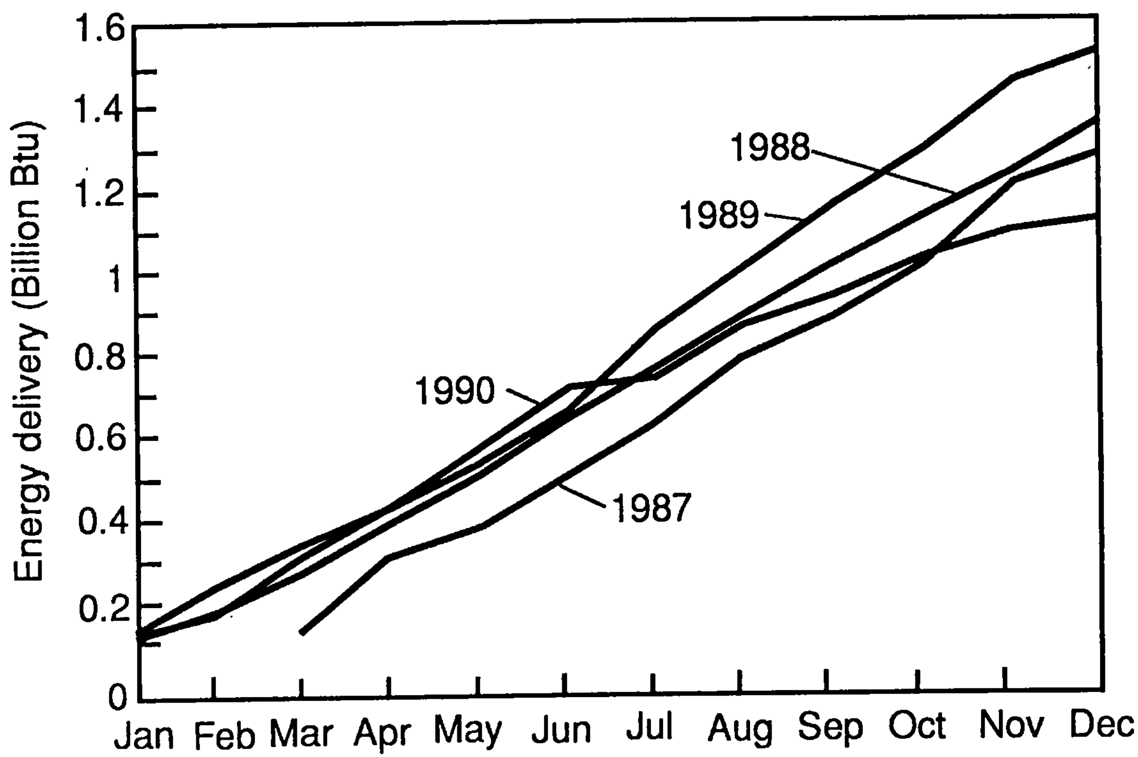
Adams County Detention Facility



P13-G0711209

Adams County Detention Facility

Cumulative energy delivery



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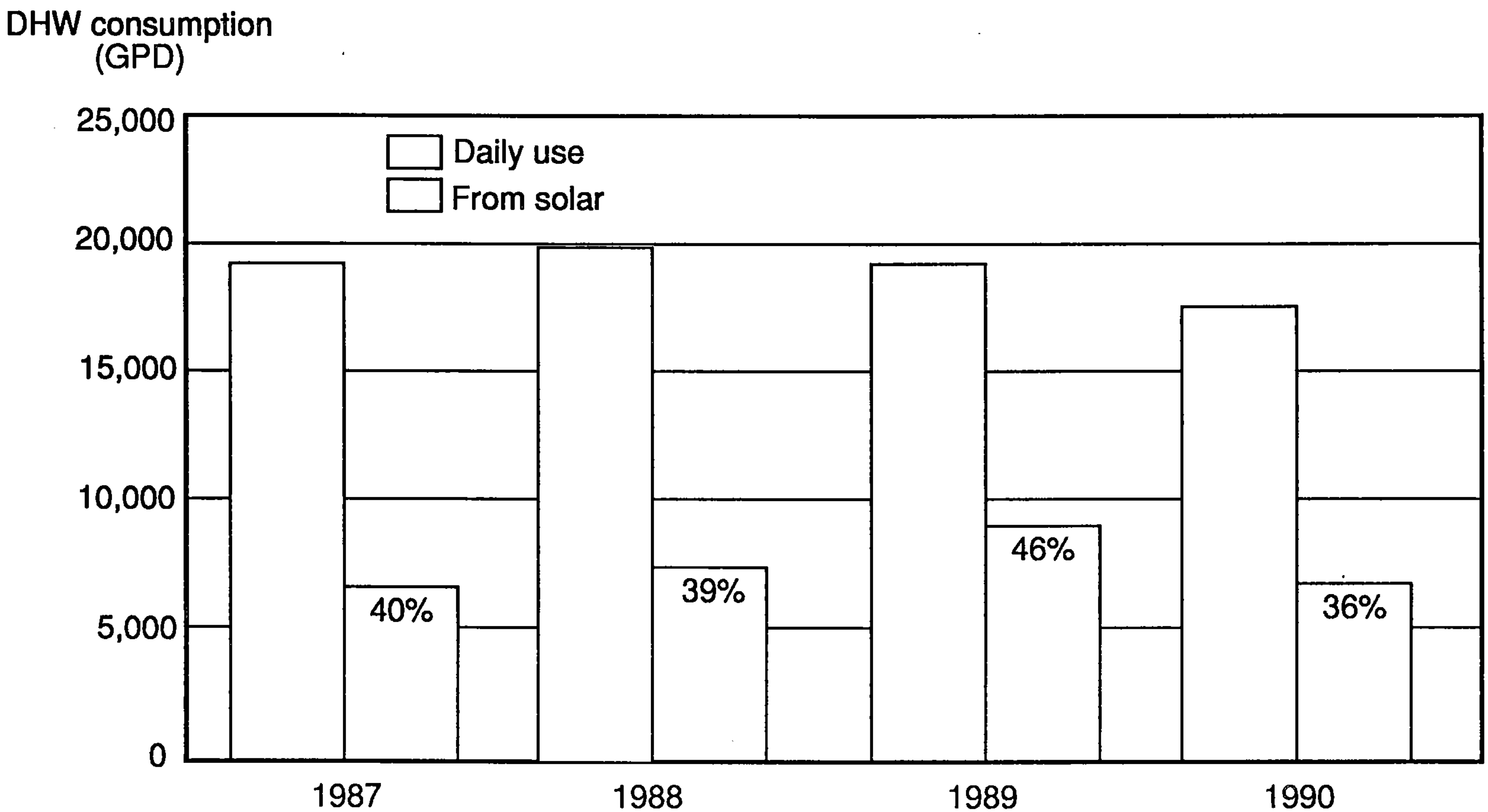
Adams County Detention Facility

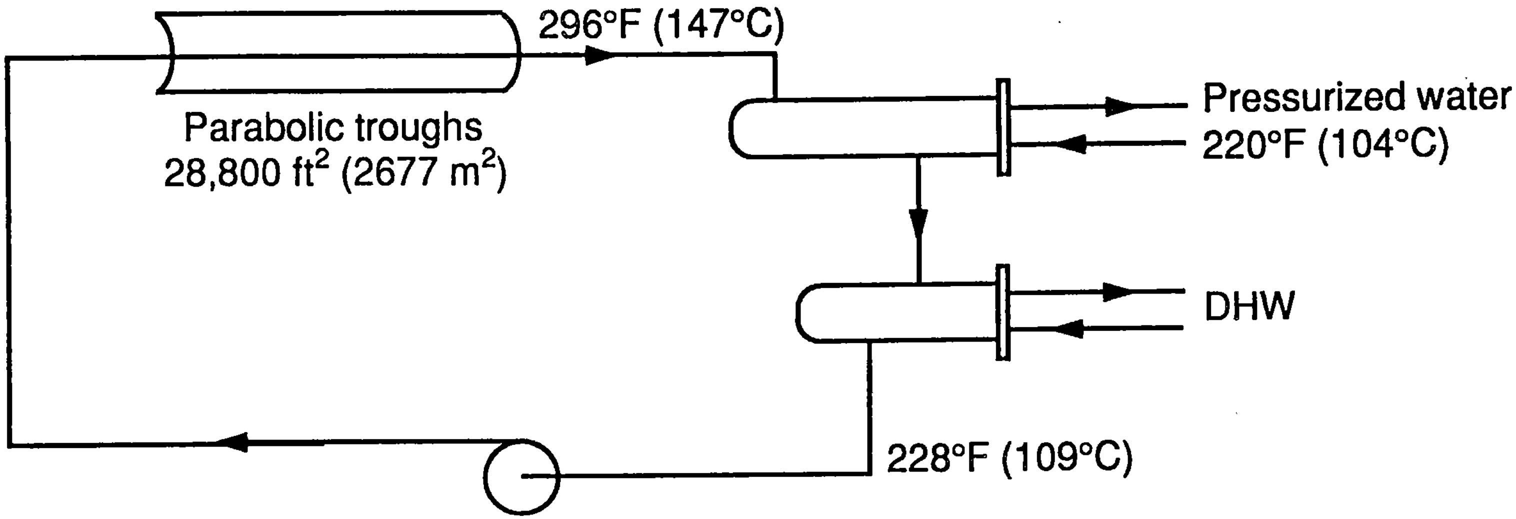


P13-G0711206

California Correctional Institute
Tehachapi, California

Inmates	5,100
Collector area	28,800 ft^2 (2677 m^2)
Field area	2 acres
Load temperature (pressurized water)	220°F (104°C)
Peak solar energy delivery	4.5 million Btu/hr (1330 kW)

California Correctional Institution



P13-G0711208

ISAAC™
SOLAR ABSORPTION ICEMAKER

by Donald C. Erickson
Energy Concepts Co.
627 Ridgely Avenue
Annapolis, MD

The Isaac solar icemaker makes ice from the heat of the sun using an Intermittent Solar Ammonia Absorption Cycle. It is designed to provide low cost and reliable refrigeration to locations off the electric grid. The Isaac technology achieves this objective by providing a modestly priced icemaking system which is free of all operating costs. The most critical demand for refrigeration in remote or unelectrified areas is for vaccine storage. The lack of this refrigeration at best will cause expensive vaccines to spoil, and at worst will place lives in danger.

Food preservation is a second highly important need for refrigeration, taken for granted in industrialized countries, but too often not available in developing sun-belt countries. Spoilage of meat, fish, and dairy products makes a costly contribution to malnutrition and malnourishment. The availability of ice for transport not only brings nourishment to needy areas, but also brings jobs to producing locations such as fishing villages.

Historically there have been three approaches available for providing refrigeration to remote areas: kerosene absorption refrigerators; conventional refrigerator with engine-generated electricity; and conventional refrigerator with solar photovoltaic electricity. Each of these options suffers from limitations which increase the cost beyond what is accessible to most needy populations. With kerosene-fired absorption refrigerators, the cost and availability of good quality kerosene is a problem. The engine generator option has a higher first cost than absorption, and a comparable ongoing fuel cost, plus high maintenance requirements. The photovoltaic option has the highest first costs, plus ongoing cost of battery replacement.

The operation of the Isaac icemaker is as follows. The ammonia-water solution is contained in a cylindrical pressure vessel covered with a black selective surface. By day a reflector concentrates sunlight on the cylinder, causing ammonia vapor to desorb from the solution. A combination of air cooling and water cooling causes the ammonia vapor to condense, and the liquid condensation is collected in a receiver.

At night the ammonia water solution is cooled to ambient temperatures. Cooling the solution reduces the vapor pressure, thus enabling it to absorb low pressure vapor from the evaporator. Liquid ammonia from the receiver is supplied to the evaporator where it evaporates at low pressure. The low temperature heat extracted from the cold box (i.e., from the freezing water) causes the liquid ammonia to boil, and the vapor is re-absorbed into the pressure vessel, completing the cycle.

Several key design features contribute to the simplicity, reliability, and low cost of this technology.

1. Solar Collector: The temperature required for ammonia vapor desorption is on the order of 100°C, too hot for efficient low cost flat plate collectors. A parabolic collector efficiently yields the higher temperature. The concentration ratio is only 1.8, therefore the only solar tracking necessary is a seasonal reaiming, and cost is minimized.

2. Absorber Cooling: A built-in thermosyphon is used to cool the solution in the pressure vessel at night. The ammonia condenser is part of the thermosyphon. A manually-operated valve activates the thermosyphon, or optional automatic operation.

3. Auxiliary Heating Coil: Cloudy day operations is easily obtained by heating a coil attached to the pressure vessel. Any indigenous fuel can be used.

4. Economies of Scale: The same basic design can be scaled from ice production levels of 5 kg/day up to about 150 kg/day before multiple units are required. The larger sizes yield major cost advantages.

5. Ease of Manufacture: The machine shop skills (welding, cutting, drilling) necessary for Isaac manufacture are generally available in most developing countries, making low-cost local manufacture a viable option.

The current status of the Isaac technology:

- Twenty prototypes and two sizes of Isaac have been tested.
- Ice production levels of 5 kg/m^2 solar aperture.
- Four prototypes in operation in remote areas.
- Early development supported by DOE Energy Related Inventions Program and by the Agency for International Development.
- One small prototype ("Mini-Isaac") under test at the Solar Thermal Design Assistance Center, Sandia National Labs.

The current needs are:

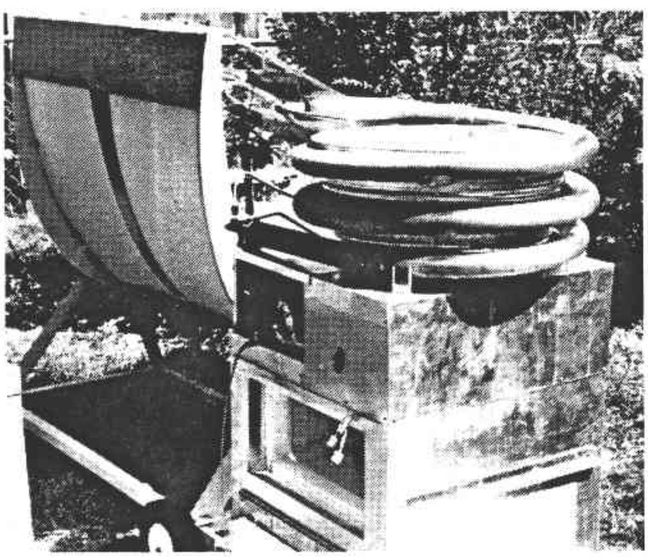
- Demonstrations of significant scale in needy areas;
- Development of volume production capability;
- Improvements such as constant temperature chill and freeze boxes, and unattended operation.

ISAAC™ Solar Powered Ammonia Absorption Refrigerator

Solar Powered Refrigeration from Energy Concepts

The **ISAAC™** solar powered refrigerator combines the dependability of an ammonia absorption refrigeration cycle with state of the art solar collector technology. The result is a design that incorporates simplicity, reliability and affordability. **ISAAC™** refrigerators produce more ice per square foot of collector area than comparable photo-voltaic powered refrigerators and cost only a small fraction of the price. Unlike diesel, kerosine and gas fired refrigeration, the **ISAAC™** solar powered refrigerator obtains its efficient output from the energy of the Sun.

Reliable-The **ISAAC™** solar powered refrigerator is reliable because of its design. There are no moving parts. It is virtually maintenance free and only requires one valve to be turned, once in the morning and once in the evening.



Easy to Operate-The **ISAAC™** solar powered refrigerator has four primary components: the reflector, the ammonia vaporizing cylinder, the condenser and the ice box. When the sun is reflected to the black surface of the ammonia vaporizing cylinder, the ammonia vaporizes and is routed to the condenser where it is condensed back into a liquid. When the sun goes down, the operator turns a valve to the "ice-making" mode which allows the ammonia to enter the cooling tubes of the refrigerator where it rapidly lowers the temperature by absorbing heat to create ice. In the morning, the operator turns the valve to the "generate" mode and the vaporizing cylinder is once again exposed to the high intensity heat of the reflector.

The **ISAAC™** solar powered refrigerator requires no pumps nor any form of electricity to operate.

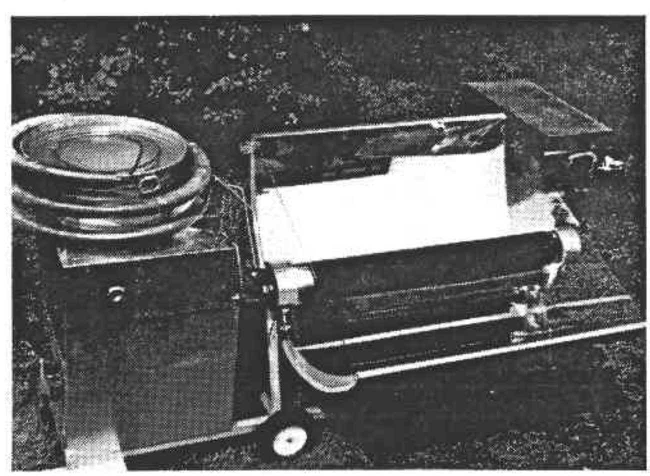
Applications-The **ISAAC™** solar powered refrigerator provides low cost refrigeration to any area of the world that is exposed to continual sunshine and lacks public utility power grids for electricity.

Rural Heath Stations-Perfect for medicine and vaccine storage.

Fisheries/Farms-Allows extended storage of fresh food products.

Remote Homes and Villages-Ice making and Food/Medicine cooling.

The **ISAAC™** solar powered refrigerator is available in two standard models that have a capacity to produce 12 to 16 pounds of ice per day or 60 to 80 pounds of ice per day. Custom models can be designed for specific areas of the world that may require a larger reflector area or for increased ice production. For cloudy days, a wood/coal burning backup unit may be specified to assure non-stop refrigeration.



Your Local **ISAAC™** Representative:

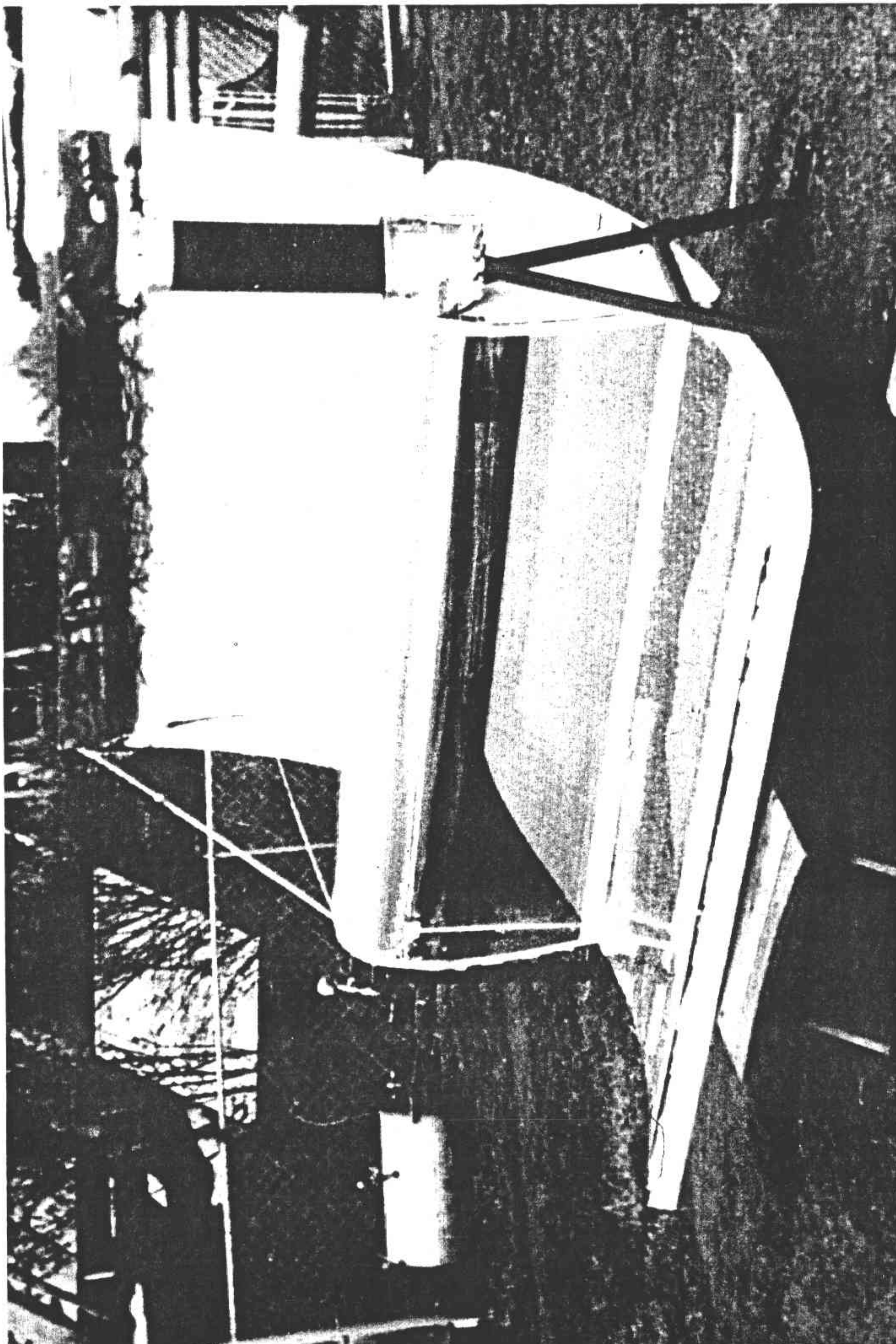
ENERGY CONCEPTS CO.
627 Ridgely Ave., Annapolis, Md. 21401 • 301/266-6521 Fax 301/266-6539

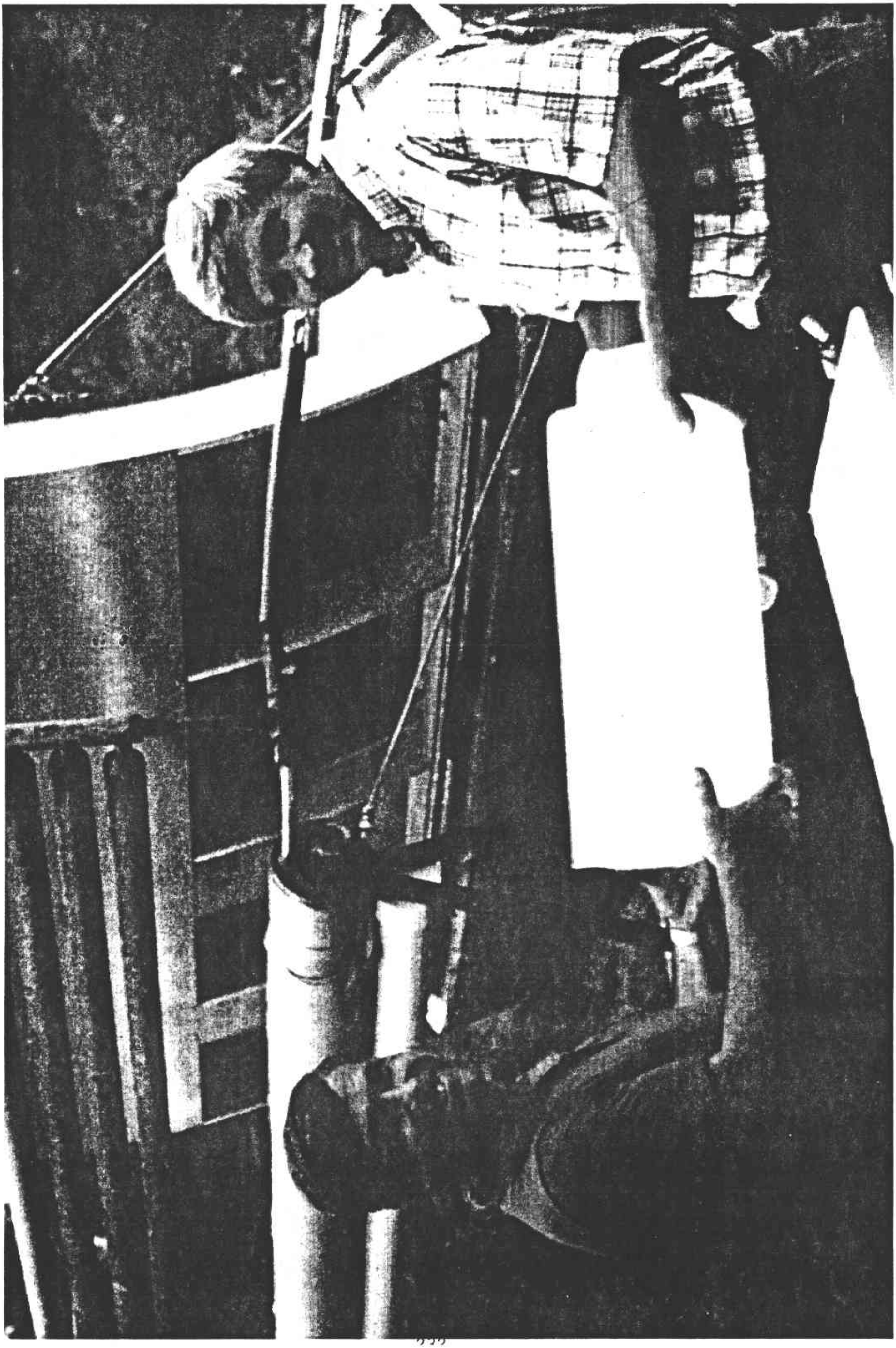
ISAAC

SOLAR ABSORPTION ICEMAKER

DONALD C. ERICKSON
ENERGY CONCEPTS CO.
March 27, 1991

SOLTECH 91



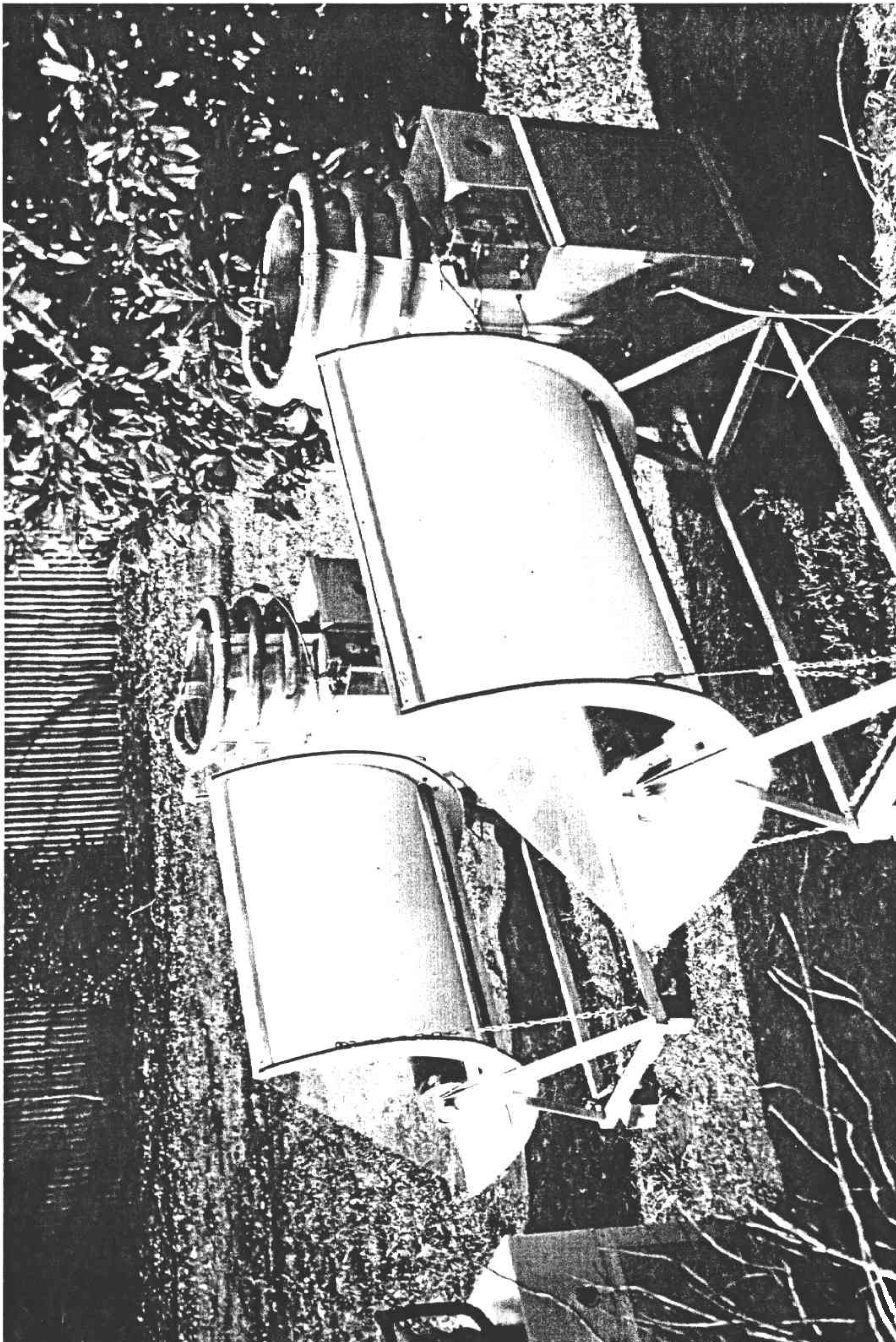


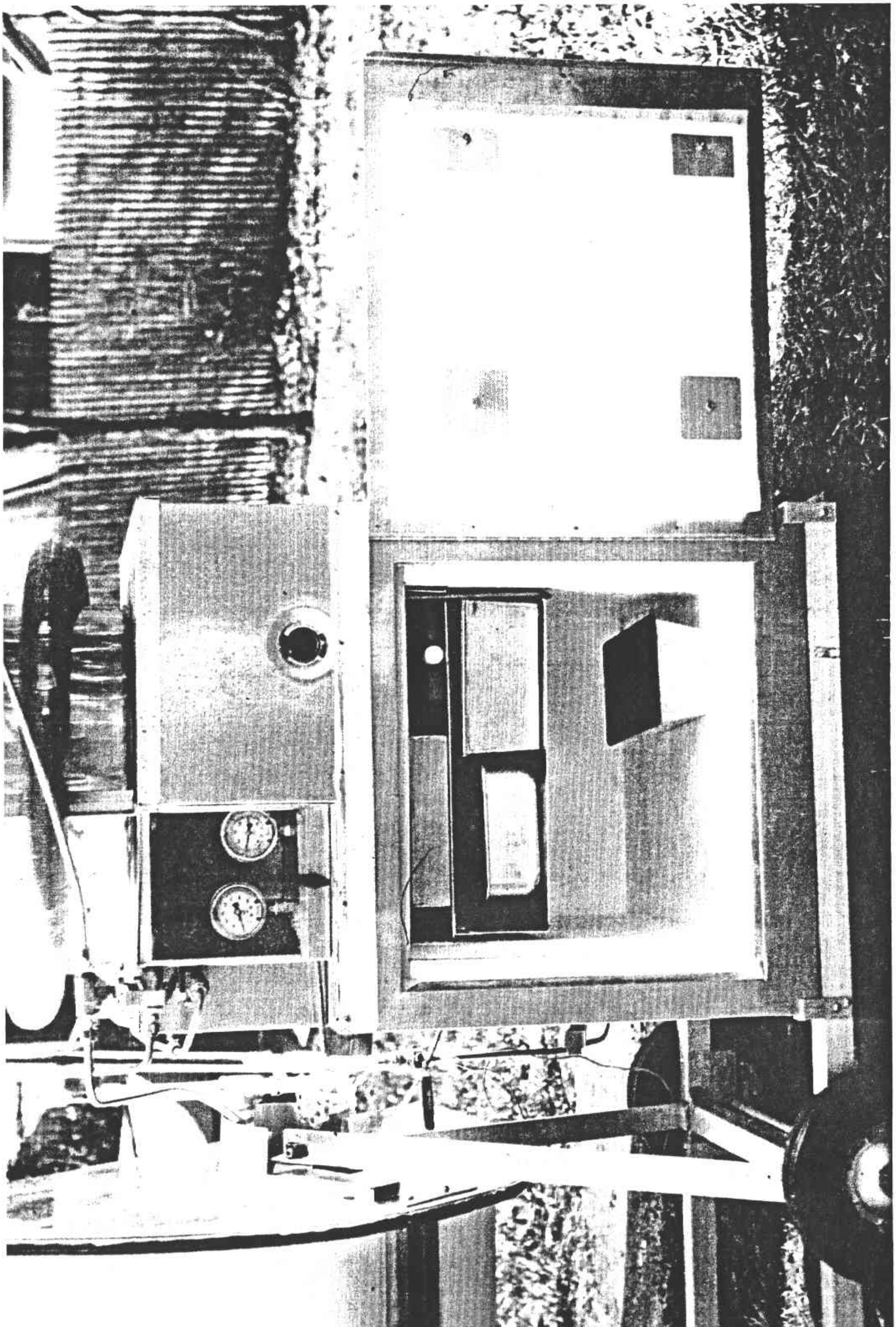
Solar Icemaker Applications

Health Clinics
- Vaccine Storage
- First Aid
- Comfort

Farms and Ranches
- Milk Chilling
- Food Preservation
- Quality of Life

Villages/Trading Posts/Islands
- Storage & Transport of Fish & Meat
- Sale for Ice-boxes



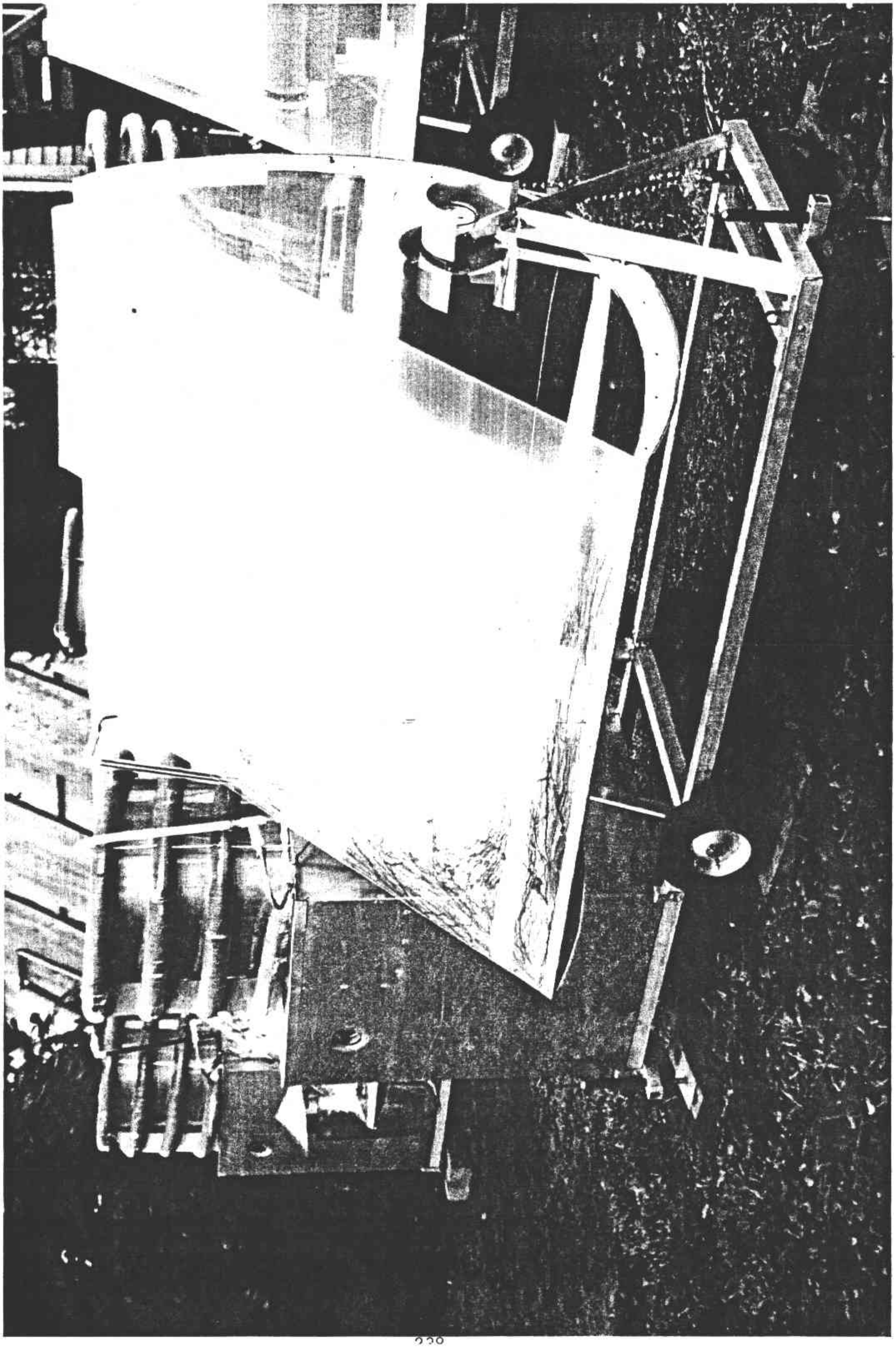


ISAAC Specifications

	ISAAC	Double ISAAC	Mini ISAAC
Solar Aperture	6.4	12.8	1.6
Shipping Weight (kg)	380	660	120
Absorbent Weight (kg)	76	152	17
Daily Ice Production (kg)	34	72	8
FOB Price ($)	9,000	12,600	3,600
Example Application	Farm	Village	Health Clinic

Performance & Cost Comparison

	Kerosene Absorption	Solar Photovoltaic	Mini ISAAC	Double ISAAC
Capital Cost	$1100	$4000	$3600	$14,600
Recurring Cost/Year	$150-$400	$100	$20	$200
Ten Year Cost	$2600-5100	$5000	$3800	$18,600
Daily Ice Yield (kg)	3	5	8	72
Cost of Ice $/kg	.24 -.47	.50	.23	.13



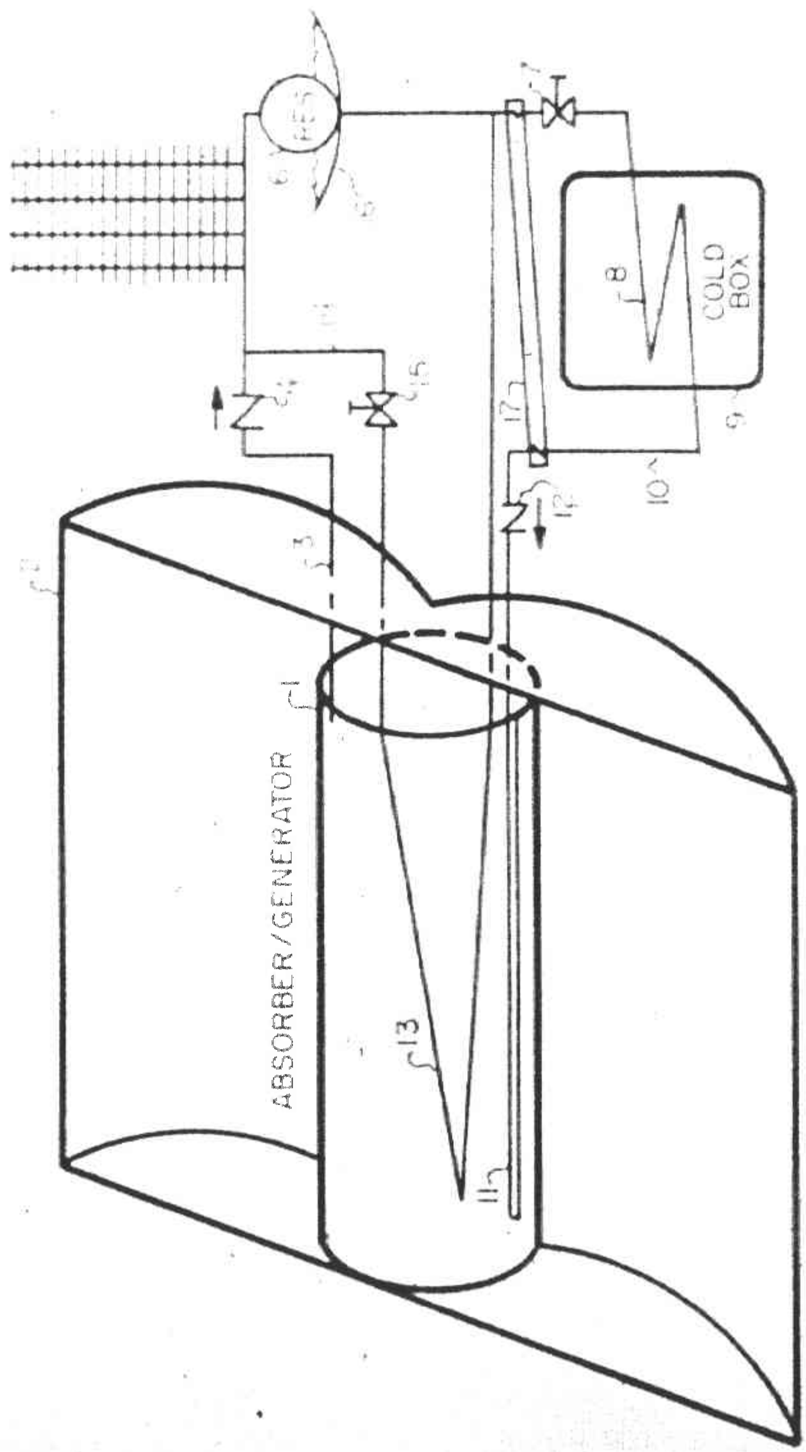
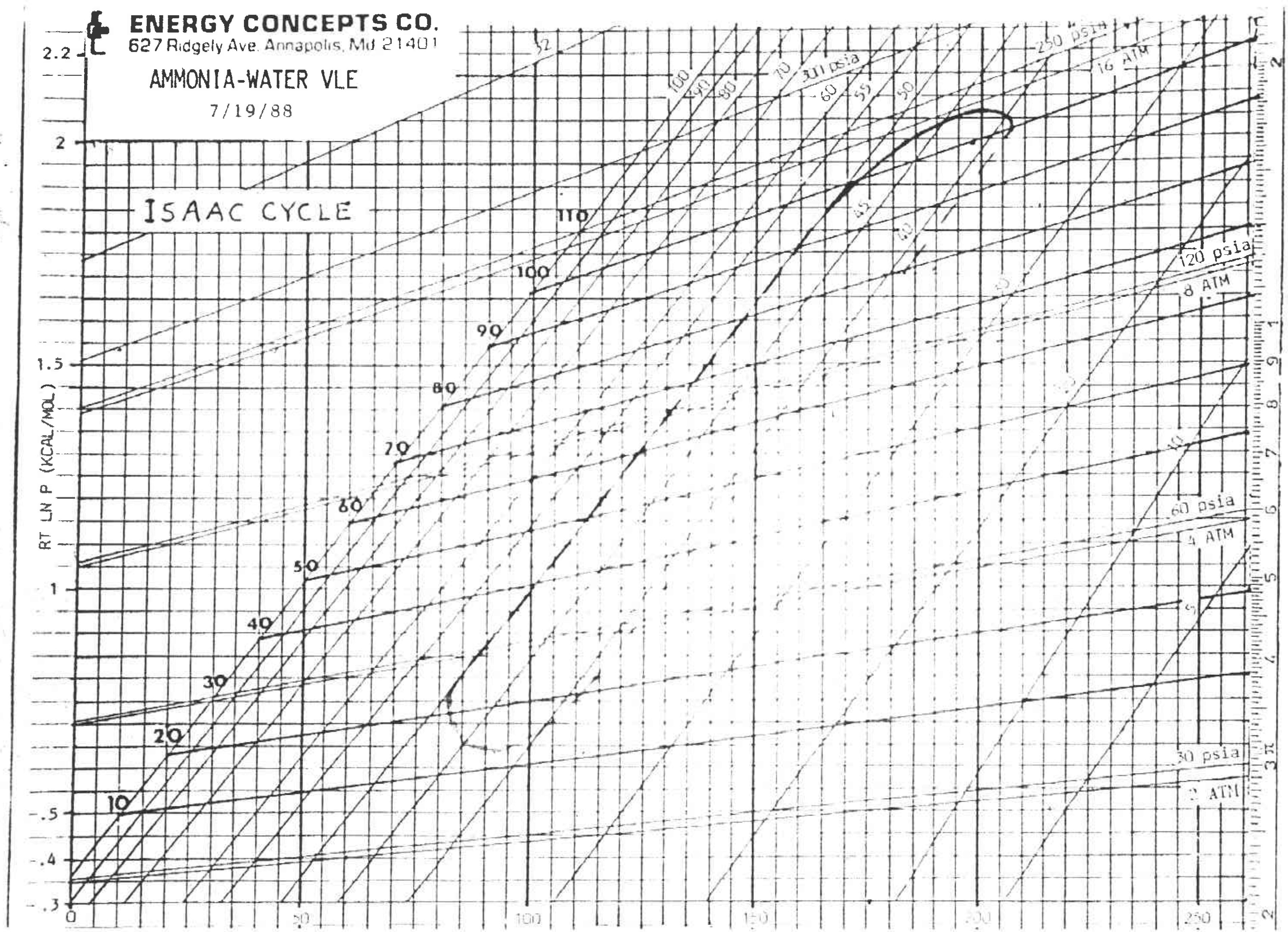


FIG. 1


ENERGY CONCEPTS CO.
627 Ridgely Ave. Annapolis, Md 21401
AMMONIA-WATER VLE
7/19/88
ISAAC CYCLE
RT LN P (KCAL/MOL)
250 psia
16 ATM
300 psia
120 psia
8 ATM
60 psia
4 ATM
30 psia
2 ATM
10
20
30
40
50
60
70
80
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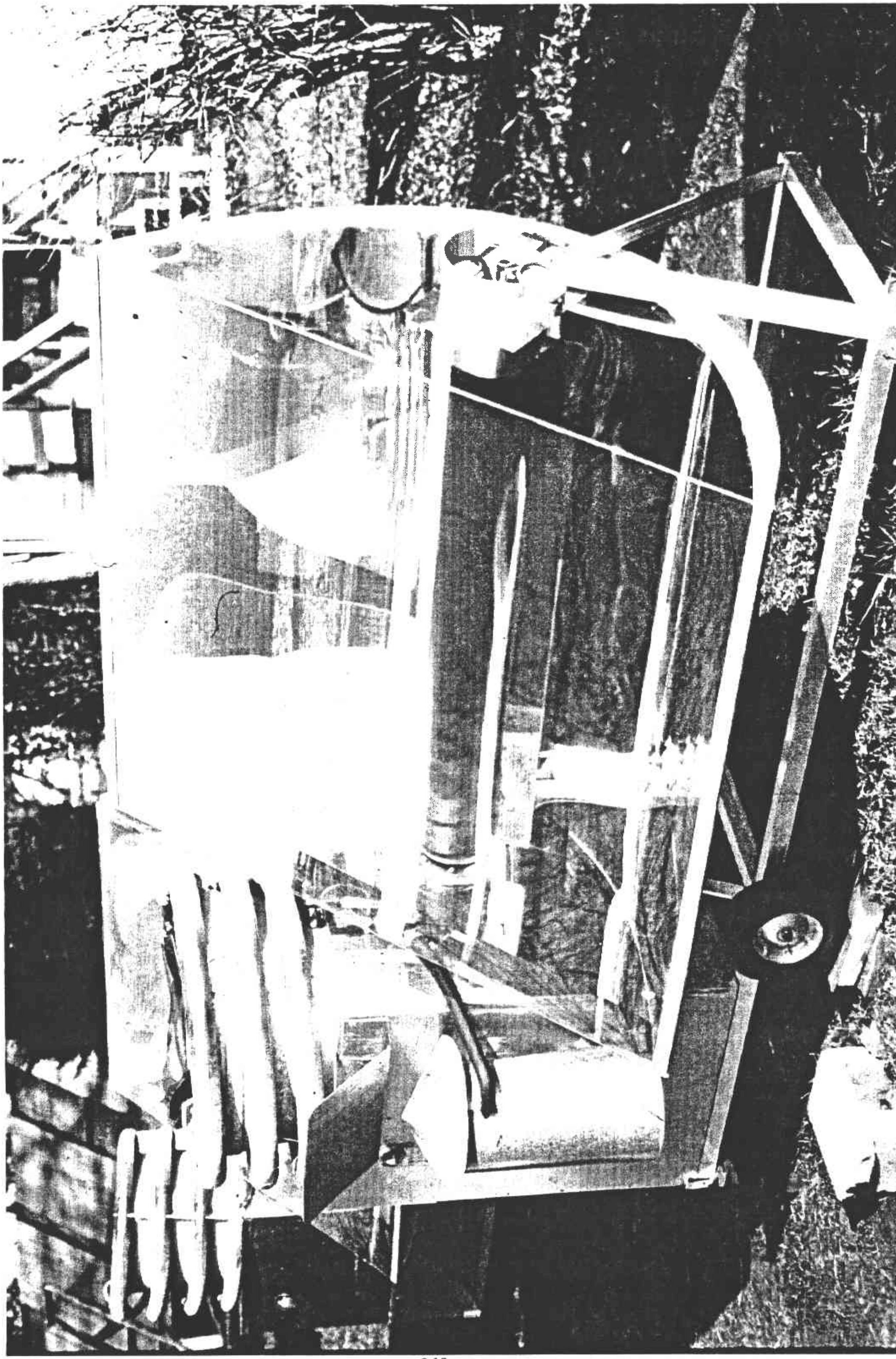
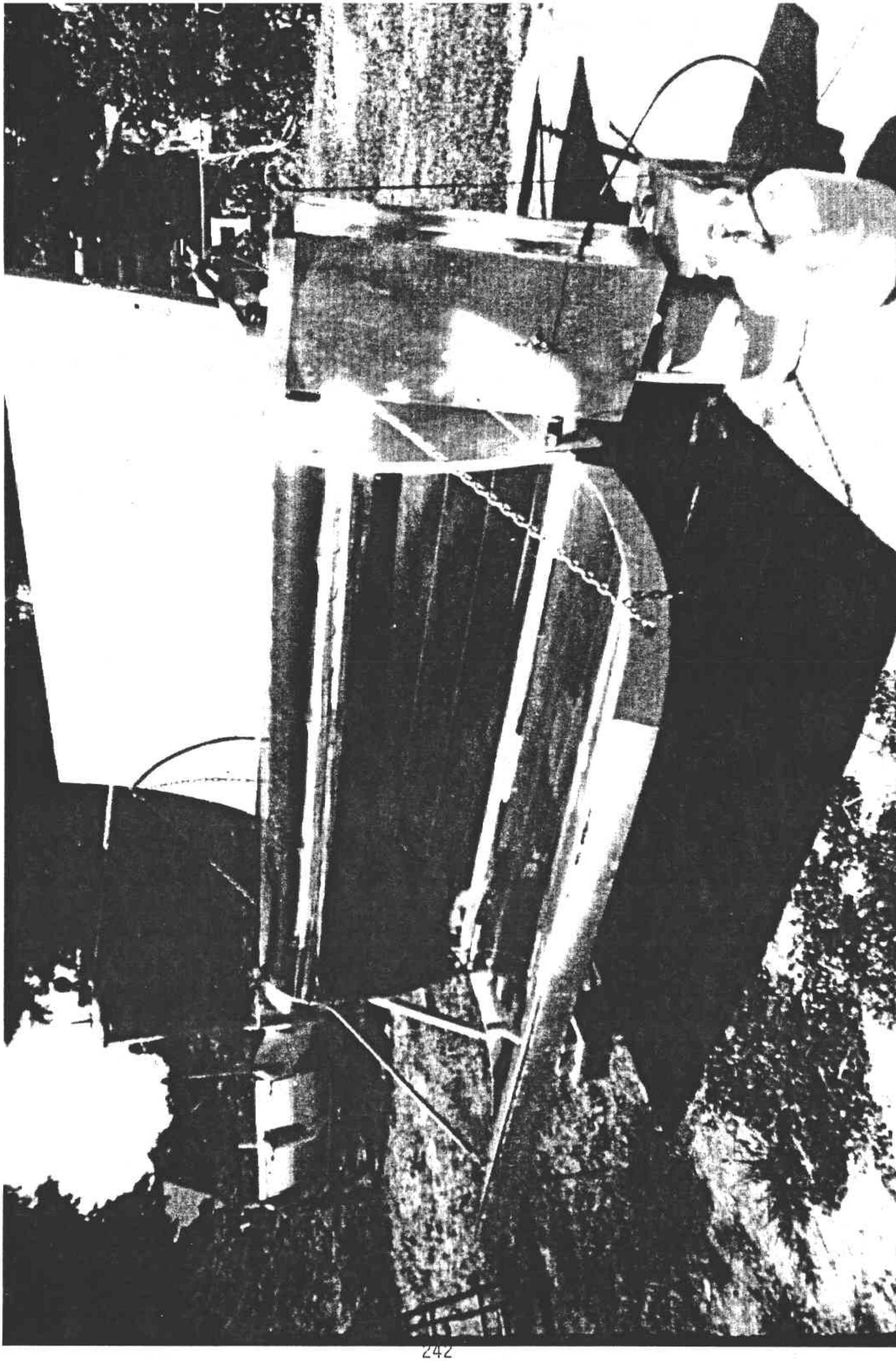
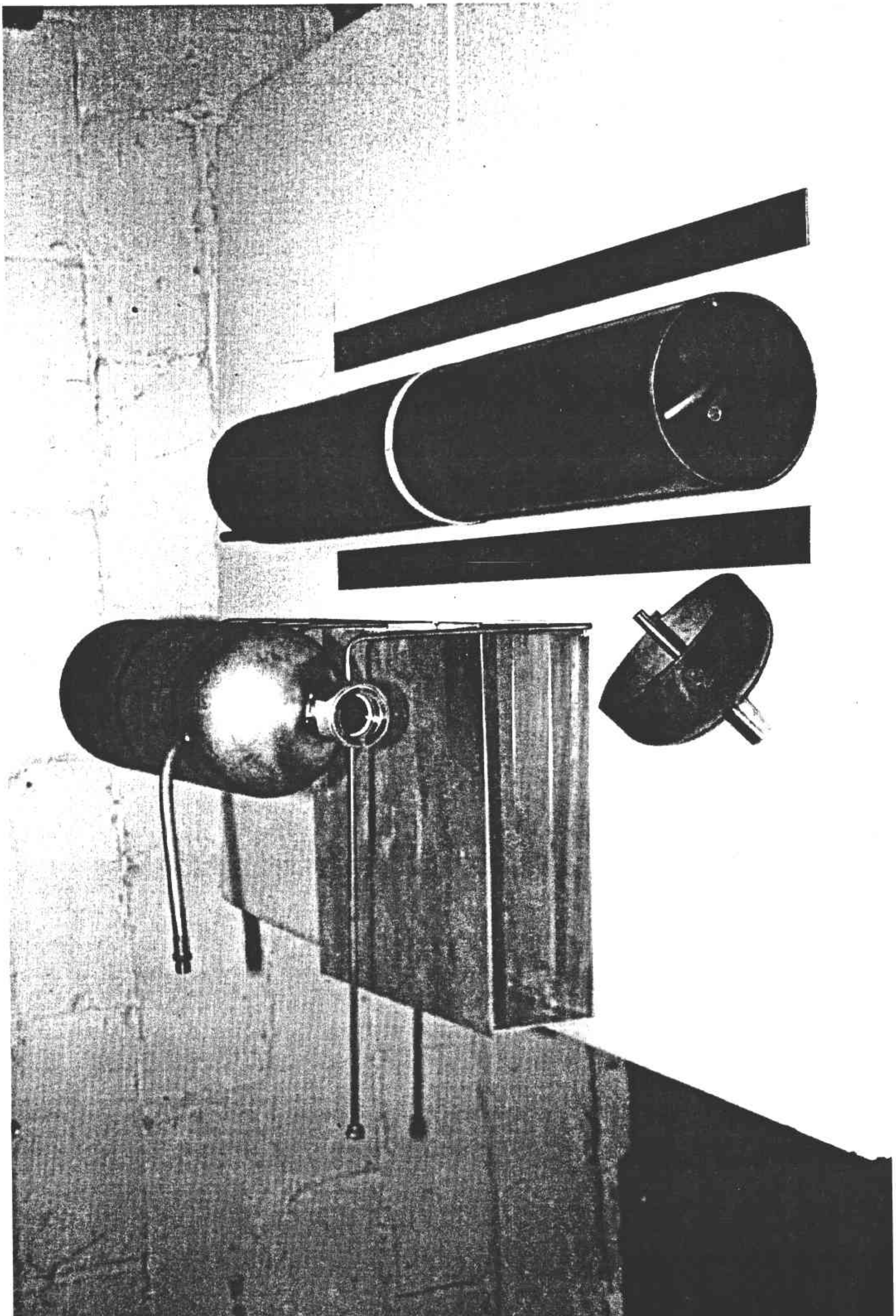
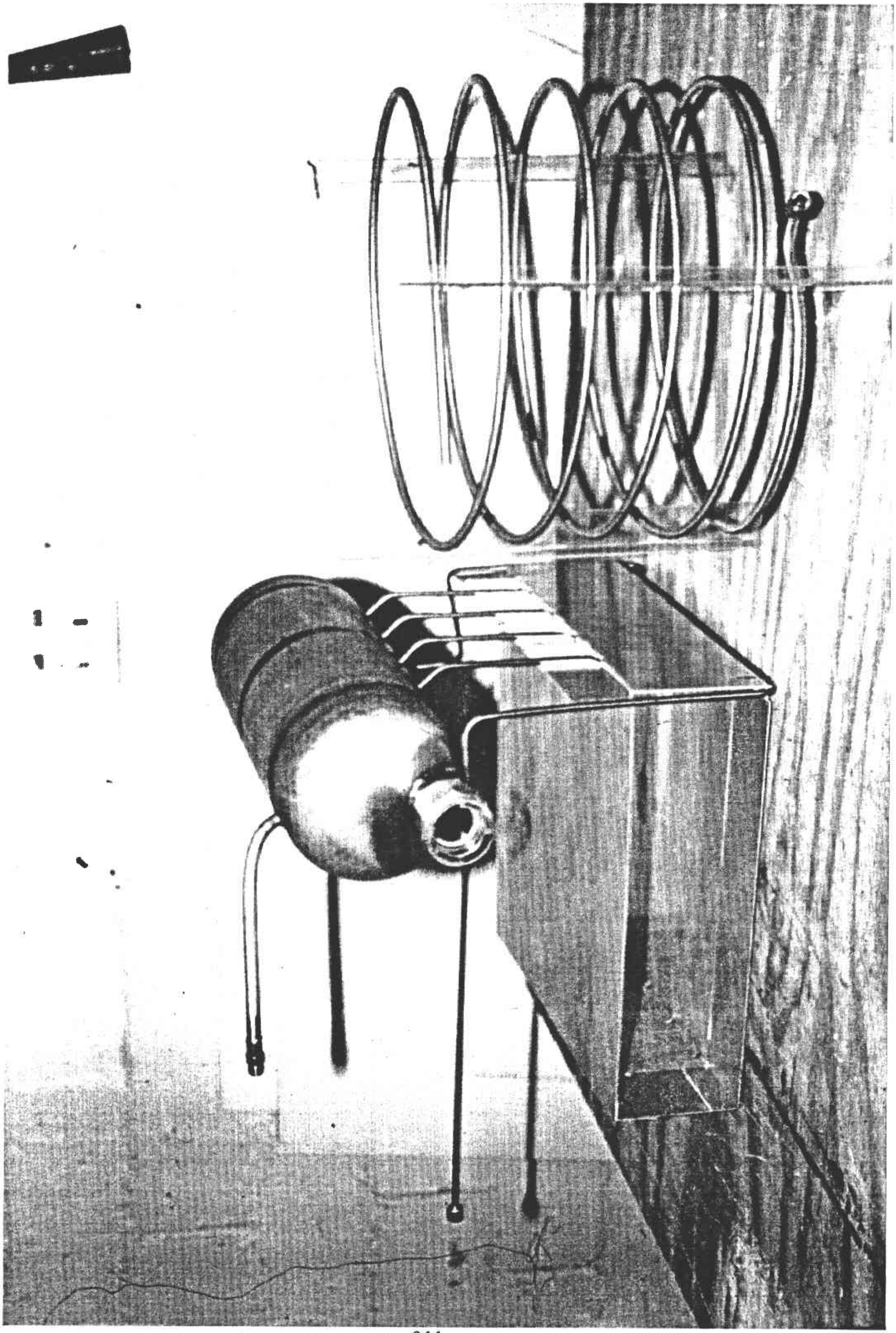
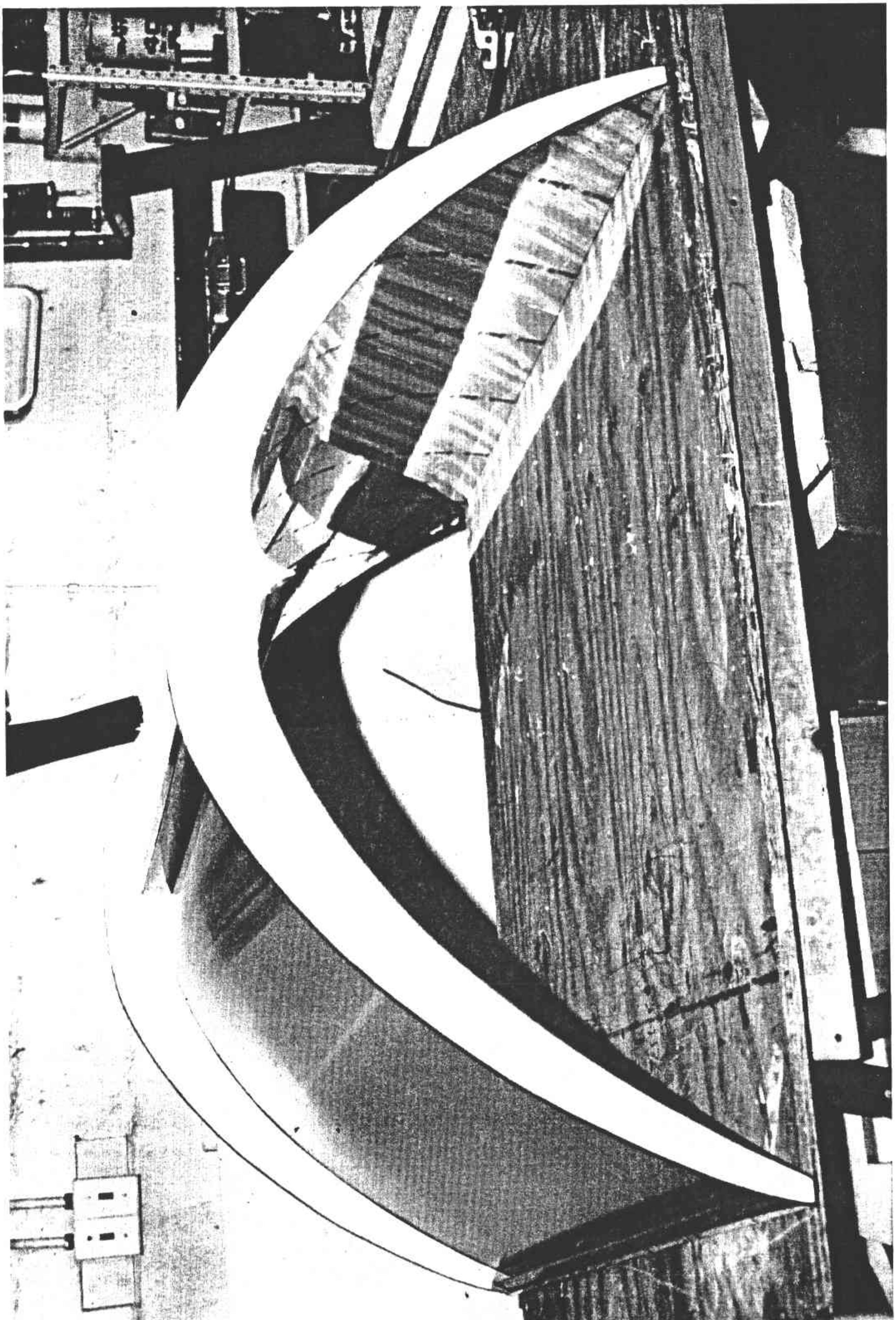
50
100
150
200
250

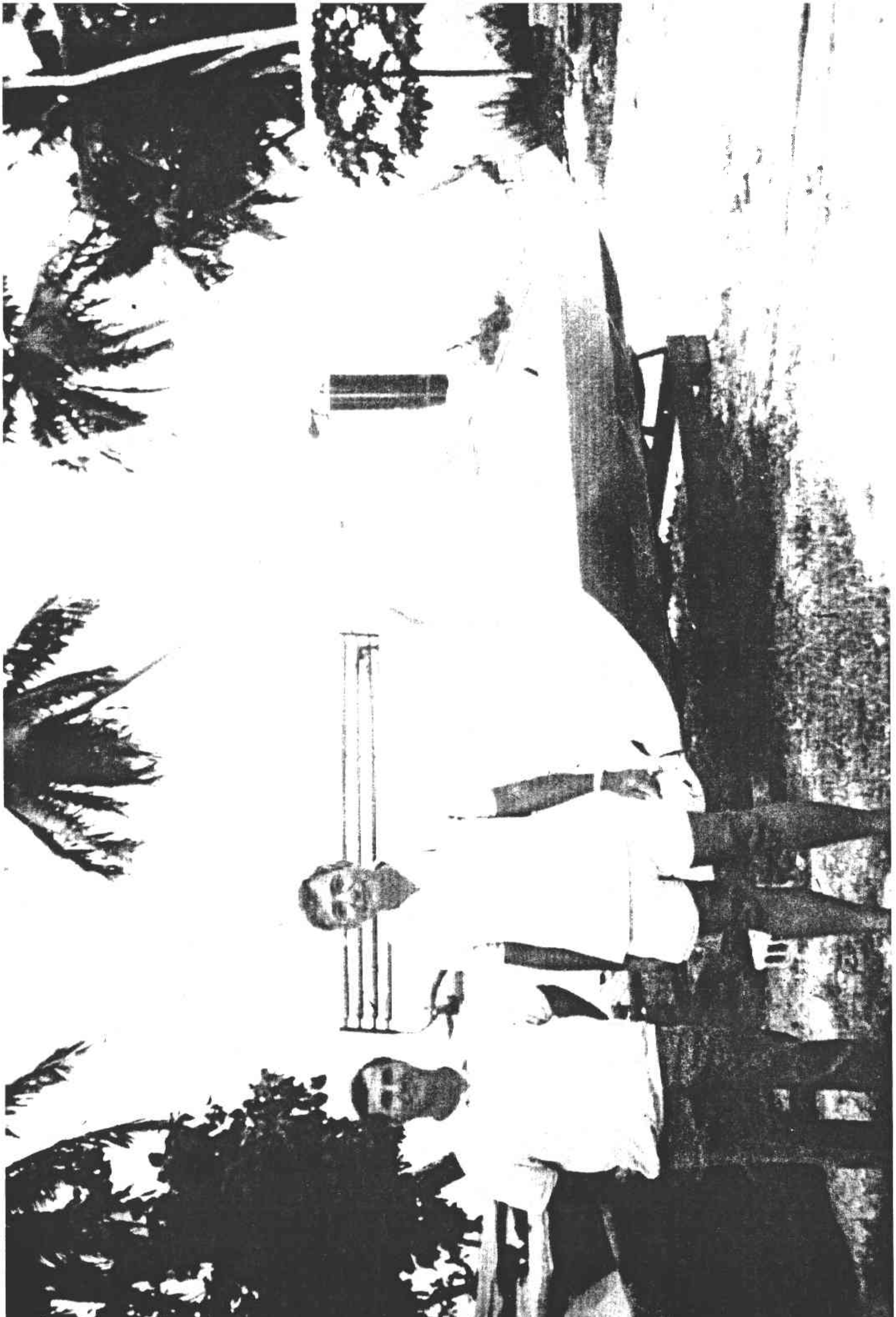










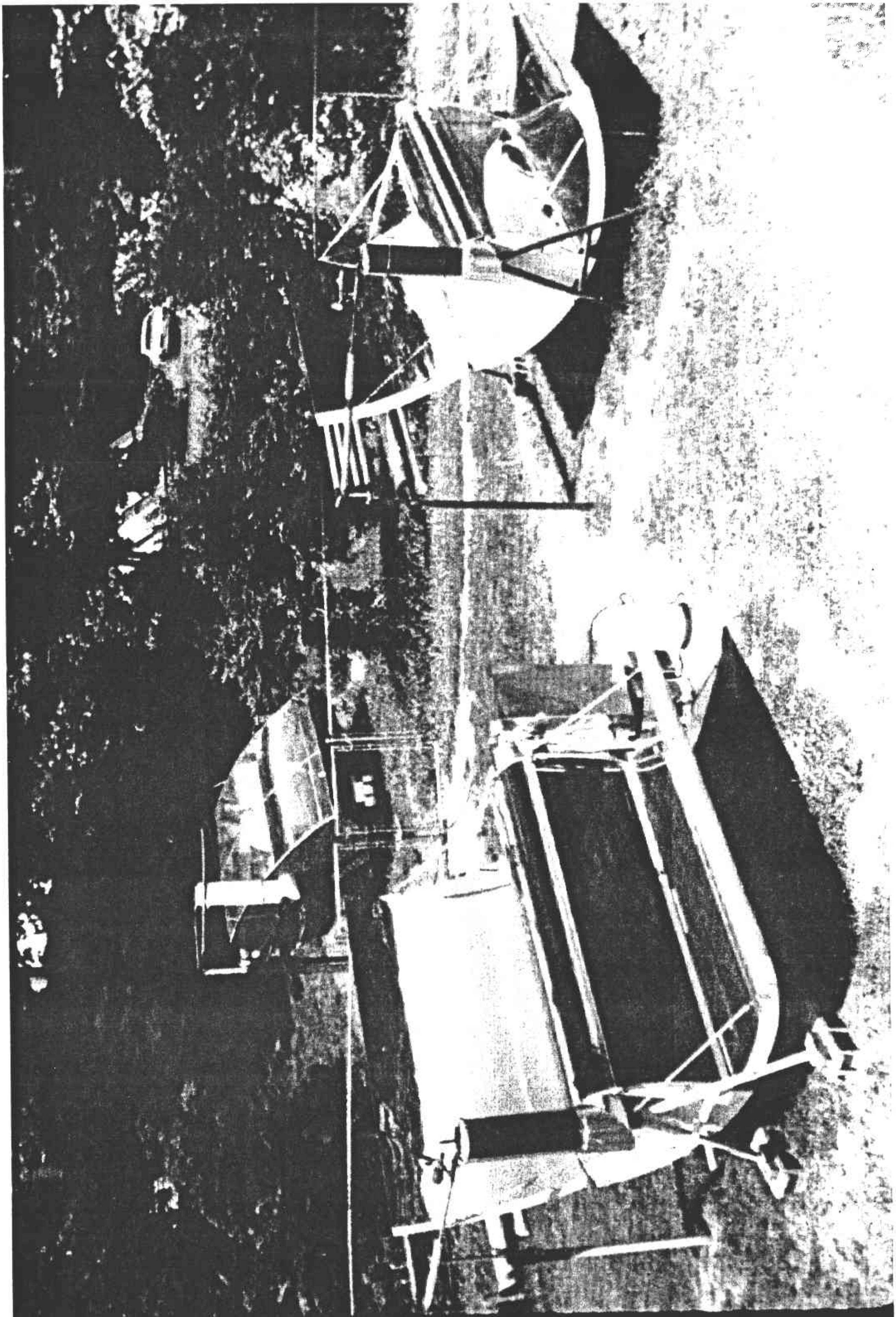


Future Development Needs

Demonstrations
- Significant Scope
- DiverseGeographic Areas

Improvements/New Capabilities
- Cost Reduction--Performance increase
- Constant Temperature Compartment
- Automated Operation

Volume Production Capability
- Facility Design
- Minimize Manufacturing Cost



SOLAR HEAT APPLICATIONS IN CALIFORNIA: STATUS AND PROSPECTS

by Pramod Kulkarni
California Energy Commission

ABSTRACT

The presentation would review the current status of industrial, commercial and institutional solar heat applications in California. It will analyze recent projects and assess their impact on commercialization of the solar heat technologies in California. The presentation will assess the emerging opportunities and discuss factors affecting growth over the next five years.

The public policy objectives regarding energy in the state and their potential impacts on solar heat applications would be discussed. The presentation will review the current programs and projects undertaken by the California Energy Commission to encourage solar applications in the industrial, commercial and institutional sectors.

BIODATA

Pramod Kulkarni is currently working at the California Energy Commission. He specializes in the commercialization, economics and financing issues affecting alternative energy technology options. Before joining the Commission, he was associated with the National Center for Appropriate Technology and worked with energy project developers, financiers and users of energy in industrial and commercial sectors. He has been working in energy technology, project development and financing fields for the last fifteen years. His other experiences include working with an independent power project developer and working as a financial analyst for a FORTUNE 200 company.

He has a MBA from the University of Minnesota, a M.S. and B.S. from Delhi University, India.

He could be reached at (196) 324-3530, FAX (916) 327-1879.

SOLAR HEAT APPLICATIONS IN CALIFORNIA: STATUS AND PROSPECTS

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PRAMOD KULKARNI
CALIFORNIA ENERGY COMMISSION
MARCH 27, 1991

SOLAR INDUSTRIAL PROCESS HEAT APPLICATIONS IN CALIFORNIA

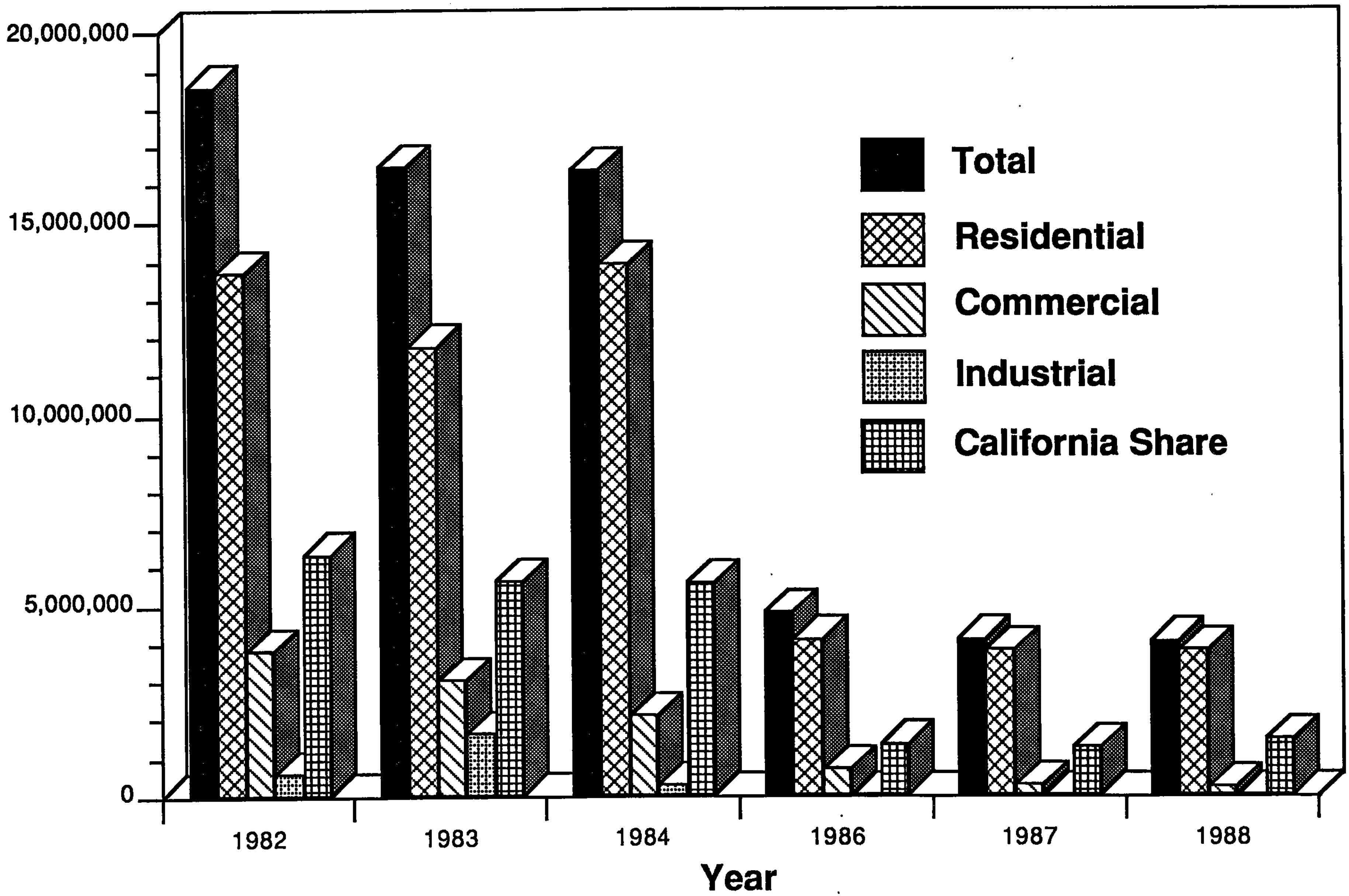
* DEVELOPMENTS SINCE 1985
* CURRENT STATUS
* ANALYZE RECENT DEVELOPMENTS
* PROSPECTS IN THE NEAR FUTURE
* FACTORS AFFECTING GROWTH
* CALIFORNIA ENERGY COMMISSION PROGRAMS

* CALIFORNIA IS THE LARGEST SOLAR COLLECTOR MANUFACTURING STATE

* CALIFORNIA IS THE SECOND LARGEST RECIPIENT OF SOLAR COLLECTORS

* MAXIMUM SOLAR COLLECTORS INSTALLED IN 1985

U.S. Solar Collector Shipments by Market Sector



* DRAMATIC DROP IN THE SHIPMENTS IN 1986

* SHIPMENTS STABILIZED IN RESIDENTIAL SECTOR AFTER INITIAL DROP

* DROP MORE PRECIPITOUS IN SHIPMENTS TO COMMERCIAL & INDUSTRIAL SECTORS

* LITTLE COMMERCIAL, INDUSTRIAL DEVELOPMENTS IN IPH SINCE 1985

* CONSOLIDATION OF SMALL, PRE 1985 PROJECTS IN MINI UTILITIES

* MINI SOLAR-THERMAL UTILITIES CATERING TO 800 ACCOUNTS WITH 1.25 MILLION SQ. FT.

* MINI UTILITIES POSSIBLE BECAUSE OF EFFICIENT MAINTENANCE AND EFFICIENCY IN BILLING

ONLY THREE MAJOR IPH PROJECTS IDENTIFIED

1.	TECHACHAPI	PARABOLIC TROUGH	INSTITUTIONAL
2.	NORDHAVEN	PARABOLIC TROUGH	INDUSTRIAL THERMAL
3.	BERGQUAM	FLAT PLATE	COMMERCIAL SPACE CONDITIONING

* **IMPORTANT BECAUSE:**

- PRIVATE FINANCING
- APPLICATION DIVERSITY
- LOW TAX CREDIT

FACTORS CONSIDERED BY IPH CUSTOMERS:

- RELIABILITY & AVAILABILITY
- LOW MAINTENANCE COST
- ECONOMICS COMPARABLE TO OTHER ENERGY SOURCES
- NO INTRUSION ON NORMAL OPERATIONS
- FUEL GUARANTEES
- GUARANTEED SAVINGS/PERFORMANCE
- ADEQUATE & SUSTAINED CASH-FLOW TO MEET FINANCIERS' NEEDS
- NO NEGATIVE ENVIRONMENTAL IMPACT/HELP POLLUTION ABATEMENT

ARE THE THREE PROJECTS ABERRATIONS OR ARE THEY FOR REAL?

HOW WELL HAVE THESE MET THE CONDITIONS THAT WOULD LEAD TO DUPLICATION?

THE THREE PROJECTS HAVE MET MOST OF THE CONDITIONS:

- **RELIABLE AND AVAILABLE**
- **NON-INTRUSIVE**
- **DEVELOPER/TECHNOLOGY VENDOR BEARS RISK**
- **HAVE GUARANTEED PRICE OR KNOWN ENERGY PRICE**
- **PROVIDED COMPARABLE OR LOWER ENERGY COST**
- **VENDOR ABLE TO RAISE FINANCING**

OBTAINING FINANCING HAS BEEN A MAJOR ACCOMPLISHMENT

HOW DOES PROJECT FINANCING LOOK:

- SOLAR PROJECTS TYPICALLY HAVE LONGER PAYBACKS
- PAYBACKS 2 TO 4 YEARS IN ENERGY EFFICIENT INSTALLATIONS
- STATE LOOKS FOR 7 YEAR OR QUICKER PAYBACK
- FINANCIERS LOOK FOR AT LEAST 15% OR ABOVE RETURNS
- FINANCIAL RETURNS MODEST IN EXCHANGE FOR MODERATE RISK

IN SPITE OF TECHNICAL FEASIBILITY, MARGINAL ECONOMICS MAKE IT DIFFICULT TO MEET THE ABOVE EXPECTATIONS IN RENEWABLE ENERGY.

WHAT NEEDS TO HAPPEN TO CHANGE PICTURE FROM MODEST RETURNS TO HIGH RETURNS:

- INCREASE IN THE VALUE OF THE COMMODITY CREATED
- INCREASE OUTPUT SUBSTANTIALLY FOR SAME CAPITAL - NOT PROVEN FOR THE NEAR FUTURE
- LOWER CAPITAL COST - POSSIBLE BY MASS PRODUCTION
- LOWER PROJECT DEVELOPMENT COSTS

DESPITE MARGINAL ECONOMICS COMMON FOR SOLAR PROJECTS, THE RECENT DEVELOPMENTS ARE ECONOMICALLY FEASIBLE WITH:

- EXTREMELY LOW PRICED OR FREE LAND & SPACE
- LARGE ENOUGH INSTALLATIONS TO PROVIDE ECONOMIES OF SCALE
- PERFORMANCE RISK BORNE BY DEVELOPERS/FINANCIERS
- NO DEMAND FOR CAPACITY GUARANTEE, BACKUPS PROVIDED BY USERS
- PARTIAL DISPLACEMENT, NO SUBSTITUTION FOR MAIN ENERGY SOURCE
- STABLE, CREDIT-WORTHY CUSTOMERS
- GUARANTEED LONG-TERM THERMAL LOADS
- WILLING CUSTOMER DESPITE WIDE SKEPTICISM BY MASSES
- FINANCIERS KNOWLEDGEABLE/SYMPATHETIC WITH SOLAR INDUSTRY

LIKELY MARKET CONDITIONS FOR NEAR FUTURE

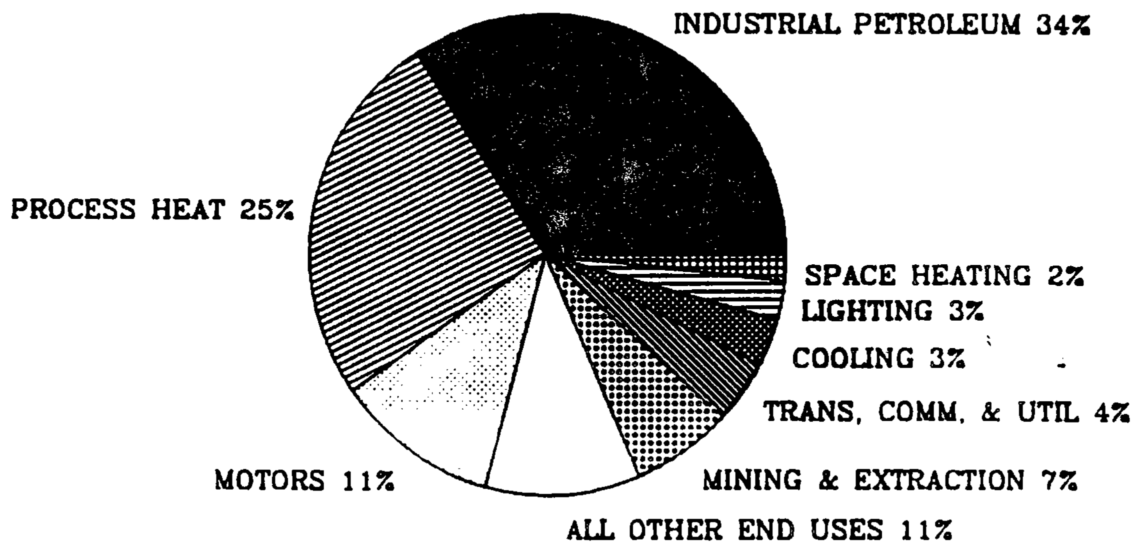
- STABLE FOSSIL FUEL SUPPLIES WITH NO DRAMATIC PRICE INCREASE ANTICIPATED
- ENERGY CONSCIOUS & ENVIRONMENTALLY CONSCIOUS IPH CUSTOMERS
- FORMALIZED & RECOGNIZED ENERGY MANAGEMENT ACTIVITIES
- CONSERVATION MEASURES MORE ENTRENCHED (e.g., more efficient boiler & system efficiencies)

HOW BIG IS THE CALIFORNIA IPH MARKET?

LET US START WITH MAXIMUM POTENTIAL AND ARRIVE AT PRACTICAL IN THE NEXT FIVE YEARS

- INDUSTRIAL
- COMMERCIAL
- INSTITUTIONAL

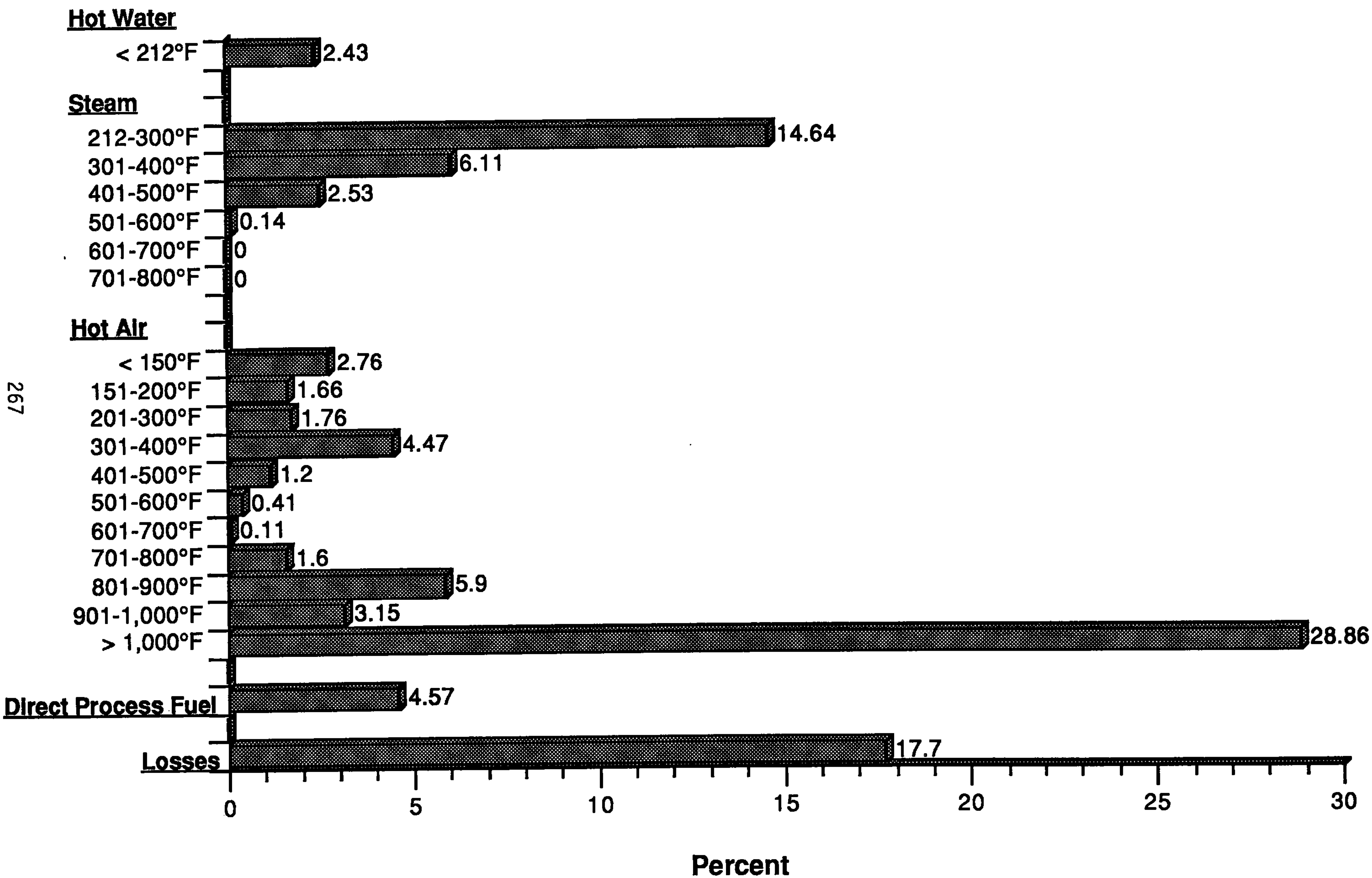
Largest Industrial Energy End Uses
In California for 1987



TOTAL INDUSTRIAL ENERGY
2.1 QUADS

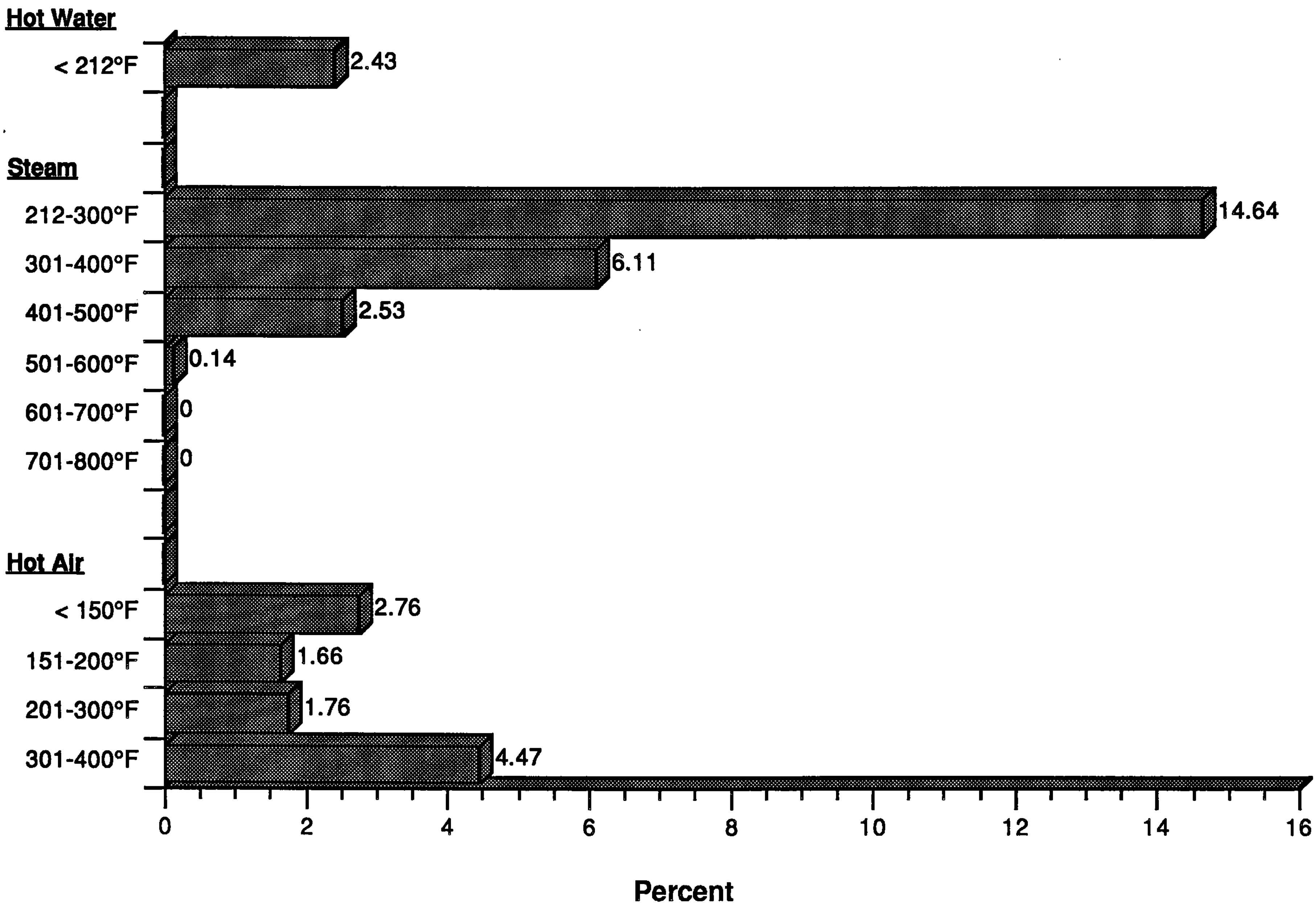
CEC CR'90 Data
TOP9IND.CHT

Purchased Fuels by End-Use/Temperature Level
California, Year 1990



Source: Energy End-Use Requirements in Manufacturing.
SERI. July 1981. SERI/TR-733-790R

Purchased Fuels by End-Use/Temperature Level
California, Year 1990



Source: Energy End-Use Requirements in Manufacturing.
SERI. July 1981. SERI/TR-733-790R

MARKETS IN INDUSTRIAL SECTORS

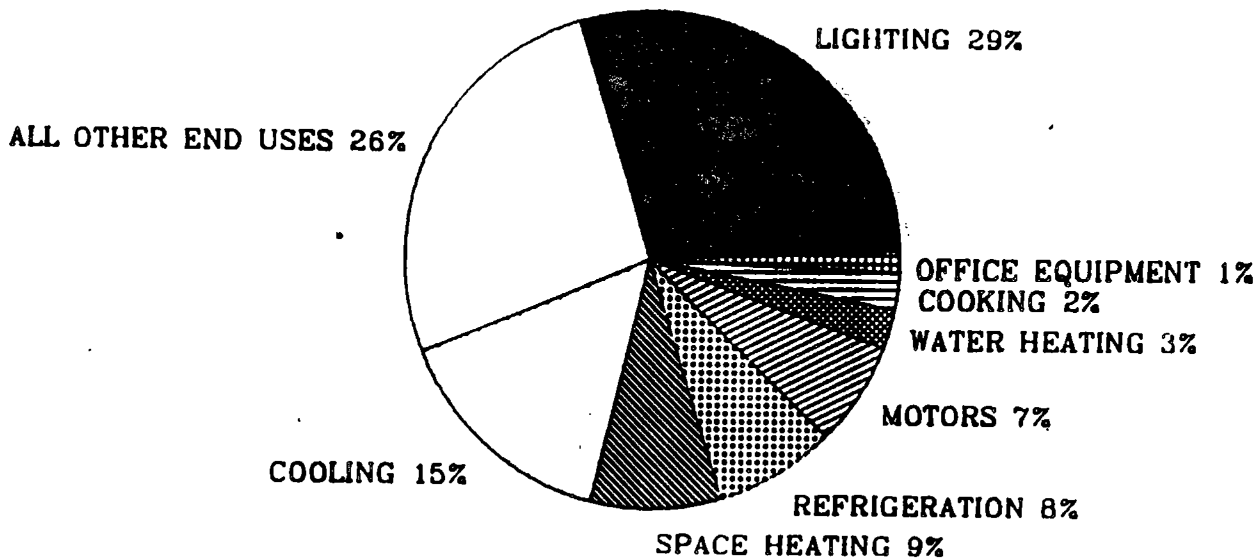
INSTALLATION POTENTIAL FOR APPLICATIONS BELOW 400°F

- 34% OF ALL INDUSTRIAL ENERGY USED FOR TEMPERATURES BELOW 400°F
- THIS IS ABOUT 200 TRILLION BTUS
- EQUALS 400,000 NORDHAVEN-SIZE PROJECTS
- BUT MARKET LIMITED BY LAND/TIMING/SEASONALITY CONSIDERATIONS

WHAT IS PRACTICAL IN THE NEXT 5 YEARS?

- GIVEN PRESENT STATUS OF VENDORS, FINANCING & TECHNOLOGIES
- NO MORE THAN 10 PROJECTS LIKE NORDHAVEN

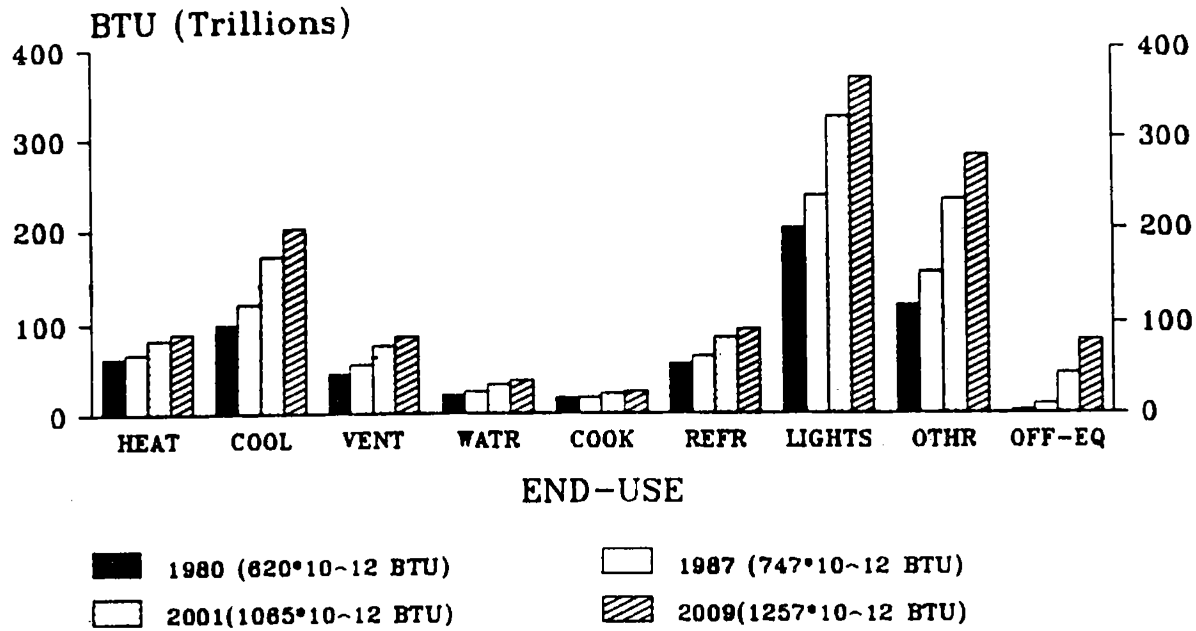
Largest Commercial Energy End Uses
In California for 1987



TOTAL COMMERCIAL PRIMARY ENERGY
0.8 QUADS

Source: "1989 Fuels Report," California Energy Commission; "California Energy Demand, 1989-2009," California Energy Commission. See also Appendix A-4.

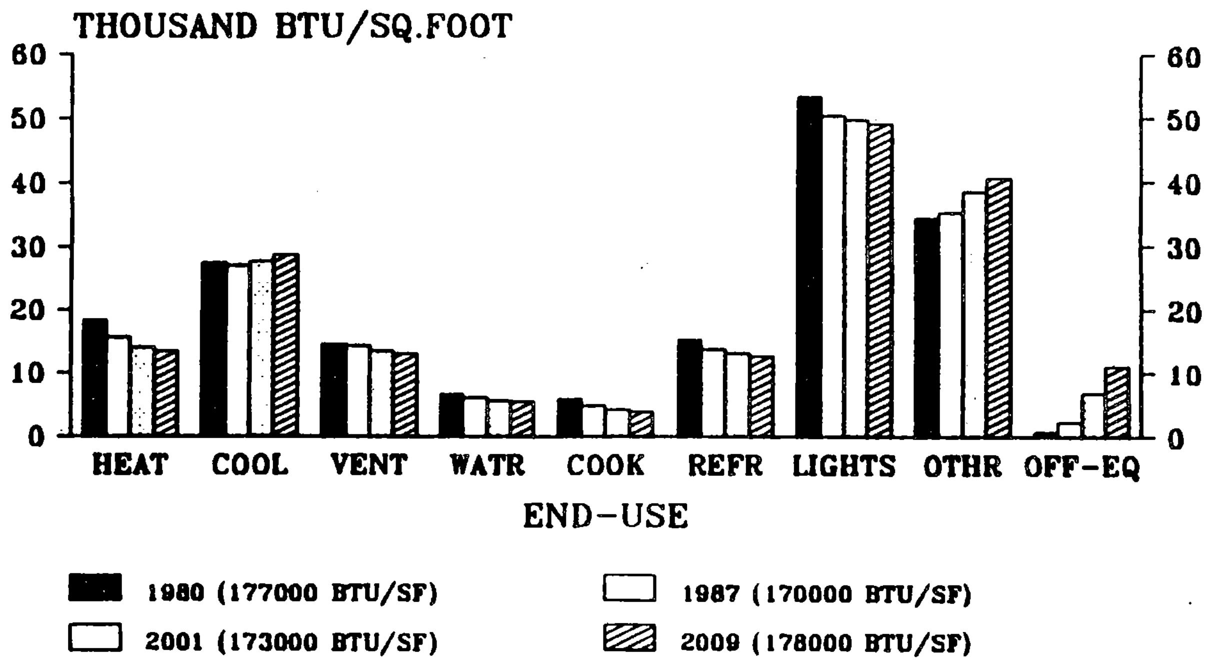
PRIMARY ENERGY USE
COMMERCIAL SECTOR–STATEWIDE



Combined electricity and natural gas use for each forecast year is shown in parentheses. COM-TOTL.CHT

Source: "California Energy Demand, 1989-2009," California Energy Commission.

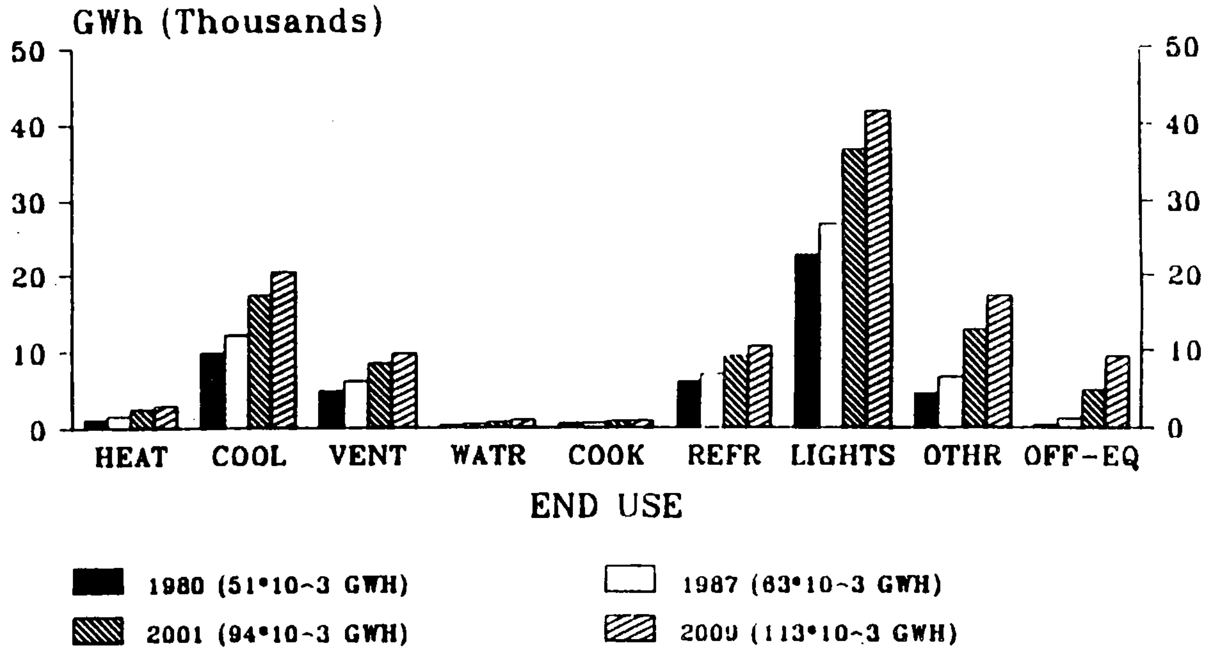
COMMERCIAL NATURAL GAS AND ELECTRICITY USE PER SQUARE FOOT



Combined natural gas and electricity use per square foot for each forecast year is in parentheses. COM-TPSF.CHT

Source: "California Energy Demand, 1989-2009," California Energy Commission.

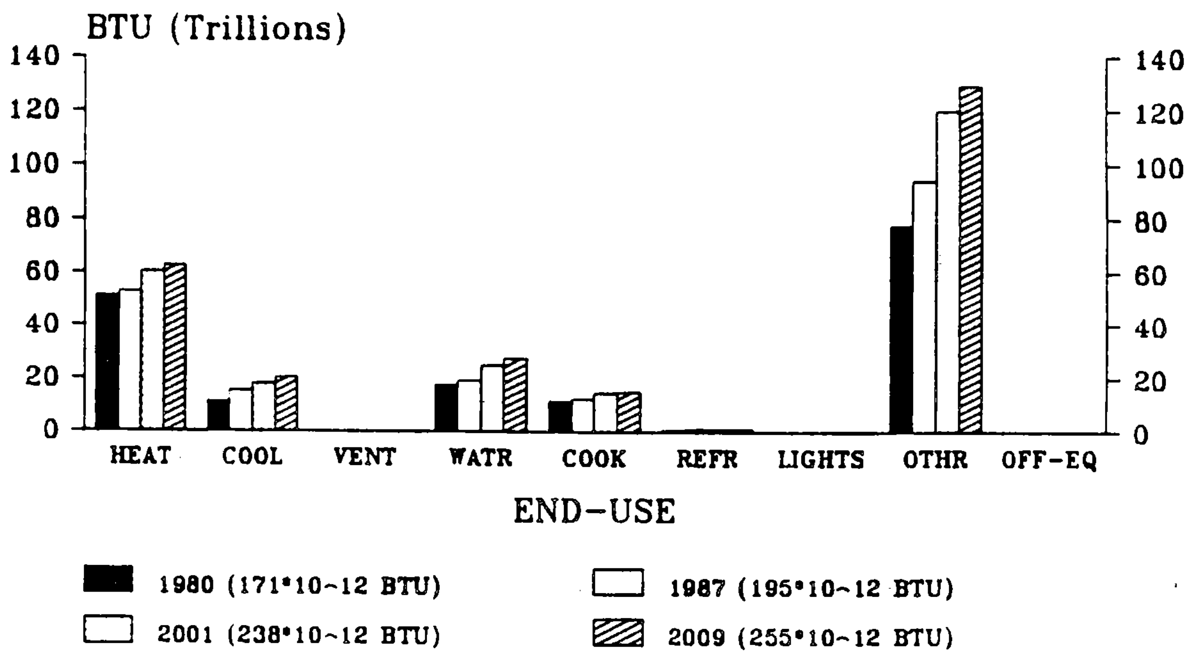
COMMERCIAL ELECTRICITY USE
STATEWIDE



Numbers in parentheses are total GWH for each forecast year.
COM-ELEC.CHT

Source: "California Energy Demand, 1989-2009," California Energy Commission.

COMMERCIAL NATURAL GAS USE
STATEWIDE



Total natural gas for each forecast year is shown in parentheses.
COM-NGAS

Source: "California Energy Demand, 1989-2009," California Energy Commission.

WITH THE LEVEL OF PROVEN SOLAR TECHNOLOGY (UNDER 400°F), FOLLOWING STATISTICS ARE OF IMPORTANCE:

* ELECTRICITY AND NATURAL GAS ARE MAIN ENERGY SOURCES IN THE COMMERCIAL SECTOR

* 39% ENERGY USED FOR COOLING, SPACE HEATING AND WATER HEATING

ASSUMING NATURAL GAS DISPLACEMENT AS MOST LIKELY POTENTIAL, CONSUMPTION PROJECTIONS FOR THE COMMERCIAL MARKET FROM 1991 TO 1995:

*	HEATING	55 TRILLION BTUS	25.0%
*	COOLING	20 TRILLION BTUS	9.0%
*	WATER HEATING	35 TRILLION BTUS	16.0%
*	REFRIGERATION	2 TRILLION BTUS	1.0%
*	OTHER	110 TRILLION BTUS	50.0%
TOTAL		222 TRILLION BTUS	

OTHER INCLUDES COMMERCIAL LAUNDRY AND POOL HEATING IN HOTELS/MOTELS.

SPACE HEATING, COOLING AND WATER HEATING IS 47% - 105 TRILLION BTUS.

THE CONDITIONS OF SPACE AVAILABILITY, EXISTING ENERGY PRICES & FINANCING AVAILABILITY WOULD DETERMINE THE MARKET DEVELOPMENT.

WHEN YOU ADD USE OF ELECTRICAL ENERGY, THE MARKET FOR COOLING, HEATING AND WATER IS AS FOLLOWING:

CONSUMPTION STATUS AND PROJECTIONS FOR 1991 TO 1995 ARE:

*	HEATING	85 TRILLION BTUS	10.0%
*	COOLING	140 TRILLION BTUS	17.0%
*	WATER HEATING	40 TRILLION BTUS	5.0%
*	REFRIGERATION	75 TRILLION BTUS	9.5%
*	LIGHTS	280 TRILLION BTUS	35.0%
*	OTHER	170 TRILLION BTUS	21.0%
TOTAL		790 TRILLION BTUS	

INSTITUTIONAL MARKET FOR IPH APPLICATION IS MORE DEFINABLE

* SMALLER NUMBER OF END-USERS
* LARGER SIZES
* OCCASIONALLY NON-FINANCIAL CONSIDERATIONS ALLOWED

A RECENT PRELIMINARY SURVEY IDENTIFIED ABOUT THIRTY LARGE-SCALE FACILITIES WHICH HAVE:

- GOOD TO EXCELLENT SOLAR INSOLATION
- YEAR ROUND THERMAL LOADS
- ABILITY TO PROVIDE MULTI-YEAR CONTRACT
- ACTIVE INTEREST IN FOSSIL FUEL DISPLACEMENT

THE FOLLOWING INSTITUTIONAL MARKET SEGMENTS ANALYZED:

* MILITARY, NAVAL, MARINE & ARMY BASES
* STATE DETENTION & CORRECTIONAL FACILITIES
* UNIVERSITIES AFFILIATED FACILITIES

PROSPECTS FOR SOLAR DEVELOPMENT IN INSTITUTIONAL MARKET:

* 23 SITES HAVE THE BASICS TO DEVELOP SOLAR IPH PROJECTS
* THEY WILL BE AS BIG OR LARGER THAN TEHACHAPI PROJECT
* 7 TO 8 PRISON FACILITIES LIKELY TO EXPLORE SOLAR
* BID ALREADY OUT FOR ONE MORE, WITH MORE FOLLOWING

FACTORS WHICH CAN CAUSE RAPID MARKET DEVELOPMENT

* REGULATORY REQUIREMENTS FROM AIR QUALITY DISTRICTS
  - PROPOSED RULE 1121 FROM SCAQMD
* ACTIVE TRADING FOR EMISSION ALLOWANCES
  - EPA REGULATION AS PER CLEAN AIR ACT AMENDMENTS 1990
  - DEVELOPMENT OF EMISSION CREDIT MARKET
* UTILITY EFFORTS TO REDUCE ELECTRICAL PEAK LOADS
  - REBATES FOR PEAK SHAVING EQUIPMENT
  - CASH PAYMENTS FOR DELIVERED PEAK REDUCTIONS
  - HIGH CAPACITY & ENERGY CHARGES AT PEAK

ANY ONE OF THE ABOVE CAN GENERATE INCREASED MARKET IN CALIFORNIA

WHAT DO THE TECHNOLOGY VENDORS NEED TO DO?

- HAVE A BETTER UNDERSTANDING OF CUSTOMERS ENERGY NEEDS
- BE WILLING TO DEAL WITH MORE ENLIGHTENED IPH CUSTOMERS
- HAVE FINANCING LINED UP
- HAVE MORE UP-FRONT PROJECT DEVELOPMENT COSTS

WHY CALIFORNIA IS INTERESTED IN IPH DEVELOPMENT

PUBLIC POLICY OBJECTIVES SUPPORT THE FOLLOWING:

* FUEL DIVERSITY
* SUBSTITUTION OF FOSSIL FUEL
* ENERGY CONSERVATION & EFFICIENCY
* ALTERNATIVE ENERGY GENERATION
* ENVIRONMENTALLY CLEAN ENERGY

MAJOR ENERGY COMMISSION PROGRAMS AVALIABLE FOR IPH:

- * SMALL BUSINESS TECHNICAL ASSISTANCE & LOAN PROGRAM;
- * ENERGY TECHNOLOGY ADVANCEMENT PROGRAM; AND
- * INSTITUTIONAL CONSERVATION PROGRAM

POSSIBLE PROGRAMS IN THE NEAR FUTURE:

- * STAFF SUPPORT IN SOLAR RFP DEVELOPMENT; AND
- * IDENTIFY & ASSESS SUITABLE SITES

EXAMPLES OF ASSISTANCE TO SOLAR PROJECTS.

* SHORT TERM, LOW INTEREST LOAN TO TEHACHAPI PROJECT
* SHORT TERM, LOW INTEREST LOAN TO BERGQUAM PROJECT
* HELP IN SECURING DOE GRANT & SCAQMD FUNDS FOR SOLAR AIR CONDITIONING
* WORKED WITH DEPARTMENT OF CORRECTIONS TO SECURE SOLAR PROJECTS
* HAVE PROPOSED INITIATIVE TO REDUCE UP FRONT PROJECT DEVELOPMENT COSTS

CONCLUSIONS:

* CAUTIOUSLY OPTIMISTIC
* MORE PROJECTS BUT NO GIANT STRIDES
* MORE PROJECTS IN INSTITUTIONAL SECTORS
* STATE REQUIRES CLEANEST ENERGY AT LOWEST COST
* EXTERNALITIES OF ENERGY PRODUCTION MAY INCREASE MARKET SUBSTANTIALLY

GOULD'S SOLAR INDUSTRIAL PROCESS HEAT SYSTEM
AN UPDATE ON ITS PERFORMANCE AND PLANS FOR UPGRADE

Presented by:

David Knipfer
Plant Mechanical Engineer

Gould Inc., owns and operates a facility near Chandler, Arizona that produces copper foil for integrated circuits. This plant uses a large amount of 200°F hot water for its manufacturing process.

In 1982, a solar industrial process heat system was designed and built on the facility site by Solar Kinetics, Inc. (SKI) using seventy-two SKI T-700 parabolic trough collectors. This 60,480-square-foot system has a designed peak daily output of about 75 MMBTU per day or about 22,000 kWh. Concentrated sunlight is used to heat oil to around 400°F. This oil then produces hot water to replace electrically produced hot water at the boiler. This boiler produces all of the facility's hot water. Electricity to run the boiler is purchased for $0.052 per kWh.

The T-700 collectors use flexible hoses to transport the oil from the field supply lines to the trough's glass-insulated collector tubes. A photoelectric cell is used to direct the tracking and focusing controls.

From the summer of 1983 to the fall of 1987, the solar plant's equipment availability was about 90%. However, during this period, numerous failed flexhoses were replaced under warranty. Hose failures have accelerated since then, and currently occur about every 8-9 months or after about 1,000 operations. Tracking control problems as well as some reflective film delamination are also reducing plant availability and output. As a result, the system is currently operating at about a 50% availability. About 90% of the lost availability is due to hose problems.

By early 1990, the solar system reached a critical stage. The Gould engineers ran out of spare flexhoses and were reluctant to purchase exact replacements because of their high failure rates. They were also unsure about the cause of the flexhose problems and, therefore, had little guidance about potential solutions such as purchasing different types of hoses. However, the Gould engineers and management agreed that if the problems could not be permanently corrected, the plant would be removed from the site.

Gould contacted Sandia's Solar Thermal Design Assistance Center for technical assistance. In May of 1990, Sandia engineers visited the plant for a technical evaluation. During the visit, the plant's major problems were discussed and a number of possible solutions were identified, particularly for the problems relating to flexhose failures. Based on the evaluation, Gould and Sandia engineers developed a three-phase approach that identifies and solves the technical problems, documents the plant's economic potential, and proposes upgrades for the plant.

The goals of the first phase were to design and install the appropriate performance monitoring equipment to assess the plant's actual energy production and to provide a first-order estimate of its economic potential. Phase one was also intended as a trial period for some of the corrective measures for the flexhose, control, and reflective film problems that were outlined by Sandia engineers following the field evaluation.

The second phase's goal is to determine the evaluation criteria for verifying the plant's cost, performance, and reliability. Based on the evaluation criteria, the plant will be operated and monitored for a sufficient period to justify expenditures for a complete upgrade. A complete, long-term operation plan will also be developed for an upgraded plant.

The objectives of the third phase will be to perform the upgrades and to operate the plant in a full production mode.

The first phase of this effort is complete. Sandia engineers have provided Gould with eight advanced generation flexhoses for evaluation on the system. These used hoses were obtained from Sandia's surplus yard and retrofitted with appropriate end fittings. They were tested on the Gould system for nine months without a failure. Considering that the hoses were used, Gould engineers concluded that these hoses were superior to the ones presently used in the field and would be appropriate for use in permanently upgrading the system.

Gould engineers also refurbished the insolation monitoring station, installed a BTU meter near the boiler, adjusted the trough tracking controls to minimize unnecessary flexing, and began repairing the delaminated section of the reflective film. These changes were based on Sandia recommendations.

Data from the BTU meter and the insolation station have been used to estimate the potential savings from an upgraded, fully operational plant. Gould concludes that energy savings of about $10,000 per month are possible.

As a result, Gould has decided to proceed into the second phase of the plan, which has just begun. Gould engineers have developed a criteria for verifying the cost, performance, and reliability of the plant, and for justifying permanent upgrades for long-term operation. The criteria, which were based on in-house economic guidelines, specify an exact performance objective over a fixed period of time. Sandia engineers have also begun work to identify a flexhose manufacturer that can supply the advanced generation flexhoses as needed. Additionally, Gould and Sandia engineers are planning to work with SKI to develop and test a small prototype modification to the existing control system that will eliminate all unnecessary hose flexing. Sandia has also agreed to provide a one-day, on-site training workshop on identifying and correcting field operational problems such as bad control boards, malfunctioning sun sensors, and broken receiver glass tubes. Finally, Gould will continue to consult with Sandia in interpreting and analyzing the plant's recorded performance data.

This presentation outlines this project in detail starting with a brief history of the plant and its early successes. Operational problems are outlined, especially those involving flexhoses. A description of the three-phase program developed by Gould and Sandia is discussed in detail including some of the data collected to date. Time lines are presented that show the progress on phase 1 and the plans for phase 2. The presentation concludes with some thoughts about the benefits of this cooperative effort to Gould as well as to the national solar program. Specifically, the benefits and critical aspects of Sandia's technical assistance will be described.

GOULD's Solar Industrial Process Heat System – an Update on Its Performance and Plans for Upgrade

Presented by

David C. Knipfer,
Plant Mechanical Engineer

GOULD

HISTORICAL OVERVIEW

- Gould plant near Phoenix produces copper foil
- Hot water is an important part of the process
- Solar IPH system installed in 1982 to supplant electrically heated water

GOULD

GOULD IPH SYSTEM

- 60,480-ft^2 parabolic trough built by Solar Kinetics, Inc. (SKI); designed daily peak production capacity of 75 MMBTU or 22,000 kWh
- Oil is heat-transfer medium; heated oil at about 400°F exchanged to produce about 200°F water
- Trough reflector is aluminized film, tracking control performed by photocell
- Flexhoses used to transport oil from supply lines to trough collector tubes

GOULD

PERFORMANCE SUMMARY THROUGH 1987

- System operated at about 90% availability
- Heat supplied for all three production shifts
- Flexhose failures were common, but covered by warranty. Average failure in less than 9 months or after 1,000 operations
- Few other problems

GOULD

PERFORMANCE SUMMARY AFTER 1987

- Flexhose problems accelerated; spares exhausted
- Some control boards have failed
- Reflective film is delaminating (3-4% loss)
- Current system availability is about 50% – mostly caused by hose problems
- Gould management required documentation of plant's cost, performance, and reliability to justify expenditures for upgrades. Gould engineers were unsure of what corrections were possible

GOULD

SANDIA'S STDAC ASSISTANCE SOUGHT

- STDAC engineers performed a technical evaluation of the plant in May 1990

- Possible solutions identified for problems

- Gould and Sandia developed a three-phase program to:
  1) identify and solve the technical problems
  2) document the plant's economic potential
  3) perform upgrades for long-term operation

GOULD

GOALS OF THE PHASES

Phase 1:

a) Install equipment to assess plant's actual energy production and estimate economic potential
b) Develop, implement, and test solutions for flexhose, control, and reflective film problems

Phase 2:

a) Determine the evaluation criteria to be used to verify the plant's costs, performance, and reliability
b) Operate the plant according to the criteria
c) If successful, develop a plan to upgrade the plant

Phase 3:

a) Implement upgrade plan
b) Develop and implement long-term operation plan

GOULD

PHASE 1 COMPLETED

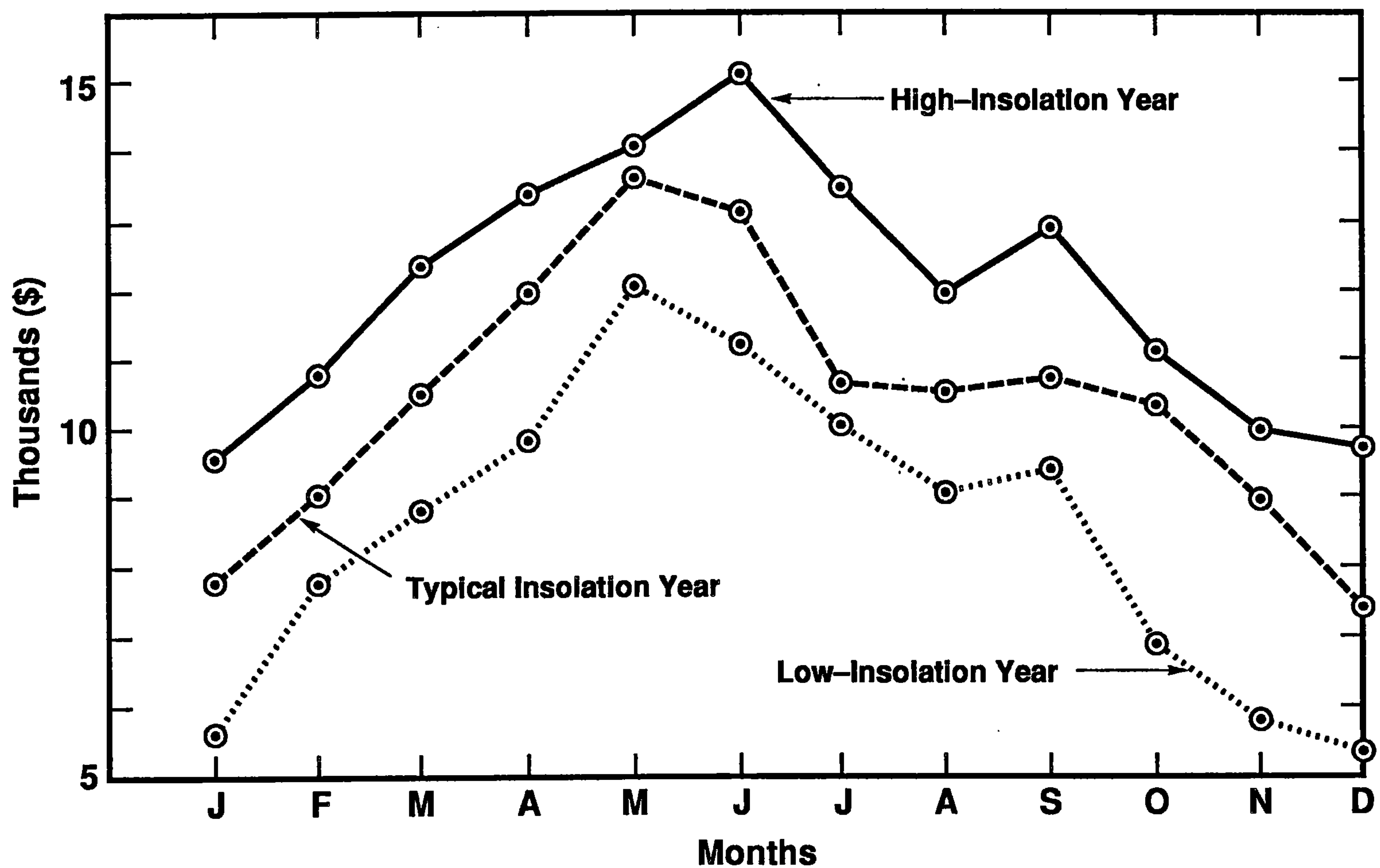
- Sandia provided eight surplus, advanced-generation flexhoses to Gould for field evaluation. No failures in nine months; Gould acceptance given

- Other changes performed by Gould based on Sandia recommendations and/or assistance:
  a) Insolation station refurbished
  b) BTU meter purchased and installed near boiler
  c) Tracking controls adjusted to minimize hose flexing
  d) Repair of delaminated film underway

- Based on data collected in December, Gould estimates plant could save up to $10,000 per month

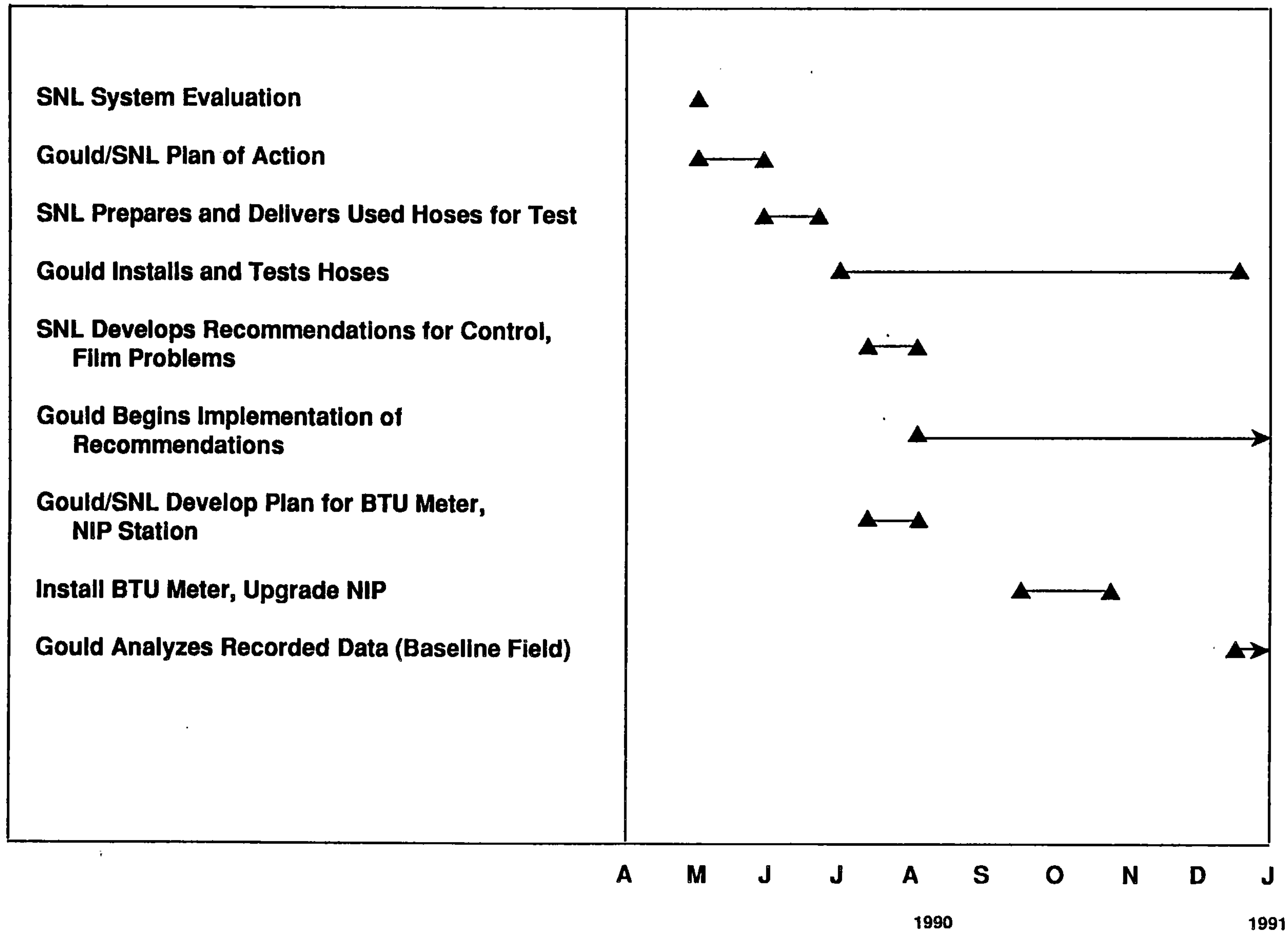
GOULD

PROJECTED COST SAVINGS FROM GOULD SOLAR PLANT OPERATING AT 25% EFFICIENCY AND 80% UTILIZATION



GOULD

GOULD IPH SYSTEM
PHASE 1 TIME LINE



GOULD

PHASE 2 HAS COMMENCED

- Gould engineers developed criteria to verify cost, performance, reliability based on in-house guidelines

- Sandia engineers are identifying a manufacturer of the advanced hoses

- Gould and Sandia to work with SKI to develop and test prototype tracking control modification to eliminate unnecessary flexing

- Sandia to provide one-day workshop for Gould maintenance personnel to identify and correct various field problems

- Gould to continue consulting with Sandia on data recording and interpretation

GOULD

GOULD PERFORMANCE CRITERIA

Gould has determined that the following formula will be used to demonstrate the solar plant's performance and reliability

The solar plant must demonstrate 70% utilization for a consecutive 3-month period

$$\text{Utilization} = \frac{\text{(Number of days system up)}}{\text{(Number of days in month)}} \times \frac{\text{(Average number of banks up)}}{\text{(Total banks)}} \times 100$$

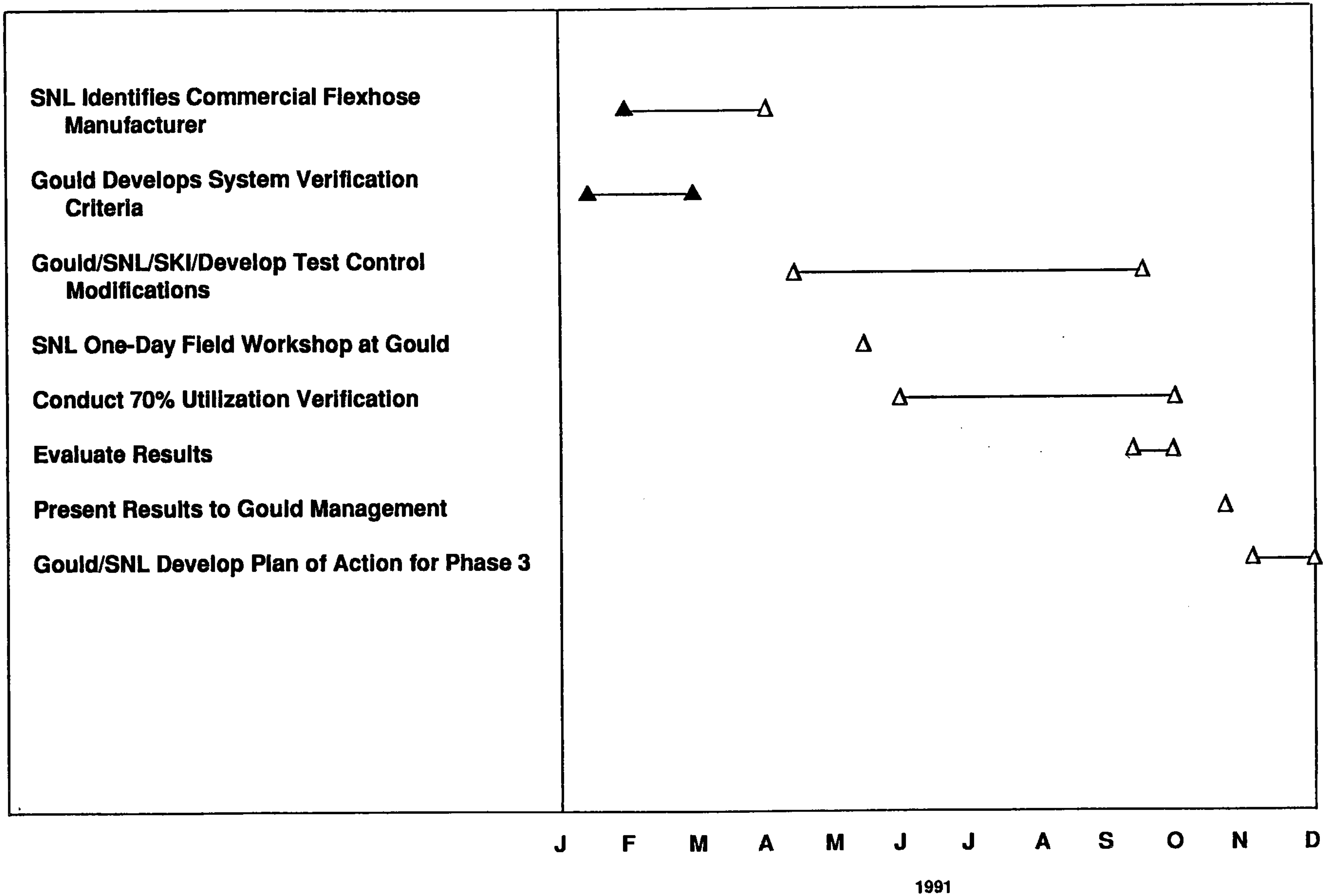
GOULD

GOULD COST CRITERIA

BTUs produced during the evaluation period will be used to calculate the solar cost savings to Gould. These savings will be used to determine the time scale for Phase 3 upgrade

GOULD

GOULD IPH SYSTEM
PHASE 2 TIME LINE



GOULD

CONCLUSIONS

- Existing system has potential to save Gould money, but proof is needed to justify expenditures for upgrades
- There is high confidence that the existing phased program will lead to a long-term, fully functional system
- The effort can be used as a model for maintaining and upgrading older IPH systems
- Long-term performance data from this upgraded system will provide proof of solar's viability
- Sandia's involvement has been very well directed and has been an essential and critical part of Gould's efforts. Gould believes that Sandia's performance exemplifies how national laboratories and industry can and should interact

GOULD

STRETCHED MEMBRANE PARABOLIC TROUGH SYSTEM FOR PROCESS HOT WATER/PLANNED SOLAR AIR CONDITIONING SYSTEM

ALLEN BRONSTEIN

NORDHAVEN RETROFIT

Retrofit of 7 troughs with stretched membrane cover design (utilizing new Tefzel glazing.)

In June 1990 SUNSTEAM, Inc. retrofitted 7 of the 34 troughs in the solar array at J. Nordhaven & Sons' metal plating company (Hayward, California) with the company's new stretched membrane cover design. The retrofit replaced seven troughs that had been damaged by flying debris during a violent wind storm. The retrofit allowed SUNSTEAM the opportunity to test assembly procedures and to confirm projected improvements in collector efficiency. The new stretched membrane cover design represents significant improvements:

- o Increased collector efficiency (12%)
- o Simplification of component design
- o Increased ease of assembly and maintenance
- o Reduction in shipping costs

The new cover is site assembled and composed of end forms, side rails, bracing components, ribs, and fluoroplastic glazing membrane. The glazing membrane is shipped rolled into a 3" diameter tube measuring 48"long. During assembly the cover membrane is attached to one end form, unrolled, attached to the opposite end form and then placed under tension. The cover membrane is a fluoroplastic film manufactured by Dupont called Tefzel. The Tefzel film replaces Tedlar fluoroplastic film used on the original troughs, and, represents a 12% increase in light transmission. The Tefzel film is crystal clear; the clarity allows greater collector efficiency at high incident angles. This is particularly important when sun angles are greatest, such as during winter months or early morning and late afternoon. Tefzel is a non-stick fluoroplastic which will stay clean for months. Nothing sticks to it. A simple daily water rinse is all that is required.

The cover membrane components are modular, compact, and easily transportable. For example, all the components needed for a 12,000 ft^2 SUNSTEAM parabolic trough system can be shipped in one standard 8'x8'x40' shipping container.

The Nordhaven system's performance has improved significantly with the new Tefzel glazing film; this improvement has been most dramatic during the winter months, where a significant improvement in performance can be seen.

SOLAR AIR CONDITIONING

SUNSTEAM is working with the California Energy Commission to demonstrate solar air conditioning utilizing parabolic troughs and water fired absorption chillers. SUNSTEAM anticipates the installation of a 70 to 100 ton solar HVAC demonstration system by summer of 1991.

The economics of solar air conditioning are very attractive. Despite its higher initial capital cost, a solar-absorption HVAC system is 80% less expensive to operate than a conventional vapor compression system, and a SUNSTEAM solar system will pay for itself in less than three years. The solar-absorption system uses no chloro-fluoro-carbons (CFC's).

Solar absorption air conditioning is not new; successful systems have been operating for many years. Most of these systems utilize flatplate solar technology. It has only been with the development of low cost concentrator technology, like SUNSTEAM's, that the economics have become attractive. SUNSTEAM's concentrator is designed for roof mounting. It can operate very efficiently at the 205° to 240° F temperatures required to drive the absorption chiller. In most U.S. Sunbelt State locations there is a perfect match between the typical air conditioning requirement of a single story building and the roof space available for the solar concentrator array.

An example of a successful solar air conditioning and HVAC system is located at the Bergquam Solar Plaza in Sacramento, California. The Bergquam system, built and designed by Professor Jim Bergquam of Sacramento State University, illustrates the design of a successful solar air conditioning system. It utilizes a 10 ton water fired Yazaki chiller combined with thermal storage. The thermal energy is produced by an array of flatplate collectors, and a natural gas auxiliary water heater. It has been in operation for five years.

To illustrate the advantages of a trough driven air conditioning system we have constructed a model substituting parabolic troughs for flatplates in the Bergquam system. The higher efficiency of the troughs permits a reduction in the collector area of the solar array by 50%. This reduces the cost of the system. Additional cost savings come from increased output of the Yazaki chiller. The efficiency of the chiller is temperature dependent; thus with the parabolic troughs producing 205° F water, the chiller's output is increased from ten tons to fourteen tons, an increase of 40%.

With the growing concern over clean air and environmental issues solar makes sense from an environmental point of view. And, with a payback of less than a three years, it makes good economic sense as well.

SOLTECH 91

Stretched Membrane Parabolic Trough System for Process Hot Water/Planned Solar Air Conditioning System

Allen Bronstein
SUNSTEAM, Inc.

P13-G07112018

Solar HVAC Air Conditioning System at Bergquam Solar Plaza

	New Building	Old Building
System description	Hybrid solar/vapor compression with ice storage	Solar driven absorption chiller
Years of operation	5 months	6 years
Building area	8,000 sq ft	10,000 sq ft
Building load	20 tons	20 tons
Solar array (flatplate)	2,400 sq ft	1,600 sq ft
Absorption chiller	10 tons	10 tons
Solar thermal storage	2,400 gal	2,100 gal

P13-G0711219

Solar HVAC Air Conditioning System at Bergquam Solar Plaza

	New Building	Old Building
Nat. gas boiler backup	Yes	Yes
Vapor compression chiller	10 tons	None
Ice storage	100 ton-hr	None
% Solar air conditioning	80%	50%
% Solar space heating	50%	30%
Solar system outlet temp	185° F	200° F
System cost	$7,000/ton	$7,000/ton

Cost Comparison of a SUNSTEAM Solar/Absorption vs. Vapor Compression HVAC Air Conditioning

	Solar	Vapor Compression	Cost Differential
Cost	$3,800/ton	$2,200/ton	$1,600/ton
O&M costs[1]	$68/ton/yr	$378/ton/yr	$310/ton/yr
Simple payback (differential cost)	5 years	None	
After tax payback (differential cost)[2]	2.5 years	None	

Assumptions:

[1] Operating cost for vapor compression
- 1,500 EFL hr/yr
- 1.4 kW/ton @ $0.125/kWh
- Natural gas: $0.55/therm

[2] After tax payback includes
- 10% Federal solar tax credit
- 5 yr DD balance depreciation

P13-G0711221

SUNSTEAM Cost Effective Solar Air Conditioning

- Payback less than three years
- 80% savings in cost of operation
- Non-polluting (no CFCs)
- Reduction of peak electric load

P13-G0711222

SUNSTEAM's Stretched Membrane Parabolic Trough Concentrator

- Low cost ($5.00/mmBtu levelized energy cost)
- 90% reflective stretched membrane reflector
- 94% transmission fluoroplastic cover membrane
- Lower installation and maintenance cost
- Can ship 12,000 sq ft in a standard shipping container

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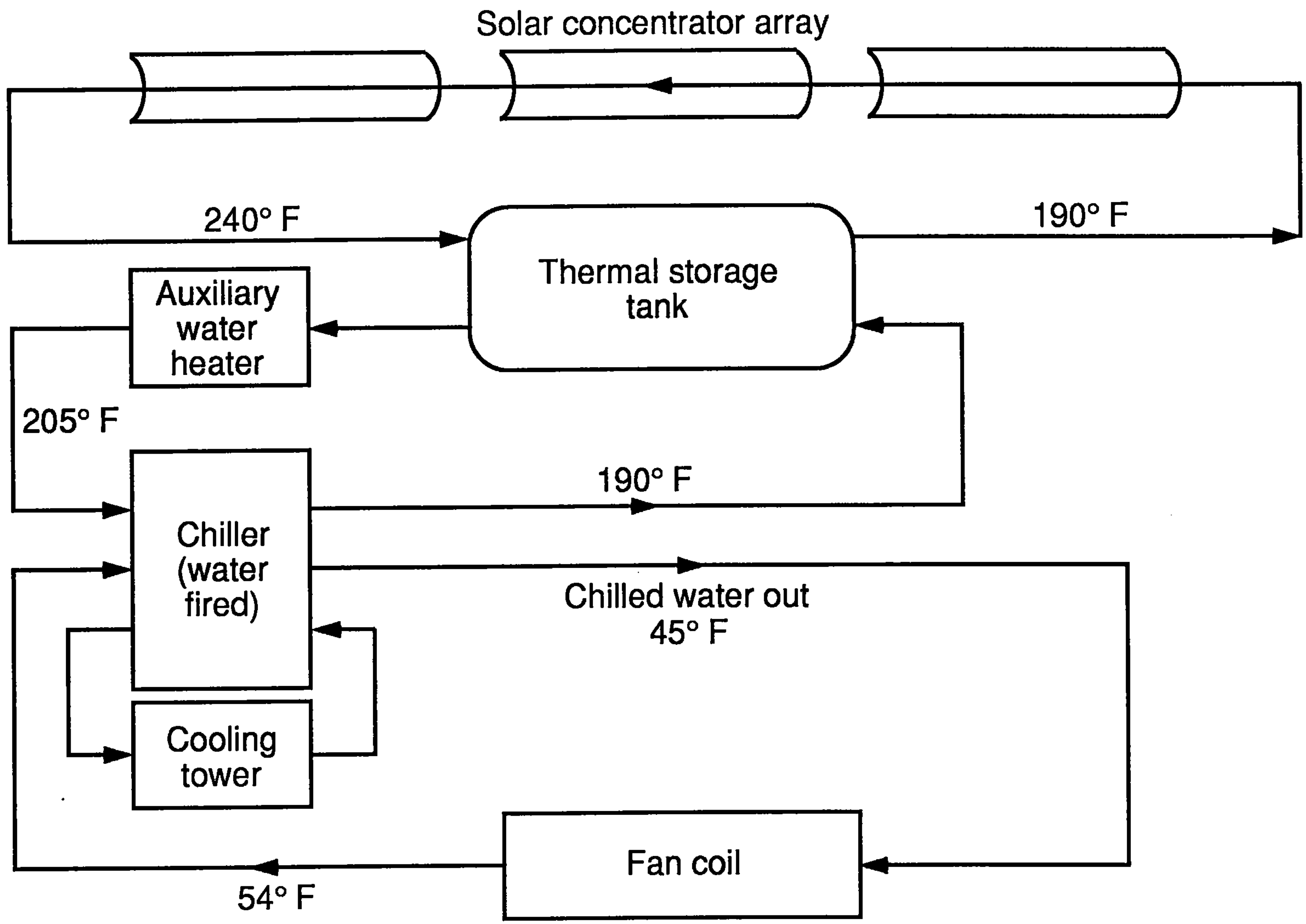

P13-G0711224

LOW AND MEDIUM FLAT PLATE TECHNOLOGY FOR INDUSTRIAL PROCESS HEATING

by Art Brooks
Sun/Earth Inc.

For many years when you mentioned Industrial Process Heating only through and parabolic collectors have been thought of. Today our attitudes are changing and with good reason. While the low and medium Flat Plate industries experienced considerable growth in the early 1980s it was considered that the business came from individual residents. While this was by and large true it wasn't until after the residential slow down that many people began to see other applications that were installed and working well with little to no maintenance. These applications were in fact industrial process heat application. These applications did not require 600 degree temperatures or even 300 degree temperatures. In many cases they required only 80 degree temperatures. It has been long thought of that the high temperature technology should be totally separate from medium and low temperature technology. This thinking is now beginning to change. The most successful applications are those that have been properly matched to the technology. By this I mean you don't need a 600 degree parabolic collector to heat a fish farm nor would you use a flat plate to power a turbine.

By blending the technologies together it will allow and justify full time sales and maintenance groups causing positive cash flow. The high temperature technology has complained that unless the system is more than 30,000 square feet that there isn't justification for maintenance people. Another common complaint is that the jobs are few and far between making it difficult to survive between jobs. My suggestion to the industry is that the technologies work closer together forming I.P.H. sales groups which are trained in all technologies and are focused on I.P.H. applications. I believe this would create more applications, constant cash flow and allow for full time roving maintenance people justifying smaller systems. The following are some industry applications for low and medium temperature I.P.H.S.; hotels, motels, fish farms, alligator farms, commercial laundries, laundromats, car washes, plating companies, food processors, military barracks, college dormitories, and prisons.

Claims have been made that solar must be sold. If we aren't installing solar it simply means we're not selling solar. The first sell we must make is to ourselves that all of the solar technologies are here for each other and what is good for one of us is good for all of us; therefore we must work together and sell each other's technologies.

SOLAR HEAT APPLICATIONS: PRODUCTS AND NATIONAL/INTERNATIONAL MARKET OPPORTUNITIES

by Kenneth G. Sheinkopf
Solar Energy Industries Association

You've just seen several examples of current and near-term solar industrial applications -- including large commercial systems, new applications, new technologies, and new ways of using the various solar heat products. I'd like to summarize this morning's session by giving you a look at the state-of-the-art of solar heat applications -- where we are today, and where we're going to be in the very near future.

It's very appropriate to be talking about this today at SOLTECH 91, because it was exactly 100 years ago -- in 1891 -- when the solar industry officially began in the United States when the first commercial solar water heating system was patented. And especially important today because we're still in the midst of worldwide concern about the environment and the hazards of burning fossil fuels, and only now beginning to feel the long-term effects of the recent Persian Gulf war and the environmental problems and long-term worry over the security of our oil supplies.

For those of you in the audience who are only now beginning to learn about solar industrial applications, my message to you today is very simple -- solar energy is a proven, reliable energy source with hundreds of uses in commercial buildings and industrial applications of all kinds. From low temperature uses like heating for commercial swimming pools to medium-temperature systems for heating water for buildings to high temperature systems that produce electricity. Solar energy is economical, cost-effective, and proven reliable.

The idea of harnessing the sun's power is nothing new -- it has been a dream for hundreds and hundreds of years. But in recent years, significant advances in science and engineering, materials and design, have made the United States the world leader in the development and application of solar thermal energy. A tremendous amount of research, most of it sponsored by the U.S. Department of Energy and taking place at our national labs or sponsored by DOE at the state level, has perfected new generations of solar thermal technologies.

Many of these are available today, are economical and reliable, and are ready to meet the needs of industry now. Others are on the near-term horizon, within our grasp in the next couple of years and almost ready for widespread commercialization.

First, let's take a look at low- and mid-temperature applications. For example, solar pool heating. These are the simplest type of systems, and are highly efficient and cost-effective. There are more than 250,000 pools in the U.S. today that have solar heating systems -- these systems supply the electrical power equivalent of a 3,000 megawatt power plant, and provide very quick paybacks to the owners.

The largest use of solar systems is for water heating. There are at least 200,000 commercial buildings in the U.S., along with more than one million homes, that use solar water heating systems. Multifamily residences, hospitals, schools, restaurants, and many other commercial buildings can save money by using solar heated water.

Large thermal systems can be easily tied to fossil fuel heaters to provide preheating of water. Excellent uses are car washes, laundries, and other industries needing lots of hot water. At state parks around the country, hot water is being provided for showers, restrooms, and other remote facilities, including campgrounds. Because many of these facilities are only used in summer, very simple, inexpensive systems can be easily installed.

Finally, the largest systems are used for such high temperature applications as electricity, process heat, and other commercial and industrial applications.

Hundreds of thousands of people in the United States today are receiving part of their daily demand for electricity from large-scale solar thermal generating stations that use concentrated solar energy to drive electric power generators.

Utilities are using solar thermal technology for peak-power applications because they produce the most power during the utility's greatest demand for electricity (around midday), have minimal regulatory obstacles because of their cleanliness (no polluting emissions) and ample availability of supply (sunlight). They can also have permits approved and be constructed in as short a time period as 18 months, far quicker than can conventional energy plants using fossil or nuclear fuels.

In addition to electric power generation, there are many other high temperature solar applications, including heat for drying, steam for cleaning, water for agriculture, sterilization and disinfection, washing and cleaning, solar detoxification, and as a preheater for existing fossil-fuel boiler systems.

There are several major advantages to these systems. They can provide both electricity and hot water at the same time for many uses. They offer electrical power for both remote and utility efficiencies, and they can work in many large-scale projects where other sources of energy aren't economical yet.

Here are a few examples of the different types of high-temperature solar thermal systems:

This is the most commonly applied high-temperature solar thermal technology, and is completely commercial today. The system concentrates solar energy onto a receiver tube positioned along the trough. Fluid in the receiver is heated and then transported through insulated pipes to the point of use.

The second type of system, dish systems, uses tracking concentrators to focus the sun's rays onto a receiver. A single dish can efficiently produce up to 50 kilowatts of electricity.

Another area of future potential involves the Stirling engine technology, which is used to run a conventional electric generator. The system has been tested successfully, and research is now working on long-term reliability for commercialization in the near future.

Finally, research and testing continues on central receiver systems which use sun-tracking mirrors to reflect solar energy to a receiver atop a tower. These systems deliver energy at very high temperatures to drive a turbine to produce electric power.

Thanks to the efforts of government and industry, there are now many sources of assistance to help you design, build, operate and maintain these systems. A number of publications, services and materials have been developed to help you avoid the mistakes of the past and build systems that perform as needed. There are a number of guides, directories, and on-going publications from the Solar Energy Industries Association, the ASHRAM-sponsored books on design, O&M, and installation, the SERI solar building assistance and the Sandia Design Assistance Center, and other Department of Energy-sponsored programs and services help building owners, government officials, and others learn how to use the technology to save energy and money.

I hope you now have a better idea of the wide range of solar heat applications. Thank you.

Kenneth G. Sheinhopf is Director of Special Projects for the Solar Energy Industries Association and Director of Governmental Relations for the Florida Solar Energy Center. He has been active in the solar industry since 1983. He is the author of more than 50 papers and articles on solar energy, and is co-author of a new book, "The Consumer Guide to Solar Energy," to be published next month. He has written a weekly column for 20 newspapers in Florida on energy conservation and home comfort since 1986. He also services as Executive Director of the American Ocean Energy Industries Association.

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