SERI/TP-250-4256 • UC Category 234 • DE91002197

The Department of Energy's Solar Industrial Program: New Ideas for American Industry

John V. Anderson
Steven G. Hauser
Richard J. Clyne

Solar Energy Research Institute
1617 Cole Boulevard
Golden, Colorado 80401-3393
A Division of Midwest Research Institute
Operated for the U.S. Department of Energy
under Contract No. DE-AC02-83CH10093

July 1991

NOTICE

This report was prepared as an account of work sponsored by an agency of the United States government. Neither the United States government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States government or any agency thereof.

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 A02

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.

THE DEPARTMENT OF ENERGY'S SOLAR INDUSTRIAL PROGRAM: NEW IDEAS FOR AMERICAN INDUSTRY

John V. Anderson
Steven G. Hauser
and
Richard J. Clyne

Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401

ABSTRACT

As society becomes more and more sensitive to the environment, and energy supplies become more scarce, the application of solar energy is expanding into new areas. The industrial sector is one of the most difficult for solar energy to impact because of its technical diversity and economic requirements. However, the opportunities are still abundant. The Department of Energy's Solar Industrial Program is dedicated to advancing the applications of solar energy in this sector. Research and technology development activities are currently focused in three areas: solar process heat, advanced materials manufacturing, and destruction of chemical wastes. The Solar Energy Research Institute manages these activities for DOE with close interactions with other federal agencies, private industry, and universities.

INTRODUCTION

The Department of Energy's (DOE's) Solar Industrial Program was founded in 1990 to work closely with industry in developing and commercializing solar-based technologies. The program's goal is to develop technologies that will reduce industry's dependence on fossil fuels and consequently improve the environment by meeting many industrial energy demands using clean solar power. The Solar Industrial Program is part of the DOE's Waste Material Management Division, which is within the office of Industrial Technology. The Solar Energy Research Institute (SERI) manages the program, and technical activities are carried out at Sandia National Laboratories and SERI.

Our research and technology development activities are focused in three areas:

1) **Solar Process Heat**. Work in this field brings existing, competitive technologies to industry as an alternative to traditional heating systems.

2) **Advanced Materials Manufacturing**. This work develops applications of highly concentrated sunlight to manufacture advanced materials.

3) **Destruction of Chemical Wastes**. This work is developing innovative methods to destroy hazardous waste products from typical industrial processes.

We recognize the importance of industry's early involvement in these research efforts. Cooperation not only enhances and accelerates the research and development (R&D) programs, but also fosters an environment in which the technology can quickly reach the marketplace. We have specific activities to educate potential users on the current capabilities of solar energy and involve private businesses in technology development, transfer, and commercialization.

SOLAR PROCESS HEAT

Industry is responsible for consuming one-third of energy used annually in the United States, and 90 percent of the process heat energy needs are still met by oil, gas, and electricity. Potentially one-third of U.S. industry's process heat requirements could be met by solar energy; we are helping industry move toward that goal by increasing market awareness of solar heating technology.

We are demonstrating that existing solar collection systems, such as flat-plate, evacuated-tube, and concentrating solar collectors are viable energy alternatives for many industrial applications. Such applications include preheating water for industry, providing service hot water, developing low- and high-pressure steam, and generating process hot air. We have developed a strategy that initially emphasizes installing these systems in the institutional market, which is broadly defined as federal- and state-sponsored facilities. A number of cost-reducing benefits are available through this approach, and the resulting range of operational systems will demonstrate the reliability of the technology. Other potential early markets include commerce-based operations such as restaurants and motels, and international development markets for water pumping, heating, and distillation. This impressive base of installed technology will serve as a platform from which the much-wider industrial market can be penetrated.

Solar process heat systems have come of age. Where 20 years ago solar heat promised much but had difficulty meeting cost and reliability requirements, it now is an extremely competitive, reliable, environmentally clean energy alternative. Ongoing research continues to improve these systems, but many federal agencies, local municipalities, and private industries have already determined these systems to be their best energy value and have installed them in large-scale projects. Exhibit 1 shows the California Correctional Institute in Tehachapi, California where a solar trough array produces hot water for the facility's showers, kitchens, laundry, and space heating. This system comprises 28,800 square feet of collectors covering a 2-acre area; the load temperature is 220 degrees F, and the peak solar delivery is 4.5 million BTUs per hour.

Exhibit 1. The solar process heat system at the California Correctional Institute in Tehachapi, California. The system was designed and installed by Industrial Solar Technology, Inc. in the fall of 1990.

Despite its proven success, solar process heat is often ignored by many potential users during the design or renovation process. Designers are unaware that solar process heat is especially attractive for low- to medium-temperature applications (300 to 500 degrees F). One of the keys to the success of this technology is removing the information barrier that exists between the solar industry and potential users. Many users, both government and private, are not aware of the system performance levels currently available, and many designers lack experience integrating these systems into their work. Many potential users still maintain the misconception that the technology is too risky. Educating these potential end users and promoting the technology by developing and distributing informational materials is an important part of this research.

We believe the best method to increase industrial use of solar heat is to aid the solar manufacturers through cooperative projects and cost-sharing programs. Much of our work is coordinated and undertaken with the Solar Energy Industry Association (SEIA). While we can assist in many different ways (often dependent on the specific circumstances of a given project), our primary current services consist of prefeasibility studies, identifying and developing new markets, and directly and indirectly helping companies meet project milestones. A number of cooperative arrangements are available to both solar manufacturers and solar users through SERI and other organizations.

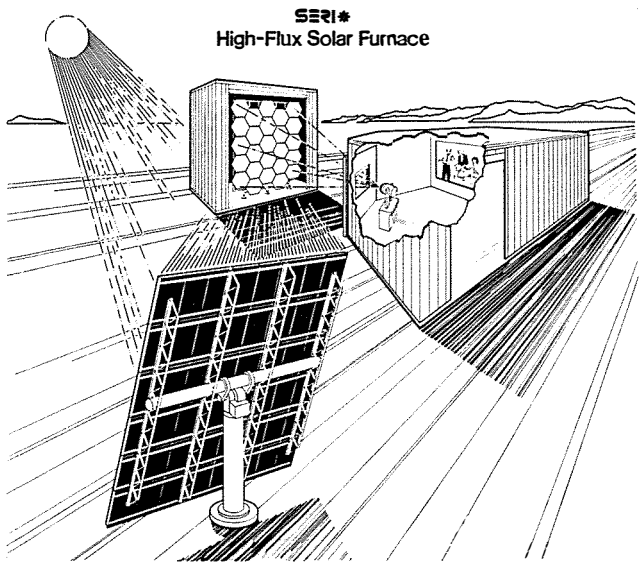
ADVANCED MATERIALS MANUFACTURING

New techniques for manufacturing advanced materials are being explored through the use of SERI's solar furnace. The solar furnace began operating in early 1990 and allows researchers to study the properties and applications of very high solar flux. The facility currently has the ability to produce solar flux densities of approximately 25,000 suns (25 MW/m^2), and this upper limit is expected to rise dramatically in the near future with the rapid developments occurring in concentrator research. New research directions for this promising technology are being discovered almost on a daily basis.

Exhibit 2 shows the physical configuration of the solar furnace. The heliostat tracks the sun and reflects incoming solar energy onto the stationary primary concentrator, which consists of 23 individual curved facets (see Exhibit 3). These facets collectively focus the solar flux at a point in the test facility. The long focal length of the primary concentrator produces a 10-centimeter-diameter concentrated beam of approximately 2,500 suns at the target area. When a secondary concentrator is placed at the beam's focus, a peak flux of 25,000 suns can be obtained. When used in conjunction with a modified secondary concentrator currently being developed, the furnace is expected to produce concentrations of over 50,000 suns. This should occur before the end of the year.

Three performance characteristics put the solar furnace at the cutting edge of industrial process research. The first is the system's ability to produce very high temperatures directly from the sun. The second is the extremely high rate of heating made possible by very high solar flux. In certain applications this rate exceeds 1 million degrees Celsius per second. These heating rates produce thermal conditions unattainable through other conventional heating processes. The third characteristic is the furnace's ability to deliver the entire solar spectrum (from 300 to 2500 nanometers); this allows researchers to study applications requiring either broad spectrum radiation or a particular frequency, ranging from the infrared to the near-ultraviolet.

Researchers have only scratched the surface of possible applications and investigations to which the solar furnace can contribute. Currently our research is primarily concerned



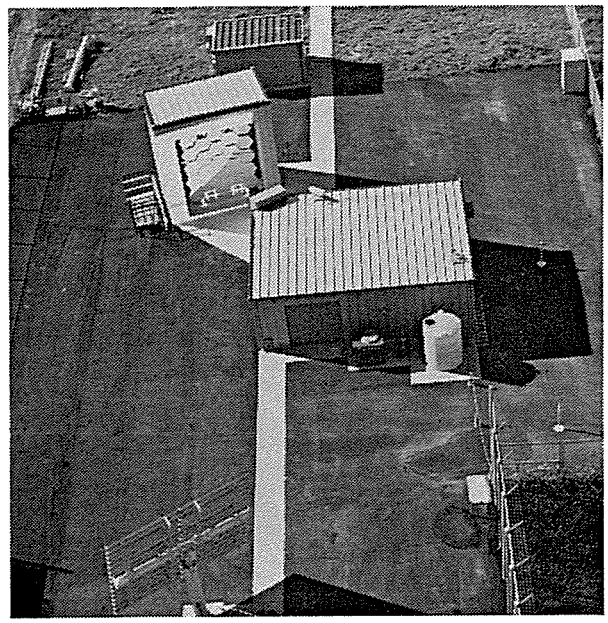


Exhibit 2. SERI's high-flux solar furnace. Left: Schematic view of system operation. Right: The actual facility located on South Table Mountain in Golden, Colorado.

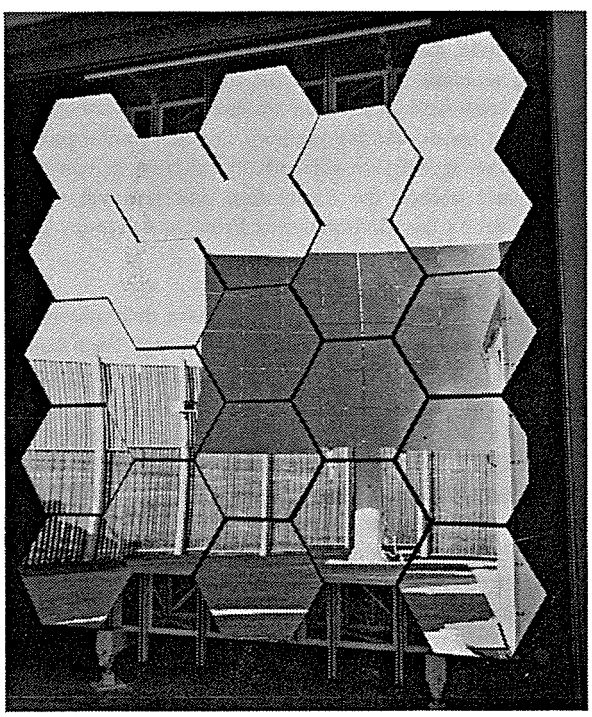


Exhibit 3. The primary concentrator of SERI's solar furnace. The 23 enhanced-aluminum front-surface mirrors focus the reflected solar flux to a 10-cm-diameter beam inside the test building (not shown). The reflection of the heliostat, which tracks the sun and directs its energy to the concentrator, is shown.

with materials surface properties. The ability of the furnace to rapidly produce high temperatures on the surface of a material without affecting the base material has led to investigations of phase transformation hardening, cladding, deposition of thin films, and rapid thermal annealing (see Exhibit 4). We are in the process of finding and developing industrial partners for a number of specific research areas, including ceramic joining, fine ceramic powders, and diamond-like carbon coatings.

DESTRUCTION OF CHEMICAL WASTES

Solar detoxification research is developing solar engineering solutions for the environmental remediation and waste management industries. The research currently consists of two areas of study: solar detoxification of contaminated water, and gas-phase detoxification of contaminants adsorbed on solids. The general public and industry are showing great interest in these investigations, and commercialization of these technologies could begin as early as 1995. We are encouraging early participation from industry in these areas—not only from potential solar technology manufacturers but also from potential users such as environmental engineering and waste management firms.

Decontamination of Water

The solar detoxification of water could revolutionize the way in which polluted surface water and groundwater are reclaimed. Many of our water resources are polluted with volatile organic compounds, dioxins, and pesticides. Solar decontamination destroys these hazardous chemicals by using the energy available from sunlight. Polluted water is brought into contact with a semiconducting photocatalyst, such as titanium dioxide, which in the presence of sunlight creates highly reactive hydroxyl radicals. These radicals react with the organic contaminants and convert them into water, carbon dioxide, and easily neutralized mineral acids such as hydrochloric acid. Because the process requires low solar flux concentrations, the reaction can be initiated using either flat-plate solar panels (one-sun concentrations) or a

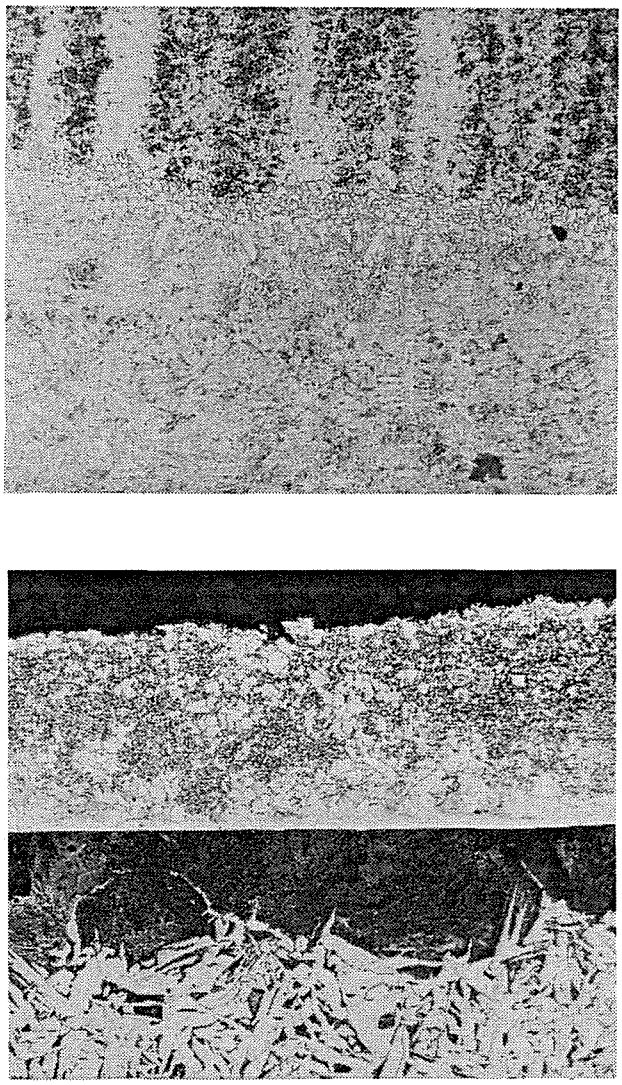


Exhibit 4. Photomicrographs of alloy coatings formed by solar melting of preapplied powders on steel substrates. Note the high density of the coatings and the good metallurgical bonds between the coatings and their substrates.

transparent tube mounted at the focus of a parabolic reflecting trough (up to 30-sun concentrations). This latter design is shown in Exhibit 5.

We will begin the first field test of the solar decontamination process this July at the Lawrence Livermore National Laboratory (LLNL) in Livermore, California. Along with three DOE laboratories, a number of private solar manufacturers will participate in developing and testing the system.

The test will occur in two phases: Phase I will begin this July and consist of a small-scale, skid-mounted system set up to gather data on the site-specific conditions at LLNL and to monitor the initial performance of the decontamination system. Phase II, scheduled to begin this fall, will significantly expand the test and will incorporate the lessons learned in Phase I, the ongoing developments from industry and DOE research, and advanced control systems, reactor designs, and catalysts. The test is scheduled to run for approximately 1 year.

The solar detoxification system will be installed upstream of a commercial decontamination system currently in use at LLNL; this eases problems with permitting and potential contamination release because all process water will still be treated with LLNL's existing treatment system. Conversely, researchers must implement and monitor additional system controls that ensure the water exiting the solar-based system is within the pH and temperature range at which the conventional decontamination system operates. An artist's conception of the initial field setup is shown in Exhibit 6.

The field test at LLNL will not only provide researchers with valuable data leading to process improvements and reduced costs, but will also be an indicator that solar decontamination of surface and groundwater containing toxic organic compounds can be a viable alternative to conventional decontamination methods.

Gas-Phase Detoxification of Solids

Our researchers are using the high solar flux produced by SERI's solar furnace to develop new methods for decontaminating polluted solids, such as soils. Traditional remediation methods, including incineration and landfill disposal, continue to be a source of controversy and often are energy-intensive operations. Researchers are developing methods driven by solar power that eliminate the undesirable side effects inherent in conventional systems and exceed the destruction and removal efficiency standards set by the Environmental Protection Agency (EPA).

We are studying two methods of gas-phase detoxification. The first is a photolytic process that can use energy from both ends of the solar spectrum. Typically, a concentration of greater than 300 suns is required to power the reaction. The contaminants are desorbed from the solid using either vacuum extraction or heat (heat produced by the infrared portion of the spectrum can be used for this purpose). After being desorbed the contaminants are introduced into a reactor (shown in Exhibit 7) that is mounted at the focus of a solar concentrator system. The near-ultraviolet portion (high-energy photons) of the flux then destroys the contaminants, resulting in end products such as CO_2, H_2O, and HCl.

The second method of gas-phase detoxification, a thermal catalytic-steam reforming process developed by Sandia National Laboratories, also requires the high solar flux produced at the focus of a solar concentrator system. This process works particularly well for detoxifying halogenated hydrocarbons. In this process a thermally activated catalyst, such as rhodium metal, is placed in the reactor and exposed to the concentrated sunlight. The contaminants and reactant steam are then passed through the reactor, where, in the presence of the catalyst, they react to form products such as CO, CO_2, H_2, H_2O, HCl, and simple halogen acids.

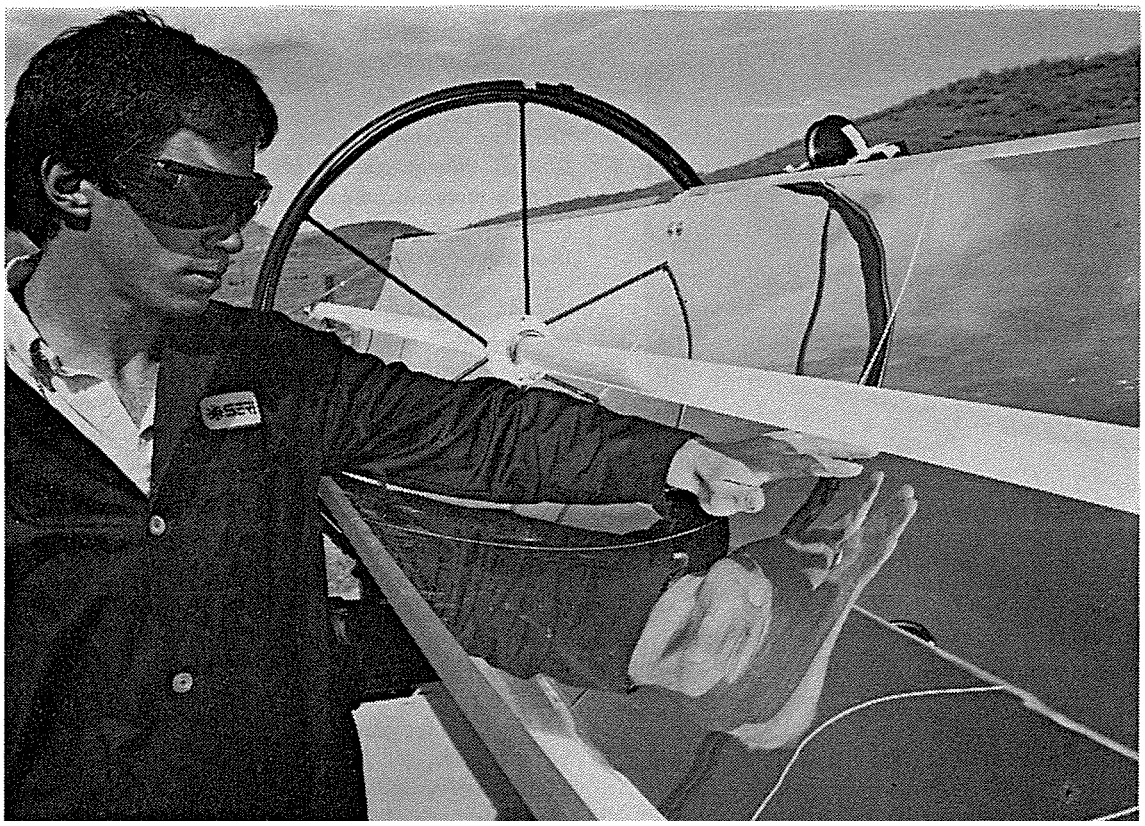


Exhibit 5. Solar Decontamination Trough

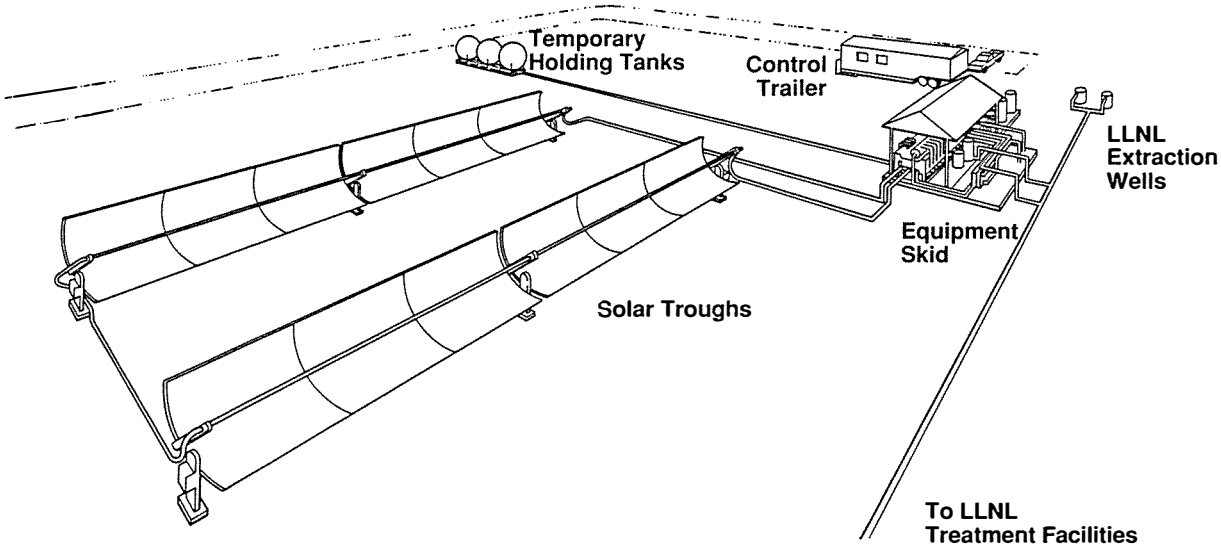


Exhibit 6. Artist's conception of the solar decontamination field test system scheduled for operation in July, 1991

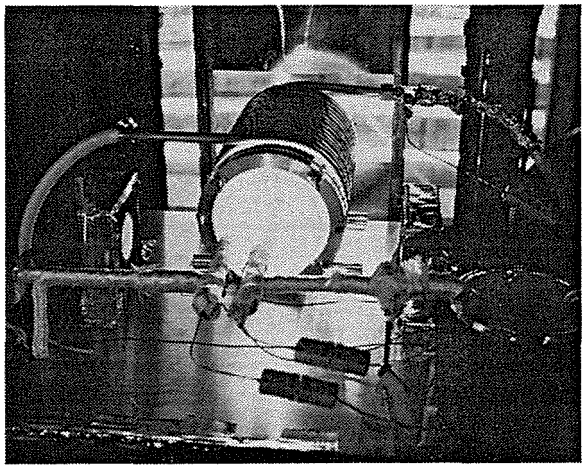


Exhibit 7. Solar Detox Reactor

Both of these methods are remarkably efficient in destroying gaseous organics (exceeding the EPA's 99.9999% requirement), and neither produce the detrimental by-products associated with conventional incineration techniques. By the latter part of this decade these methods could become standard tools in the environmental remediation and waste management industries.

INDUSTRIAL INVOLVEMENT

Other federal agencies and private companies are encouraged to participate with us in developing and commercializing these technologies.

Technology transfer within the Solar Industrial Program is fostered through written material, presentations, workshops, training programs, and traveling exhibits. Our participation in industry projects, and exchanges between our researchers and their industry counterparts, also play an important role.

We can work with our industrial partners through a variety of arrangements, including cost-shared demonstrations, joint research, and cooperative research and development agreements (CRADAs). Only through close cooperation and information exchange among researchers, manufacturers, and operators will solar technology continue to make inroads into U.S. industry.

CONCLUSION

Although less than 2 years old, the DOE's Solar Industrial Program has made great strides in developing closer ties between solar technology and American industry. The Solar Industrial Program offers the kind of clean, far-sighted solutions sought by industry, government, and the general public. By directly tapping the sun's energy to destroy hazardous wastes, meet industry's heating needs, and perform advanced materials processing, we equip ourselves with a powerful, clean natural tool.