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THE NATIONAL SOLAR OPTICAL MATERIALS PROGRAM PLAN: AN OVERVIEW

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NOTICE

The national solar optical materials program plan: an overview

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Abstract

A coordinated national program is being formulated to adapt and develop optical materials to support a goal of meeting 20% of our national energy needs with solar by the year 2000. The program contains elements covering absorber, reflector, and transmitter materials but not photovoltaic materials. These elements include research on glass and polymer materials for glazing and reflector components, environmental testing, and long-term reliability modeling. Program subelements that support R&D and encourage commercialization of new products are also discussed. An overview of the proposed funding levels is presented.

Introduction

Materials play an important role in all of our industrial technologies. Materials research has often been a prerequisite of the evolutionary and innovative changes that mark technological advances. As we strive to utilize solar energy more fully by its direct conversion to heat, shaft power, or electricity, it is evident that materials research will also play an important role in providing the durable, high-performance, and cost-effective components necessary for the successful commercialization of this non-polluting, renewable energy source.

The Solar Energy Research Institute (SERI) is coordinating the development of a national program plan for research on materials used in solar energy conversion systems. The plan represents many disciplines, including optics, and addresses the many functions of materials in various system components including concentrators, receivers, energy transfer systems and structures. The optical materials functions are the absorption, reflection, and transmission of radiant energy from the sun in a way that provides high system performance. However, a balance between maximizing efficiency and durability and minimizing costs must be made in order that solar energy conversion systems become economically attractive.

Under the Department of Energy structure as it existed until the Fall of 1979, the United States solar energy program was organized into technological areas of solar thermal (ST), industrial process heat (IPH), active heating and cooling (AHAC), passive, photovoltaics (PV), fuels and chemicals, ocean thermal electric conversion (OTEC), biomass, and wind. Elements of the program and technologies were dispersed over four DOE divisions. The program philosophy was to fund materials research when it was needed for a specific project or technology. As a result, materials research was sometimes 1) neglected in important areas that were assumed to be covered by another technology, 2) not considered to be significant enough for development within a technology, even though collectively it would benefit all technologies or 3) sometimes duplicated by the various program offices.

Optical materials play an important role in all but OTEC, biomass, and wind. With coordination by SERI, a national Solar Optical Materials Program Activity Committee (SOMPAC) was formed in 1978 in order to provide a broader technological base from which the cost and performance of collectors could be improved, to identify and discourage duplicative research efforts except where needed, and to identify key research areas and prioritize their funding levels, thereby impacting the benefit to cost ratio of the research effort. SOMPAC's membership presently represents six national laboratories involved in solar energy research.

The solar optical materials program plan

The solar optical materials program plan is composed of three major elements, an absorber materials plan, a reflector materials plan, and a transmitter materials plan. The three plans exist in various stages of completion.

1. Absorbers

The absorber surface program plan was the first to be completed.[1] Unlike the reflector and transmitting material plans described below, it was derived using a constraint of a maximum annual funding level equal to the funding available in FY78. No manufacturing technology support provisions are included and the activities represent a minimum balanced effort. The plan is organized in a slightly different format than are the transmitter and reflector plans. A program management section provides support for four development activities and four supporting functions. The four development activities address the improved durability and cost effectiveness of low temperature selective absorber surfaces for passive, flat-plate, and evacuated tube collectors to 200°C; commercial black chrome and an identified alternate selective surface for applications to 400°C; intermediate temperature (400-700°C) selective absorbers; and absorber surfaces for high temperatures (>700°C). The selection of temperature regimes was somewhat arbitrary. The choices were determined by adding an approximate 100°C buffer to operating temperatures for generic applications. The four supporting functions are optical measurement, durability testing, and components evaluation; systems analysis; data base; and basic and generic research. An outline of the program plan is provided in Figure 1.

Table 1. SUMMARY OF PROPOSED PROGRAM SUPPORT LEVELS AND THE PRESENT VALUE OF PERFORMANCE IMPROVEMENTS

Plan	Element	Subelement	Proposed 5 yr Support (M$) Plan Total	Element	Subelement	Present Value of Performance Improvements (M$)
Absorber			8.2(1.6/yr)			405
	Management			0.8		
	Development			3.9		
		o <200°C			1.5	
		o 200°C to 400°C			0.8	
		o 400°C to 700°C			1.1	
		o >700°C			0.5	
	Support					
		o Measurements, testing			3.5	
		and evaluation			1.7	
		o Systems Analysis			0.2	
		o Data base			0.3	
		o Basic and Generic Research			1.3	
Reflector			35.9(7.2/yr)			520
	Management			3.8		
	Materials R&D			18.9		
		o Glass			1.1	
		o Other Materials			9.1	
		o Long term performance				8.7
	Support			6.7		
		o Data base and dissemination			1.3	
		o Standards and measurements			5.4	
	Manufacturing technology			6.5		
Transmitter			51.7(10.3/yr)			290
	Management and Coordination			3.9		
	Materials R&D			42.7		
		o Polymers			35.5	
		o Other Materials			6.5	
		o Long Term Performance				0.7
	Support			3.1		
		o Data base and dissemination			0.9	
		o Standards and Measurements			2.2	
	Manufacturing technology			2.0		
Totals for Optical Materials			94.8(19/yr)			1215

Absorber Materials Program Plan Outline

- **Management**
- **Development Activities**
  - selective absorbers
    - to 200°C
    - 200 to 400°C
    - 400 to 700°C
  - non-selective absorbers
    - 700°C
- **Support Activities**
  - measurements, testing and evaluation
  - systems analysis
  - data base
  - basic and generic research

Figure 1. Outline of Absorber Materials Program Plan

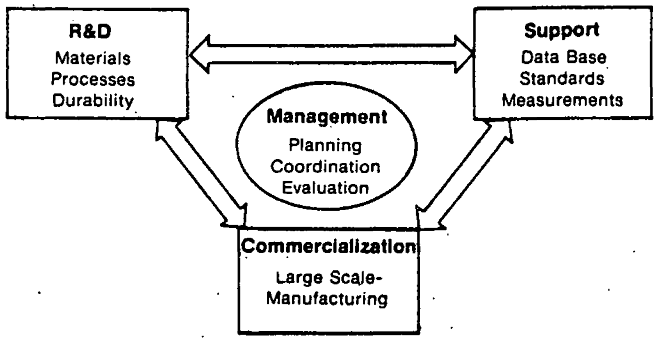

Figure 2. Elements of Reflector and Transmitter Materials Program Plan

2. Reflectors and Transmitters

The reflector and transmitter materials plans have been published in outline form[2] and are presently being completed in more detail. Each follows a common form containing four main elements as shown in Figure 2.

The first element provides for the necessary materials R&D that will produce the technological basis for cheaper and more durable collectors. Research on new materials, adaption of existing materials, materials processing, and durability are all addressed. A knowledge of the durability of the optical parameters of candidate materials is important in assessing the long-term performance of solar energy conversion systems. The correlation of accelerated weathering test to actual long-term performance for many component materials is not well understood. Part of the research and development activity is to perform accelerated and long-term aging of solar optical materials in order to predict more accurately the environmentally caused degradation of candidate materials, and to reduce the design margins required for meeting a specified system output.

The second element of each plan is unique from most government programs. Specifically, there is a substantial effort in the area of manufacturing technology to promote commercialization of the most promising results of research and development. A good example of this type of activity is a pilot run of thin glass made by Corning Glass Co. using the fusion process. Under a SERI sponsored contract over 200 square meters of 1 and 1.5 mm thick glass was produced in sheets approximately 1 m wide. This glass is flexible and has a low solar absorptance of 0.01. Under a SERI accelerated materials commercialization plan,[3] the glass produced by Corning was distributed to a number of laboratories and manufacturers to assess its performance and handling characteristics in solar components. The results of these experiences will be collected by SERI and used to assess the potential of this product.

The third element common to the reflector and transmitter plans is the provision of a support activity to assure accuracy, uniformity, and availability of reported material parameters. This will facilitate communication and intercomparison of results obtained in different research or manufacturing organizations. Most of the solar community is aware of the importance of the abosrptance, reflectance, and transmittance of optical components. They are less aware of the measurement techniques, standards, and data analysis required to obtain the solar weighted values for these parameters. For concentrator technology, the specularity of the concentrator optics whether they be reflective or transmissive is of primary importance. Specularity is a much more difficult parameter to measure accurately and to quantify. The establishment of measurement techniques for determining specularity in order to obtain consensus standards is being addressed by the American Society for Testing and Materials (ASTM). Standard reference materials for reflectors and absorbers are being developed by the National Bureau of Standards. As part of this support activity, the optical properties of materials will be assembled into a national data base under development by SERI for use by the solar community.

The last element is a management activity that provides support for the program by securing appropriate funding, providing program planning and organization based on analysis and review, and by facilitating communication of the results of R&D and commercialization activities throughout the solar industry.

A large portion of the reflector materials program is a research and development activity in glass technology. The commercialization of thin glass described above is a part of this effort. Although glass is a transmitting material, its prevalent use for substrates or superstrates for reflector materials led to its incorporation into the reflector materials plan. In a similar manner, a large portion of the transmitter materials plan is a polymer program. As in the case of glass, polymers are widely used for both glazings and substrates or superstrates for reflectors. Although the decision to put glass research into the reflectors material program and polymers into the transmitting materials program was somewhat arbitrary, this division represents present use in the solar industry and provides a balance in funding levels for these two main program areas.

The above program plans are projected for five years with a maximum involvement of industry in the development projects. Universities and national laboratories will be involved primarily in research and support activities.

Funding

The absorber materials plan was derived using a constraint of maximum annual funding equal to the funding available in FY78. In detailing the program needs and research opportunities for the reflector and transmitter plans, SOMPAC made initial estimates of man-year efforts and monetary resources required to carry out a minimum effective program. The assumption of a restricted budget required the committee to constrain the scope of some investigations and to defer work on several issues considered less urgent. The funding recommended by SOMPAC for many of the specific research areas is the minimum or critical level to provide a meaningful effort. In all cases, funding at approximately twice the level of the amount indicated in Table I would be desirable and cost effective over a long-term period.

The resource estimates in Table I include direct R&D labor as professional man-years independent of whether they come from national laboratories, universities or commercial research organizations. These estimates were converted into dollar values for the preparation of the summary tables by using a rate of $130,000 per man-year assuming an average mix of senior and junior professionals, a one-to-one professional-to-technician ratio, and a labor burden cost typical of government and aerospace laboratories. The resource estimates include dollar costs for materials laboratory equipment and instrumentation test services, subcontracts with commercial organizations to produce prototype materials, and/or construction of prototypes for pilot scale manufacturing facilities.

The proposed funding over a five year program for the three elements totals about $90 million dollars, as shown in Table I. In order to verify that expenditures of this level were justified, the benefits that might be expected from implementing the proposed national optical materials program plan have been assessed. The technique for calculating these benefits was developed in the absorber materials program plan[1] and is a simple and conservative approach based only on the additional energy delivered by modest improvements in collector performance. The technique is based on market penetration studies[4] weighted toward the MITRE-SPURR numbers. It does not give any credit for additional market penetration that might result from improved collector performance. Using the market predictions, the total energy delivered from 1985 to 2020 by solar conversion systems using optical materials was calculated. The value of improving the long term performance of transmitter, reflector, or absorber optical components is calculated to be the value of the additional energy delivered by the improved system. The energy is always assumed to be valued at the present price of fossil fuels with the savings discounted to their present value. The results of this conservative analysis are included with the summary of recommended funding in Table 1. They show probably benefits of approximately 15 times the proposed program costs.

Summary

Under SERI's coordination, a national plan for solar optical material research and development is being developed. Included are activities that support large-scale manufacturing in order to accelerate commercialization of the research products. The national plan consists of separate elements that cover absorber materials, reflector materials, and transmitter materials. Program plans for development of glass and polymer materials are coordinated with and included in the reflector and transmitting materials elements respectively.

The program outputs are expected to impact the technologies in a timely manner. In early stages of the program, better handbook and design data on materials properties and durability will reduce system overdesign. Later in the program, the adaptation of existing materials and processes for application to solar optical components will make available more options to system designers for selecting better performance materials. Finally, the materials R&D will provide new materials with better durability and/or performance that will be ready for future commercialization.

The impact of the proposed program should be to increase long term system performance and reduce life cycle cost over a broad range of solar technologies. Even modest gains in performance or cost are projected to provide additional energy worth many times the costs of the program.

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