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March 1980

# The Accelerated Commercialization Program for Materials and Components

## Solar Sheet Glass: An Example of Materials Commercialization


Rob Livingston
Barry Butler


SERI


**Solar Energy Research Institute**
A Division of Midwest Research Institute

1617 Cole Boulevard
Golden, Colorado 80401



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# THE ACCELERATED COMMERCIALIZATION PROGRAM FOR MATERIALS AND COMPONENTS

## SOLAR SHEET GLASS: AN EXAMPLE OF MATERIALS COMMERCIALIZATION

ROB LIVINGSTON
BARRY BUTLER

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PREPARED UNDER TASK NO. 3141

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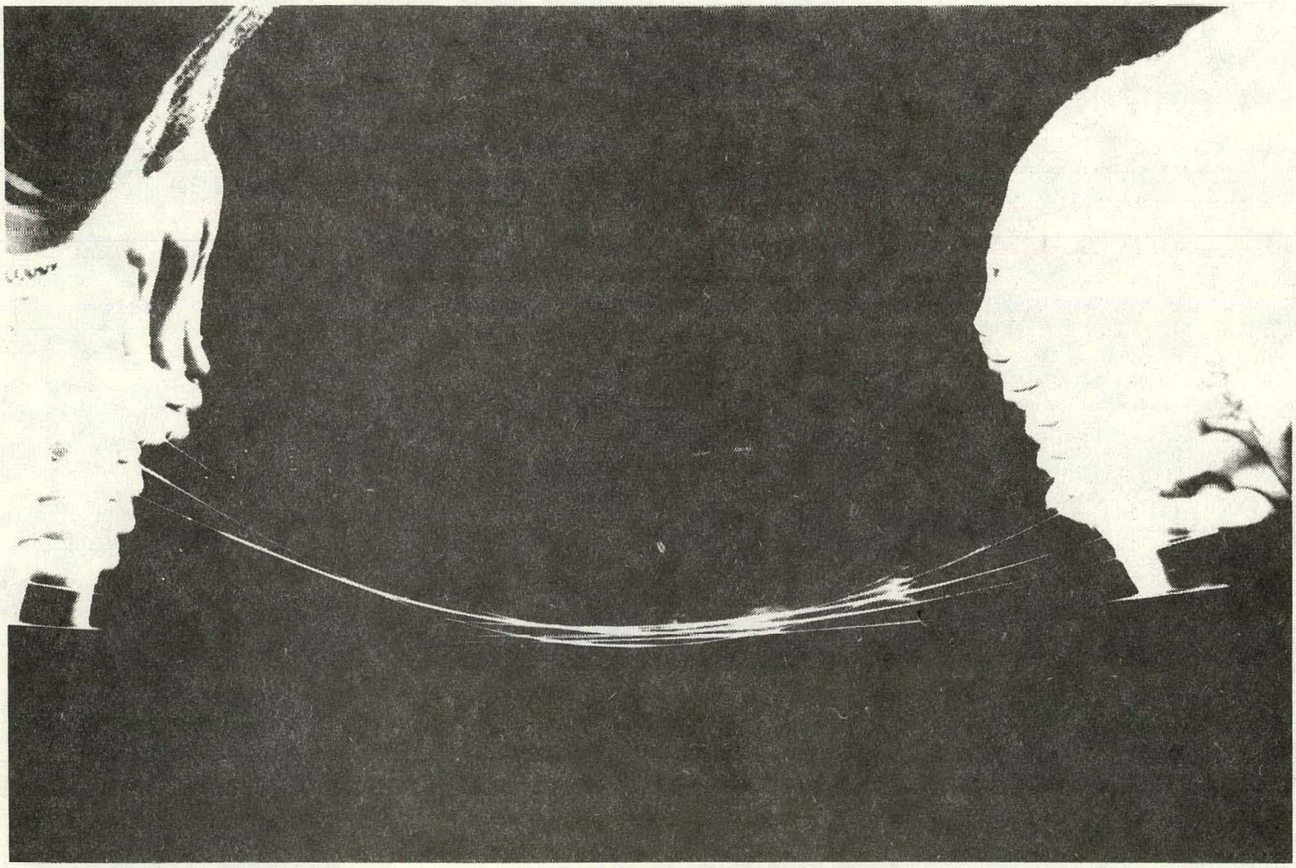

**Strobe Photo Showing the Elastic Properties of the High Optical Quality Corning 7809 Solar Fusion Glass.**

## PREFACE

The SERI Accelerated Commercialization Program for Materials and Components is designed to serve as a catalyst in promoting the rapid and efficient introduction of new materials to manufacturers of solar equipment. In addition to disseminating data and information, the program sends test quantities of new materials to solar equipment manufacturers, thereby accelerating the use and acceptance of promising new materials. This report describes the program and uses solar sheet glass as an example of how the program is implemented.

Rob Livingston
Industrial Application and Policy Branch

Barry Butler, Acting Division Manager
General Research Division

Approved for:

SOLAR ENERGY RESEARCH INSTITUTE

David Feasby, Branch Chief
Industrial Application and Policy Branch

Neil Woodley, Acting Division Manager
Utilities and Industry Division

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# SECTION 1.0

# INTRODUCTION

On 9 Feb. 1979 the Working Committee on Concentrating Collectors, of the Solar Thermal Energy Association, a Division of the Solar Energy Industries Association (SEIA), approached SERI for assistance in preparing recommendations for a commercialization plan to be submitted at a meeting with the Department of Energy (DOE). The meeting had three major objectives:

- to assess the current status of concentrating collectors,
- to identify the goals of commercialization, and
- to recommend programs to accelerate the commercialization of concentrating collectors.

The committee found the concentrating collector industry in a poor state of health, because its activities were largely in response to the Federal solar demonstration programs. Although these demonstration programs have value in highlighting possible solar applications, they also tend to retard technological development of newer and more cost-effective systems. The concentrating collector community is quoting equipment produced by proven technology; improved designs and materials that may be available would not qualify for these programs because of the warranty and reliability demands of the government programs. The committee felt that government-initiated programs should provide for an orderly progression of product development. Members of the committee stated that the demonstration programs tend to freeze the development process and emphasize applied engineering; they would prefer that emphasis be placed on product development.

The committee recognized that government and industry must cooperate to achieve commercialization of concentrating collectors. Committee members believe the role of government should be to stimulate private industry and to develop more cost-effective systems. Further, they recognize that much work needs to be done in innovative materials, installation, and maintenance techniques; moreover, hardware development work should be funded on selected components critical to concentrating collectors to improve system reliability and cost effectiveness.

In response to this need and similar needs identified by materials researchers, suppliers, and the appropriate technology community, a new program has been initiated at SERI. The "Accelerated Commercialization Program for Materials and Components" is designed to identify advanced materials and designs and to facilitate their transition from the research and development stage to the commercialization stage.

The balance of this report discusses in detail the methods to be used in this program. Also given as an example are the activities to determine the accelerated commercialization potential of a solar sheet glass.

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## SECTION 2.0

## A GENERAL PROGRAM DESCRIPTION

Each solar technology encounters impediments to commercialization for a number of reasons, some of which are traceable to performance limitations and some to the cost effectiveness of the technology's materials or components.

A wide variety of solar collecting devices is available in the marketplace. In the fabrication of these collectors, existing materials were adapted to numerous design schemes. If a large market existed for solar collectors, companies manufacturing collectors would use their profits to develop more cost-effective materials and designs. Manufacturers would use the "design, build, test, evaluate, and redesign" process to improve the performance and marketability of their systems. To this point, they have had neither the flexibility nor the liquidity to operate in this way. Instead, depending on the market conditions, they optimize for minimum first costs or for minimum life-cycle costs, whichever consumers demand. Because of the long payback times of present solar energy conversions systems, life-cycle costs appear to dominate the materials and design optimization process.

In the ideal case, materials suppliers and collector manufacturers exchange money for materials, and profit is sufficient to explore new materials and designs in each industry. However, because there is no large-scale consumer market for solar collectors at this time, manufacturers are reluctant to finance development or testing of new materials and designs. SERI can intervene and help to develop the materials, processes, components, and designs needed by the collector manufacturers and material suppliers. To do this, SERI must act as a catalyst between the material suppliers and collector manufacturers. The Materials and Design—Accelerated Commercialization Program describes how SERI is acting to reduce the barriers to commercialization of new or improved materials for solar collectors, incorporate these materials into innovative designs, and thus reduce the product development time (Fig. 2-1).

A diagram showing how SERI could be effective in catalyzing the interaction between the materials and collector manufacturing industries is shown in Fig. 2-2. SERI's Industrial Policy and Applications Branch and the Buildings Systems Branch are the main links between the collector manufacturers and the materials suppliers. SERI's Materials and Systems Development branches recommend technologies, materials, components, and designs that are ready for evaluation in the commercial sector. For materials suppliers, funds may be provided to purchase test quantities of material in order to accumulate data on the material costs and production rate sensitivities. SERI can promote the evaluation of these new materials and designs by collector manufacturers. The collector manufacturers would supply to SERI data on the performance and effectiveness of the new materials and designs. The data would then be synthesized into a technology commercialization transfer report summarizing the new materials, designs, or systems.

In the first step in this liaison process, new concepts or materials with commercialization possibilities would be screened by SERI's research branches. Those concepts or materials seen as having potential would be matched with the needs perceived by the solar collector manufacturing community, as represented by the SEIA. Appropriate technology input will also be sought. If a match were apparent, the Planning, Applications, and Impacts Division would be asked to study the potential impact of such a technology transfer to industry. If the potential benefit were suitably high, the Industrial Policy and

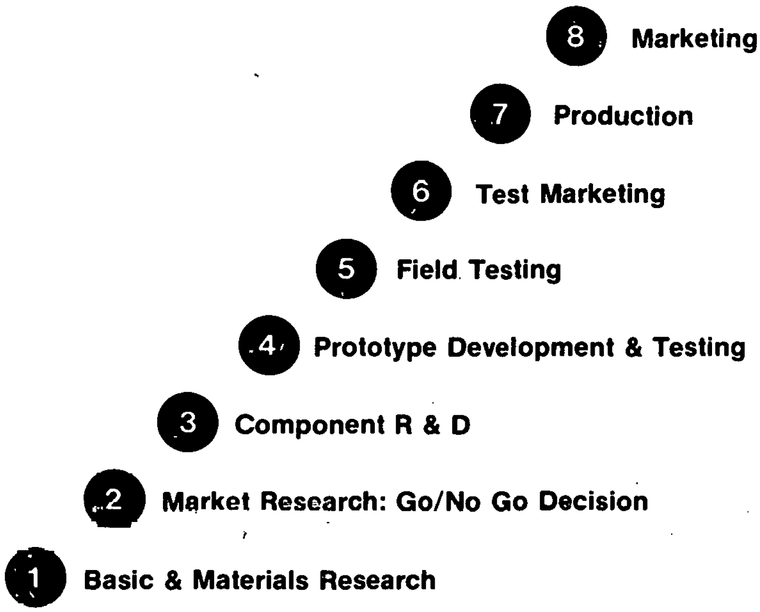



**Figure 2-1. Product Development Sequence**

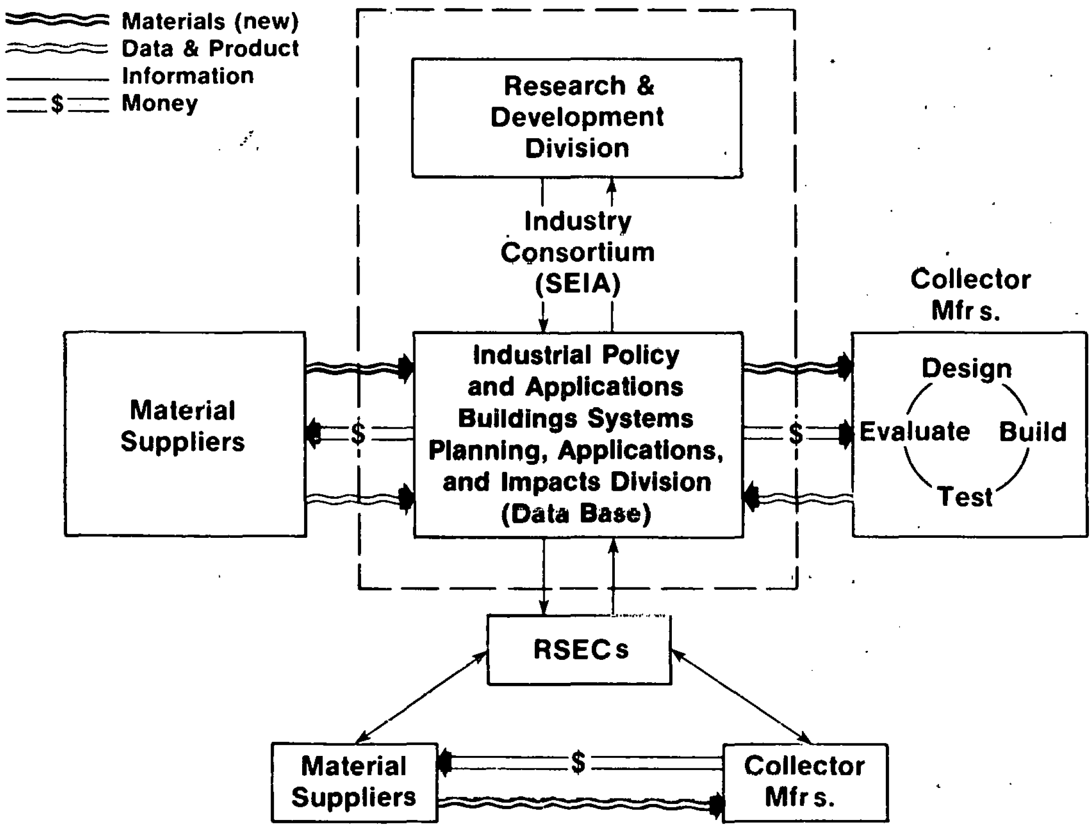



**Figure 2-2. SERI's Role as a Catalyst Between Material Suppliers and Collector Manufacturers**

Applications and Buildings Systems branches would proceed as outlined in this commercialization plan. This two-way communication between industry and researchers will benefit both parties.

It is proposed that reports on the technology transfer activities would be sent to the Regional Solar Energy Centers (RSECs) and to the SEIA. By the resources of these organizations, information could be transmitted to collector manufacturers and materials suppliers who were not involved in the initial commercialization activities. Such a process would allow additional collector manufacturers and material suppliers to evaluate their interest in producing and marketing products within the solar collector industry. The RSECs and SEIA could become very effective in establishing buyer cooperatives that would work to reduce new material costs for the industry. In summary, this process of research commercialization would enable SERI to stimulate the development of better collectors based on improved materials and designs in both the industrial and residential sectors.

Using solar thermal energy systems as an example, Fig. 2-3 shows the functions that materials must perform in solar energy systems. Optimizing the functions of reflection, transmission, solar absorption, heat transfer, and fluid containment includes three items: material cost, performance, and reliability and durability. DOE is sponsoring a significant research program in materials that addresses these functions, as well as a program to develop new components based on innovative materials and designs. Innovative components are, in turn, chosen on the basis of the needs of the solar thermal systems, which include home heating and cooling, industrial process heat, and high-temperature linear and point-focus collectors for electric power generation.

## 2.1 PROGRAM GOALS

- To shorten the transfer time for market introduction of new materials and components.
- To facilitate the commercialization of good candidate materials, components, or designs that otherwise would not find their way into the marketplace.

## 2.2 SCOPE AND OBJECTIVES

- To provide rapid application and analysis of new materials/components on a test basis. To make promising materials/components available for application testing and to facilitate their transition from the research stage to the development and commercialization stage.
- To accelerate the transfer of information about innovation in materials.
- To provide within a five-year time frame higher efficiencies, system familiarity, and reproducibility of systems and hardware.

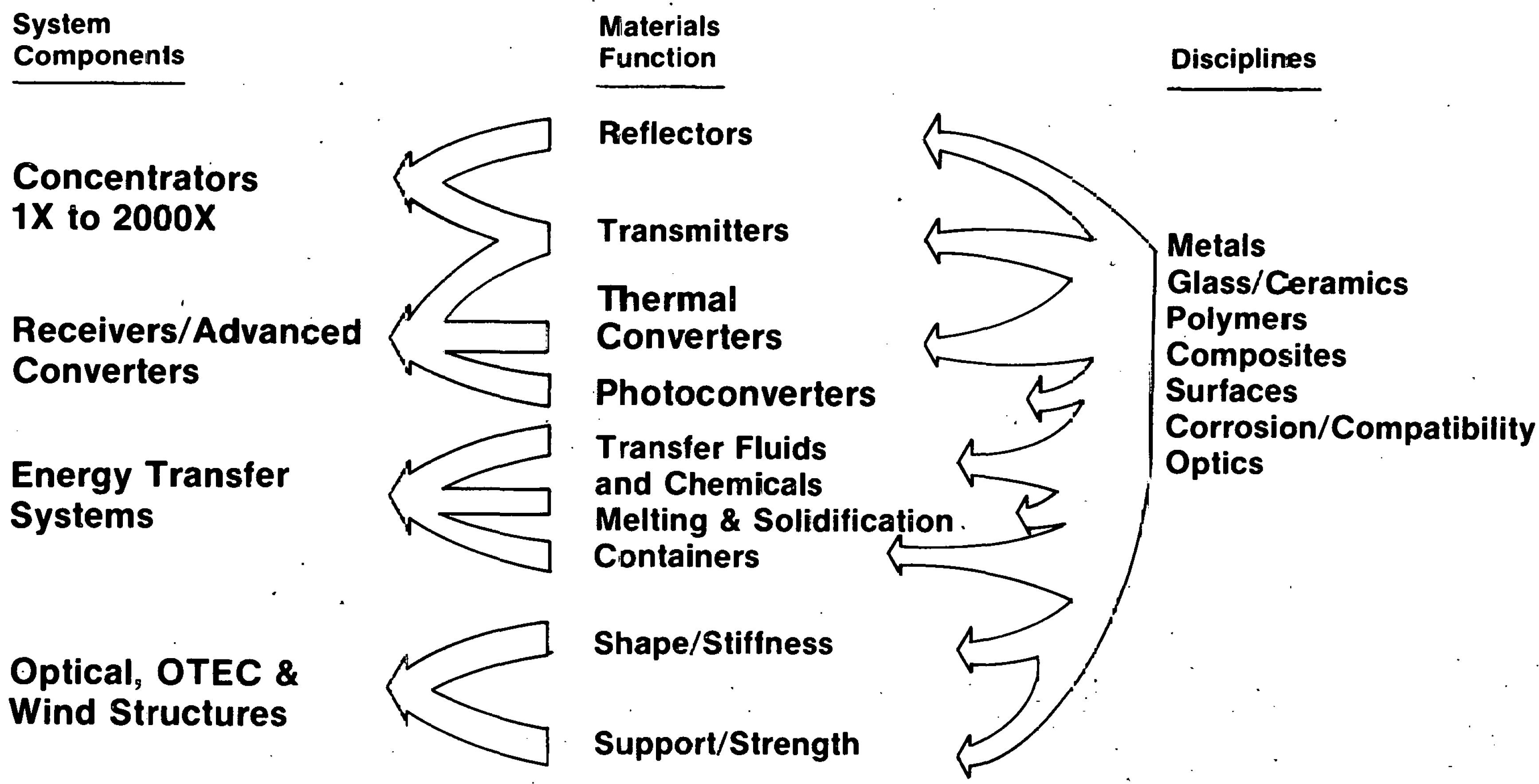



Figure 2-3. Solar Materials Supporting Research

# SECTION 3.0

# ELEMENTS OF THE ACCELERATED MATERIALS COMMERCIALIZATION PLAN

## 3.1 MATERIAL IDENTIFICATION AND CHARACTERIZATION

In the initial phase of this task, information will be gathered on new material and component advances. SERI's Research and Development Division will take the lead role in determining, through in-house screening and evaluation, whether a material or component meets expectations.

Preliminary material selection criteria are:

- Material specifications: size, weight, density, etc.
- Physical Properties
  - -Thermal conductivity, expansion, etc.
  - -Optical properties, index of refraction, extinction coefficients, etc.
  - -Electrical potential, conductivity, etc.
- Processing information
- Preliminary cost information
- Preliminary durability information
- Preliminary materials comparative performance tables

## 3.2 MARKET POTENTIAL ANALYSIS

SERI's Industrial Policy and Applications and Buildings Systems branches will determine the market potential for a new material. Essential for an effective market analysis is the identification of potential users (equipment manufacturers and consumers). A part of this activity will identify and evaluate the infrastructure or technology delivery system required to fabricate and transport advanced materials to users. Where an existing infrastructure supplies a particular industry or area, its willingness and capability to perform the required functions will be determined through field contact with its personnel and organizations. The potential effect of incentives, individually or collectively, also will be discussed with users and suppliers via workshops, seminars, and on-site visits.

## 3.3 DEPLOYMENT

If the market potential analysis indicates that a material or component offers the potential for meeting selected applications, SERI will facilitate distribution of products to users. One method of doing this is to purchase a limited production run of the material and ship it directly to the users. In effect, SERI will act as a market broker for materials and technological resources, assisting business and industry to respond to changing technological environments. The materials manufacturer will be obligated to provide SERI with cost estimates on specific production rates and economies of scale.

Other methods, such as educating potential users and encouraging them to purchase the products for test purposes, are possible. The main purpose is to deliver the product to the user for evaluation and testing in his design and to stimulate the development of new designs that might make better use of the new material. If appropriate, new design development might also be supported by SERI. In exchange for the advanced material placed with solar manufacturers, the user will be obligated to provide to SERI his actual use, handling, and performance data.

### 3.4 MATERIALS COMMERCIALIZATION

If the results of the tasks described in Secs. 3.1, 3.2, and 3.3 indicate that a material warrants introduction into the mass market, then SERI will work with the RSECs, the SEIA, the Federal Laboratory Consortium, and industry to develop a marketing and implementation plan for the material. The content and emphasis of the commercialization plan will vary with the stage of solar material development and the sophistication of the intended application. Activities will include efforts to:

- develop comparative performance and handbook data, and
- involve RSECs in the generation of a commercialization plan and in gathering regional supply and demand data, etc.

## SECTION 4.0

## AN EXAMPLE OF MATERIALS COMMERCIALIZATION (7809 SOLAR GLASS)

Materials technology has been chosen as an example of how an accelerated commercialization plan can accomplish technology transfer. Components or designs could be commercialized by a similar process.

The Solar Energy Research Institute has been conducting a program in the development of very thin (0.25-mm) glass for solar applications. The advantages of this glass are very high transmittance and, when silvered, very high reflectance, because the very short optical path within the glass minimizes the effects of absorption. In addition, this glass can be elastically bent to fit many solar concentrator geometries and can also be used as a protection for photovoltaic devices.

The use of second-surface silvered glass mirrors for solar applications has focused considerable attention on the initial and long-term optical properties of the glass superstrate. Of prime importance has been minimizing the absorptive losses in the bulk glass. These losses are known to arise from the presence of iron impurities, primarily $Fe^{+2}$ and $Fe^{+3}$ (see Fig. 4-1). The high spectral transmittance of the 7809 glass differs markedly from the transmittance of the more common soda-lime float glass. In conventional soda-lime float glass, the iron content is in the ferrous state ($Fe^{+2}$), indicated by a broad absorption band centered at about 1000 nm, a region in which there is considerable solar irradiance (Fig. 4-2). Low iron and/or highly oxidized glasses are considered to be the best approach to minimizing absorptive losses arising from the $Fe^{+2}$ band. The 7809 glass, in which the iron content has been oxidized to the $Fe^{+3}$ (ferric) state, absorbs in the ultra-violet (uv); this absorption is of little consequence to solar applications. The broad absorption band around 1000 nm in soda-lime glass, due to the $Fe^{+2}$, is conspicuously absent in the 7809 glass, as shown in Figs. 4-1 and 4-2. The transmittance of the 7809 glass is close to the theoretical maximum, showing little absorption and only reflective losses (Fig. 4-3). Similarly, the reflectance is high due to the low absorption (Fig. 4-4). A comparison of solar reflectance of second-surface silvered mirrors on different glasses is presented in Fig. 4-5.

The composition of the new fusion glass optimizes the characteristics necessary for efficient solar utilization. For a more in-depth discussion and analysis of the technical properties of this glass, i.e., forming, composition, solar transmittance, optical flatness, weathering, chemical durability, solarization, and mechanical properties, refer to SERI/TP-334-565, "Properties of Solar Alumina-Borosilicate Sheet Glass," by R. T. Coyle et al., forthcoming.

The manufacturers represented by the Solar Thermal Collector Manufacturing Division, SEIA, have indicated a strong interest in using this material in the silvered state as a mirror or as a protective cover for solar collector components. A preliminary analysis has indicated a high market potential for this new product. Research indicates that some applications may require using the glass in the stress state, which requires further understanding of the static fatigue of the glass. (Static fatigue is the tendency of the glass to break spontaneously after a certain time at a given load.) SERI's Industrial Policy and Applications Branch made plans to distribute test quantities of this glass to research laboratories and manufacturers of solar collectors. The material was accompanied by sufficient data on its properties to evaluate it in a variety of collector applications.

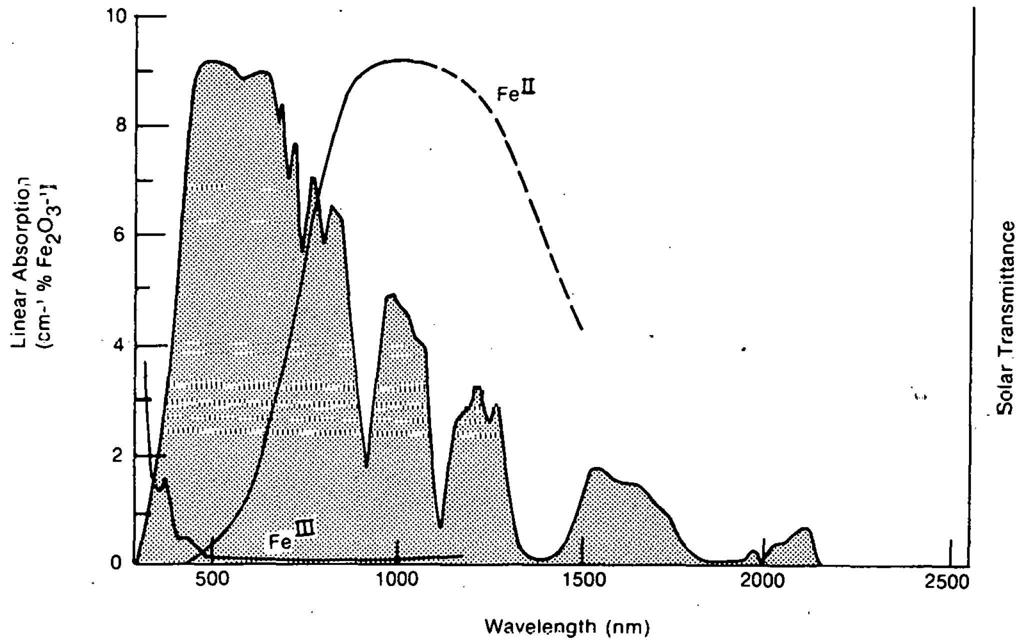



**Figure 4-1. Absorption Coefficients of $Fe^{2+}$ and $Fe^{3+}$ in Soda-Lime Glass**

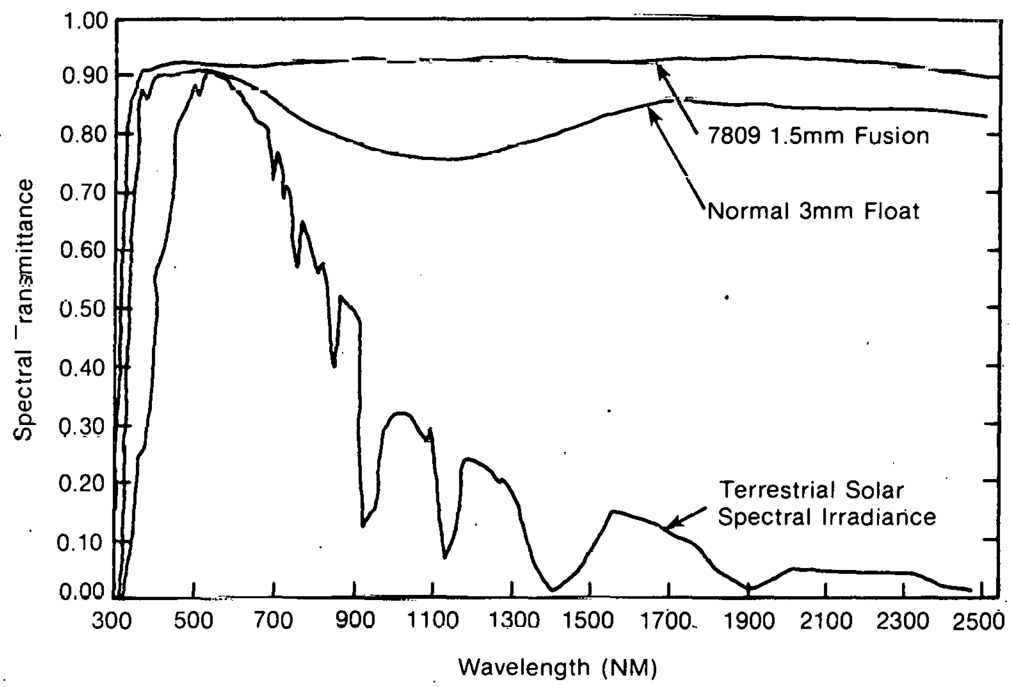



**Figure 4-2. Transmittance in Solar Spectrum and Relative Intensities of Solar Irradiation**

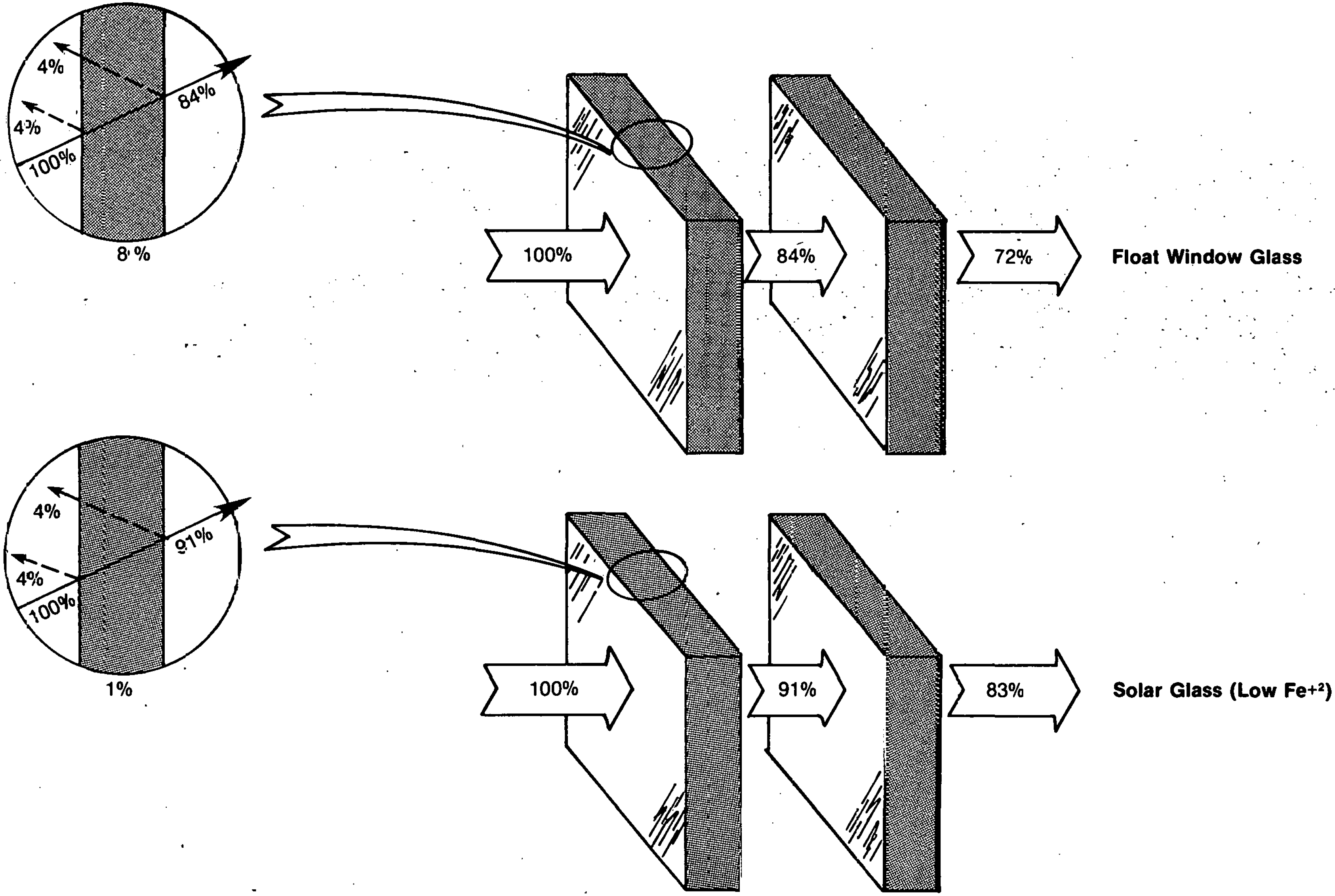



**Figure 4-3. Comparison of the Solar Transmission of Window Glass and Solar Glass at 2.5 mm (0.1-in.) Thickness**

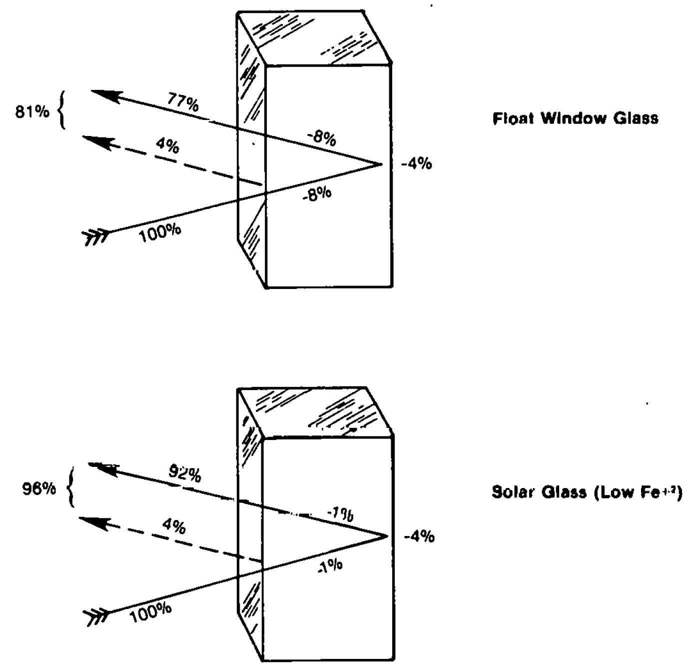
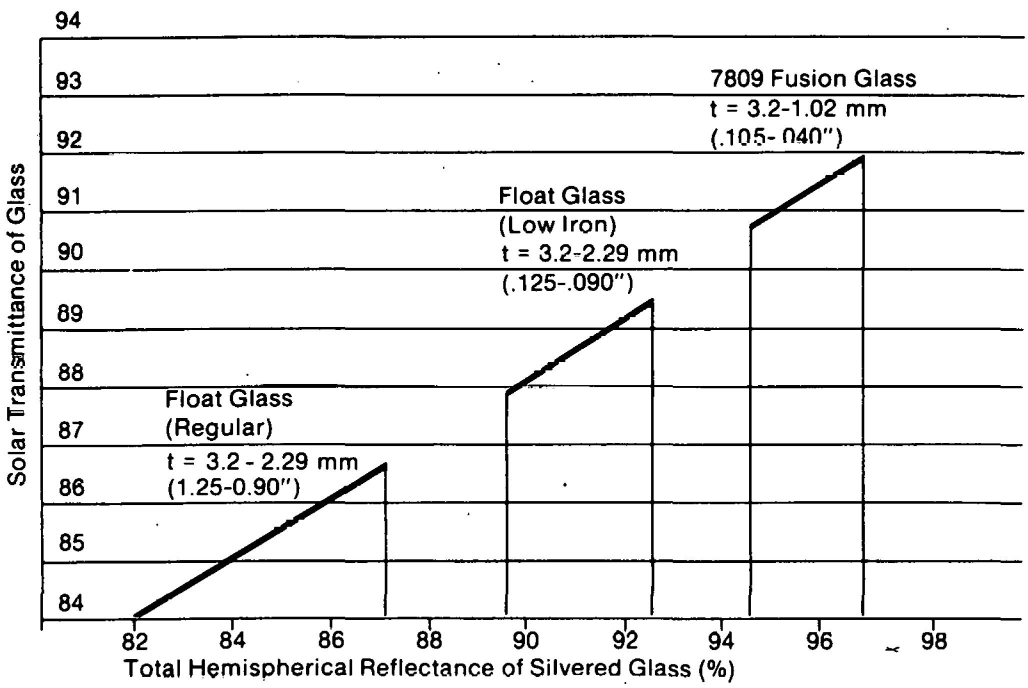



**Figure 4-4. Comparison of Solar Mirror Losses for Window and Solar Glasses at 2.5 mm (0.1-in.) Thickness**




Reflectance is a Function of Silvering Quality
Variations Up to a 6% Have Been Noted.

**Figure 4-5. Solar Reflectance of Second Surface Silvered Mirrors on Different Glasses**

In response to the interest of the collector and appropriate technology communities, a subcontract was let by SERI to Corning Glass Works in May 1979 to develop forming methods for and to produce this glass for solar applications. The goal of the work, which was performed as a corollary to activities ongoing in SERI's Basic and Applied Research Program, was to achieve technical and marketing goals in support of the Accelerated Commercialization Program for Materials and Components. The Materials Research and the Industrial Policy and Applications branches worked together to define the specific objectives and terms of the subcontract.

The subcontract called for Corning to explore the melting and forming characteristics of Code 7809 glass, test the limits of Corning's patented fusion process for producing glass to as thin as 0.25 mm (0.010 in.), and manufacture 1,000 $m^2$ of glass ranging in thickness from 1.5 mm (0.60 in.) to 0.25 mm (0.010 in.).

SERI's Industrial Policy and Applications Branch was responsible for identifying solar firms to participate in the SERI program. This high transmission solar glass could easily have been incorporated in many end-use applications, in a wide range of solar technologies such as inner glazings for flat-plate collectors, south wall glazing technologies, or use with Heat Mirror (See Sec. 5.4). However, the limited amount of glass available and its characteristics suggested that the best cost/benefit ratio would be realized by placing it in the concentrating collector community (troughs, heliostats, dishes). Future plans call for offering the glass on an experimental basis to other segments of the solar community.

Program participants were chosen on the basis of the following criteria:

- the firm is a nationally recognized leader in its field;
- as such, it has the labor, equipment, money, and expertise to properly evaluate a new material or component; and
- the material provided fits directly into work currently underway within the firm.

Candidate firms (Table 4-1) were contacted and apprised of the Accelerated Commercialization Program for Materials and Components and the availability of the 7809 solar sheet glass. Most firms were enthusiastic about participating in the program, under which they would receive the glass free of charge in exchange for documentation on their experience in its use. Each firm was asked to submit a letter of intent outlining its willingness to participate in the program, how much glass would be required, the types of applications, and measurements to be taken. A "No Cost Agreement" specifying the terms and conditions for participation was prepared and sent to each firm for signature. The agreement contained a list of glass performance areas of interest to SERI, including:

- substrate bonding techniques,
- elastically cold forming techniques,
- adhesion tests,
- thermal expansion tests,
- bonding studies,
- laminating techniques,
- thermal sagging,
- thermal cycling,

**Table 4-1. PARTICIPATING FIRMS FOR THIN GLASS PLACEMENT**

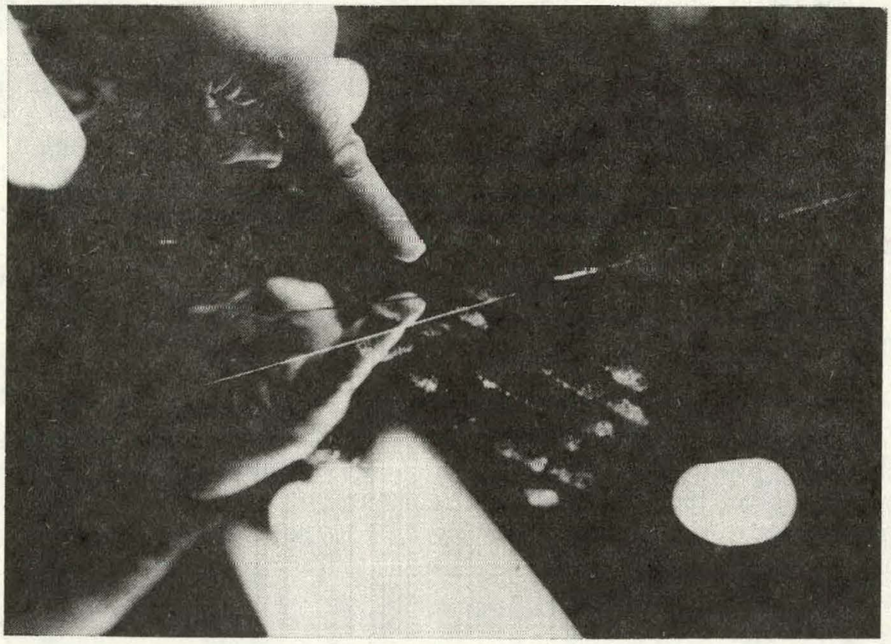
| | | |
|---|---|---|
| OMNIUM - G<br>1815-1/2 N. Oranethorpe Pk.<br>Anaheim, CA 92801<br>ATTN: Ronald C. Derby<br>(714) 879-8421 | Boeing Engineering and Construction Company<br>P.O. Box 3707<br>Seattle, WA 98124<br>ATTN: Roger Gillette<br>FTS 435-2121<br>(206/575-5724) | Del Manufacturing Co.<br>905 Monterey Pass Road<br>Monterey Park, CA 91754<br>ATTN: Gilbert Herrera<br>(213) 264-0860 |
| Jet Propulsion Laboratory<br>Mail Stop 157-507<br>4800 Oak Grove Drive<br>Pasadena, CA 91103<br>Attn: Frank Douquet<br>FTS 792-4482 | Martin Marietta Aerospace<br>Denver Division<br>P.O. Box 179<br>Denver, CO 80201<br>Attn: Melvin Frohardt<br>(303) 973-3000 | Custom Engineering, Inc.<br>2805 S. Tejon Street<br>Englewood, CO 80110<br>ATTN: Carlos A. deMoraes<br>(303) 761-7585 |
| Acurex Corporation<br>485 Clyde Avenue<br>Mountain View, CA 94042<br>ATTN: John W. Schaefer<br>Jeff Fletcher<br>(415) 964-3200 | Solaramics<br>1301 E. El Segundo Blvd.<br>El Segundo, CA 90245<br>ATTN: Hal Felix<br>(213) 322-5804 | Rensselaer Polytechnic Inst.<br>Dept. of Mechanical Engineering<br>Troy, NY 12181<br>ATTN: William Rogers<br>(518) 270-6301 |
| Toltec, Inc.<br>40th and East Main<br>R.R. 1<br>Clear Lake, Iowa 50428<br>ATTN: Dave Chenault<br>(515) 357-7001 | McDonnell Douglas<br>5301 Bolsa Avenue<br>Department A3-214<br>Mail Station 14-3<br>Huntington Beach, CA 92647<br>ATTN: John Dietrich<br>(714) 896-3066 | Solar Kinetics, Inc.<br>8120 Chancellor Row<br>Dallas, TX 75247<br>ATTN: Gus Hutchison<br>(214) 630-9328 |
| Sandia Laboratories<br>Receiving Building 894<br>Albuquerque, NM 87115<br>ATTN: Bernie Stiefeld<br>Division 4722<br>FTS 475-1678 | Donnelly Mirrors, Inc.<br>49 W. Third Street<br>Holland, MI 49423<br>ATTN: Martin DeVries<br>(616) 394-2200 | Sandia Laboratories<br>Division 8451<br>Livermore, CA 94550<br>ATTN: Clay Mavis<br>FTS 532-3031 |
| Ford Aerospace & Comm. Corp.<br>3939 Fabian Way<br>Palo Alto, CA 94303<br>ATTN: I.E. Lewis<br>(415) 494-7400, ext. 4429 | Suntec Systems, Inc.<br>2101 Wooddale Drive<br>St. Paul, MN 55119<br>ATTN: Vernon Rees<br>(612) 735-7600 | |

- mirror coatings and backings,
- cutting and handling,
- annealing,
- structural characteristics,
- moisture intrusion,
- long-term outdoor weathering, and
- hailstone testing.

Falconer Glass Industries, Inc., Falconer, N.Y., was designated to handle the cutting, silvering, crating, and shipping of the fusion glass. This decision was made principally because it was felt that Falconer had more experience than Corning in handling and crating thin glass. In addition, Falconer could provide services for the participating firms such as specialized cutting and silvering. Falconer worked closely with SERI and the individual firms to send the finished product in the fashion and design that the recipients requested, created specialized shipping crates for the glass, and gained a working knowledge and expertise in the proper manner in which to score and break the glass. This vital information was transmitted to the industry recipients in an effort to lessen breakage. The photographs on the following pages show some of Falconer's experience in handling this glass.

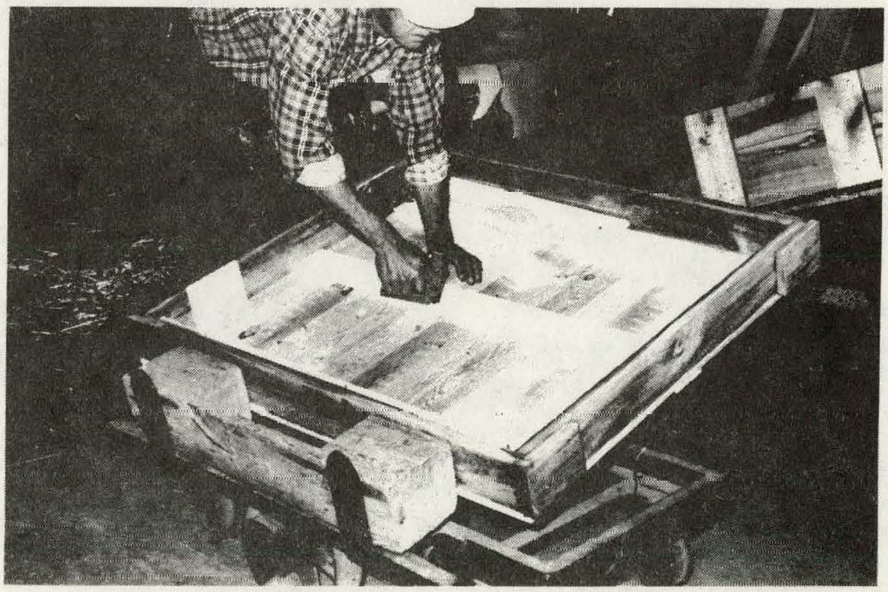
On 1 July 1980, the preliminary reports are due to SERI on the actual use, fabrication, handling characteristics, data gathering, etc., involved in the use of the glass. If the results are favorable and the industry feels that this product might meet its present and future needs, then another, larger run will be procured, which will allow greater flexibility in placement. At that time the RSECs will be asked to help with the coordination, placement, and follow-up procedures. In addition, the RSECs can implement a similar program in their regions so as to broaden and hasten the search for new materials.

The concept for this program is based upon a typical technology transfer objective. However, unlike traditional technology transfers, the SERI program is designed to disseminate not only data and information but a tangible material (or product) that can be applied to a given product (or process). The experience and data will come principally from the private sector and it is by using their resources that we can advance the state of the art in a given technology. Neither the government nor the industry alone is likely to accomplish what we can accomplish by working together.

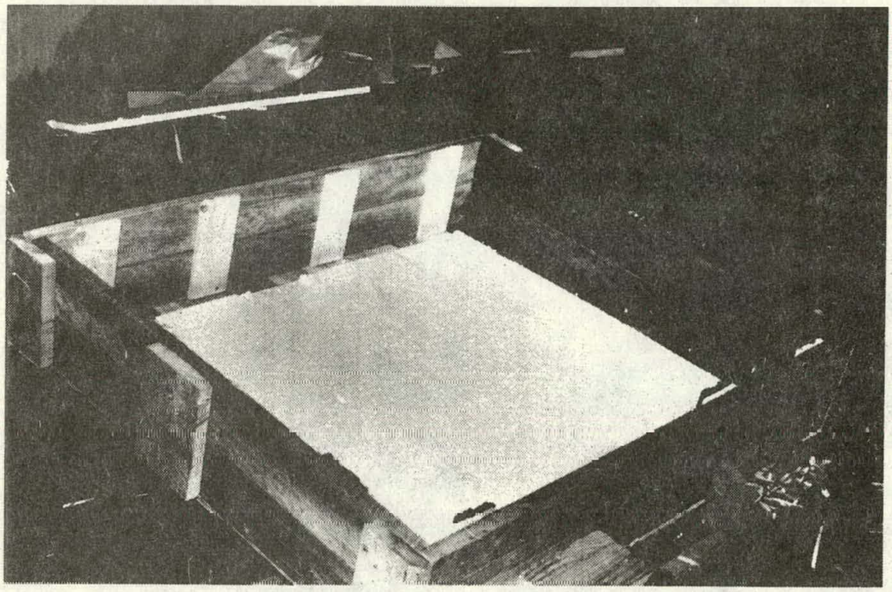


Attempting to cut the 0.40 in. lite (sheet) of glass in strips 12 in. x 42 in. resulted in a high percentage of loss. The score would not run straight, but would relieve itself by fracturing into the larger piece of glass. Falconer discovered that the stress left in the glass relieves itself by pushing the lighter piece of glass away from the larger piece. This was remedied by using a formica float table. Scoring was done with the float off, and running the cut was successfully accomplished with the float on. This, in effect, reduced the inequality of friction and permitted the score to run straight.

Mirrors papered on an "L" rack for in-plant transit.



Styrofoam strips being placed in box for cushioning.



Overall photo of crate at proper angle for packing.

## SECTION 5.0

## POTENTIAL CANDIDATE MATERIALS FOR COMMERCIALIZATION IN THE NEAR FUTURE

### 5.1 CONDULYTE

Condulyte is a monofilament fiber optic with tremendous light carrying capacity. The light cable is made from a cover tube of fluorinated ethylene propylene resin similar to Teflon and an inner core of clear plastic used in expensive eyeglasses. The plastic is a thermoset type and will not melt. The cable is so flexible that a 1/4-in. diameter cable can be wrapped around the waist or tied in a knot. Light may be added or taken out at any point.

The obvious immediate solar applications would be in the area of daylighting and energy conservation. Conceivably a single 500- or 1,000-W bulb could supply light to as many areas of a residence or work area as would be required of many separate light sources, thus effectively eliminating a vast amount of electrical wiring, many unnecessary window and skylight (heat loss) areas, and frequent maintenance. In addition, natural daylight could be captured, concentrated, and piped to work areas, thereby totally eliminating the use of artificial lighting in the daylight hours.

The following are within the realm of possibility for Condulyte:

- Eliminate the use of wire conductors in all places where lighting is the purpose of the wire.
- Have an inexpensive source of cold safe light wherever needed.
- Eliminate the use of some light bulbs.

### 5.2 DOW SILICONE-RESIN-COATED GLASS CLOTH

Silicones are well known in many industries, including the construction industry, for their outstanding resistance to weathering, insolation, and other extreme environmental factors. This durability results from the basic structure of silicones which, like glasses, have a high energy bond between silicon and oxygen atoms.

Unlike other polymers based upon carbon atoms, silicones generally do not have sufficient strength to form strong supporting films like polyethylene or acrylics. This can be overcome by coating silicones on strong fabrics. Dow has recently done this, applying the silicone resin to a woven glass cloth to produce a fabric that lends itself to many passive applications such as Trombe walls, collector glazings, greenhouses, solar ponds, etc. The fabric is durable, has a very high solar transmission, is cost competitive with existing materials, and is extremely easy to handle and fabricate. SERI contracted for the purchase of 200 $m^2$ with Dow in August of 1979; however, the material samples supplied did not meet specifications. It is thought that the batch of resin was bad, and a new batch was sent to Dow's London fabricator. Dow is currently looking for a domestic fabricator and is refining the resin. It is hoped that their problems can be resolved by the beginning of FY81 and that SERI can then begin to assist in the commercialization of this product.

## 5.3 ABSORPTIVE COATINGS FOR CENTRAL RECEIVERS

The Department of Energy is engaged in developing the technology for the practical and economic conversion of sunlight into electricity. An objective of the solar thermal energy conversion program is to establish engineering feasibility and gather economic and environmental data which may lead to construction of solar thermal electric plants by the electric utility industry.

DOE has selected the central receiver configuration for early research, development, and demonstration. A central receiver solar thermal power plant incorporates a number of subsystems. The collector subsystem is a field of mirrors (heliostats) mounted on drive axes that can be controlled to steadily direct the sun's reflected energy on a focal zone. The receiver subsystem includes a tower-mounted absorber located in the focal zone, in which the concentrated solar radiation is converted into thermal energy for transfer into a working fluid (water-steam). In the turbine generator facilities, the working fluid is used to drive a turbine generator set for production of electricity.

A 10-MW pilot plant in Barstow, Calif., is being designed, and construction is scheduled for completion by 1981. The electricity produced by the solar plant will be distributed over existing power lines. This pilot plant will determine the feasibility of future solar thermal power generation plants on the order of 100 MW in size.

A substantial percentage of the total system cost will be that of the collector subsystem. The Barstow system will use 1760 heliostats, each with a reflective area of 39 $m^2$. The land area required for these heliostats is 29.5 X $10^4$ $m^2$. A larger power producing plant will require a proportionally larger number of heliostats displacing a proportionally greater area of land.

Exxon has been under contract to SERI/DOE to develop a high temperature absorptive coating for central receiver applications. Their work, performed from October 1978 through September 1979, resulted in candidate paints that seem to offer significant increases in efficiencies over PYROMARK, the coating presently specified for the Barstow facility. The maximum improvement in efficiency would be provided by lithium sodium silicate paint (Li/$NaSiO_3$), which will increase the solar absorptance 4% over that of PYROMARK, as determined by post cycling exposure optical tests. This increase in solar absorptivity will increase the solar receiver efficiency and decrease the required number of heliostats by approximately 4% for a given power output of the total system, potentially representing a multimillion dollar savings for the full size commercial plant. SERI will provide all data and formulation information to Barstow and Sandia for scaled test demonstrations.

## 5.4 HEAT MIRROR

Heat Mirror transparent insulation is the first major advance in window insulation technology in more than a century, since the invention of the multipane glazing in 1865. It was first shown in 1978 in the Solar 5 Building built by the Architecture Department of the Massachusetts Institute of Technology and has been widely reported in the business and trade press. Heat Mirror is the closest anyone has come to a really good transparent insulation.

Heat Mirror transparent insulation works by transmitting short wavelength solar rays, including visible rays, while blocking longer wavelength infrared radiation by reflecting it back into the room. The reflection principle is the same as the silvering in a thermos bottle but, unlike the reflective coating in a thermos, Heat Mirror is transparent.

Glass also transmits solar radiation and blocks infrared radiation; however, glass blocks heat by absorbing it. This raises the temperature of the glass. To disperse the accumulated heat, glass reradiates it—partially inside and partially outside. Thus, a single pane of glass can stop only a fraction, half or less, of incident heat radiation. To stop a greater portion of the escaping heat, a second, third, or even fourth pane must be added. But performance of multiple panes in blocking radiation is still not as good as that of a single Heat Mirror pane, and solar transmission is drastically reduced while weight and complexity increase.

In short, Heat Mirror transparent insulation reduces fuel costs and increases comfort. In the future, it will become a major factor in reducing fuel consumption for building heating.

### 5.5 FOYLON REFLECTIVE FABRIC

FOYLON is a reflective fabric produced by bonding thin metal foils to a wide variety of woven and nonwoven fabrics. Initial use of these materials was as a safety barrier against cigarette burns in mattresses. Duracote, the manufacturer, has sold millions of yards for this use since 1973. About 50% of the mattresses manufactured in the United States in 1974 included a FOYLON component.

The reflecting fabrics produced by the FOYLON process are unique in a number of ways. As hybrid materials, they combine the heat and light reflectivity of aluminum with the flexibility and lightweight strength of fabric. Further, by selection of substrates, varying degrees of porosity and moisture vapor transmission (MVT) can be designed into the product. A special process can partially wrap each thread with foil, preserving some of the substrate porosity.

The manufacturing process is relatively inexpensive, so that the cost of FOYLON reflective fabric is largely determined by the substrate. A typical 2-1/2 oz product combining a 1/3-mil aluminum foil on a lightweight, inexpensive polyester fabric can be available in volume at costs as low as $\$0.07/ft^2$. Substrates can be woven or nonwoven, made with glass, nylon, polyester, polypropylene, or other plastic materials.

The use of FOYLON reflective fabrics for energy conservation has barely begun. A number of universities have proven the utility of FOYLON in greenhouses as a heat conserving material. Pennsylvania State University now has a FOYLON thermal blanket in a greenhouse installation, where it significantly reduces heat loss. Reflective window shades and drapery liners made of FOYLON have been considered.

In summary, the potential uses for FOYLON in the areas of energy conservation have yet to be explored. This low-cost reflective material could be used in many areas of energy conservation and passive solar technology.

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