APPENDIX A

A.1 DISCUSSION OF MATERIALS

INTRODUCTION. The MODEL-TEA collector is constructed from standard materials, including caulks, paints, sheathings, fasteners, insulations, industrial sidings, sheet metal, and glazings. Most of these materials are available in a variety of formulations and grades from numerous manufacturers. However, all are not suitable for use in a solar collector, which is subjected to UV radiation, high temperatures, and large temperature fluctuations. Many materials which perform well in ordinary building construction will fail in solar collector applications.

This appendix presents a brief discussion of each class of material. The discussion is followed by a list of materials that, based on manufacturers' data and in some cases limited testing, should provide adequate service in the intended applications.

The materials for the rock bin are standard construction materials which should be available from local suppliers. On the other hand, the materials for the air-handling and control systems are very specific, and should be ordered carefully according to the information listed in Appendix A.2.

It should be noted that this list is not necessarily complete. New materials are constantly being developed and introduced. However, before substituting, the user should consult knowledgeable sources to insure that the new materials will perform satisfactorily.

SHEATHING/ABSORBER BACK. On the MODEL-TEA collector, the sheathing serves as the absorber backplate. Thermo-ply, a pressure-laminated, foil-faced, structural sheathing, is recommended as the sheathing. Thermo-ply, unlike plywood, does not outgas and is not as easily degraded by long-term exposure to high temperatures. In addition, the low weight and foil-face reduce the capacitance effects in the collector. A collector with a low thermal capacitance is desirable, since most of the heat stored in the collector is lost when the collector shuts off at night or during cloudy periods.

Thermo-ply is available in several grades. The super strength grade (Blue) can be used without corner bracing on 24 in O.C. framing. It is strongly recommended over the structural grade (Red). It may, however, be difficult to obtain in some areas of the country.

The Thermo-ply can be installed without painting the foil-face. Although painting the Thermo-ply would increase efficiency by 3-4%, it would also increase the capacitance of the collector, resulting in little net increase in performance. It should also be noted that Thermo-ply is easier to handle and significantly less expensive than plywood. Experience at TEA indicates that the use of CDX plywood will result in significant leakage from the collector.

CAULK. Caulking should make an air-tight and vapor-proof seal between two materials, adhere to a moving joint, and withstand weathering, ultra-violet degradation, and extreme temperature variation. Caulks should be able to tolerate continuous temperatures of 140°F, and intermittent temperatures of 200-300°F. In the construction of the MODEL-TEA collector, caulks must remain relatively fluid and tack free for at least a half hour to allow proper positioning and fastening of materials.

All caulks should be applied to clean, dry surfaces. The aluminum absorber plate and the Thermo-ply should be cleaned with a solvent to remove oils and greases. Wood should be clean and dry. Some caulk manufacturers recommend the use of primers, but primers are probably not essential for the type of bonds used in the MODEL-TEA collector.

One-part urethane (polyurethane) caulks appear to be the best all-around caulks for use in the MODEL-TEA collector. They can tolerate continuous temperatures of over 275°F, and satisfy all of the other criteria. Urethanes can be applied without priming on all surfaces, and they remain tack free sufficiently long to allow proper positioning of materials.

Only one type of silicone caulk, GE Silglaze, is appropriate for use in the layered-joint construction of the MODEL-TEA collector. Silglaze is satisfactory in most respects, but is a second choice to urethane because its maximum continuous temperature should not exceed 200°F.

Standard silicone construction adhesives (such as GE 1200, Dow Corning Silicone Rubber Sealant and Dow Corning 790) are unsatisfactory for use in the layered joints of the MODEL-TEA collector. These caulks skin over in approximately ten minutes or less and prevent satisfactory "sandwich" type joints such as the seal between the Thermo-ply and the manifold pans. (These silicone caulks are suitable for use in the glazing details. However, if they are ordered for this application, care must be taken to insure that they are not inadvertently used in other construction steps.)

Polysulfide caulks may also be used in the MODEL-TEA collector. They satisfy all criteria, and can tolerate a continuous temperature of approximately 250°F. However, primers may be necessary; manufacturers' directions should be followed. Butyl rubber caulks are satisfactory in most resepcts. However, their life is estimated at only 7-10 years in normal applications, and might be less in solar collector applications. Consequently, they are not recommended for use in the MODEL-TEA collector. Acrylic terpolymer caulks such as Tremco MONO are unsatisfactory due to excessive degradation at normal collector operating temperatures. Low performance caulks such as oil base, acrylic latex, and other inexpensive formulations, do not satisfy several of the criteria listed in the first paragraph and are also unsatisfactory.

ALUMINUM SIDING ABSORBER. Aluminum siding is available from several manufacturers in "4-inch rib" and "8-inch rib." The choice of rib type depends on the length of the absorber plate (the distance between manifolds). If this distance is greater than 16 feet, 8-inch rib should be used to avoid excessive pressure drops. This will be the case for most roof installations. If the distance is less than 12 feet, 4-inch rib should be used. This will be the case for most wall installations. For absorbers between 12 and 16 feet, either rib design may be used.

Aluminum siding is available with two finishes: mill finish aluminum and factory painted. The mill finished aluminum has an oil residue on its surface and must be degreased prior to painting. (See Absorber Surface Preparation.) It must be primed and painted with an appropriate black paint. (See Paint.)

The factory painted panels are not available with a black finish and must be repainted. There are conflicting opinions from manufacturers regarding the procedure. TEA applied Nextel epoxy directly to the factory painted absorber without primer. There was no evidence of problems following a 30 day stagnation test, but long-term durability is unknown.

Absorber sections should be ordered in lengths sufficient to cover the collector from manifold to manifold; whether from end manifold to end manifold, or from end manifold to center manifold.

Galvanized steel siding can be substituted for aluminum siding as long as the rib width, and dimensions are the same. It is difficult to find and is heavier than aluminum. However, less energy is consumed in the manufacturing of galvanized steel than aluminum.

RUBBER CLOSURE STRIPS. EPDM rubber end closure strips are available from the supplier of the ribbed siding. "Inside" closures, which fit under the absorber, must be specified. ("Outside" closures are available, but will not fit.)

SMOKE BOMBS. It is very important to do a smoke test before glazing the collector. Improper installation of the end closures or inadvertent omission of caulk can result in significant leaks which can easily go unnoticed unless a smoke test is performed. Leaks reduce collector efficiency and must be avoided.

Although smoke can be produced by burning burlap or using (Toxic) rodent smoke bombs, it is best to purchase smoke bombs specially developed for detecting leaks. Superior Signal Company, Inc. makes a suitable smoke bomb for this purpose.

ABSORBER SURFACE PREPARATION. It is very important to clean the absorber surface very thoroughly to insure good adhesion of the paint. Machining oils must be removed from the surface of mill-finish aluminum using a degreaser. Tri-sodium phosphate (TSP) is a good degreaser that is available at many hardware stores. Precautions should be taken to protect the eyes and skin when using degreasers.

Just prior to painting the absorber, it should be wiped with the paint solvent in order to remove residues from the degreaser or from handling the absorber. The absorber can be painted either before or after installation. A surface painted before installation is likely to be scratched and smeared with caulk and will usually require considerable touch-up. Therefore, painting after installation is recommended.

PAINT. Paints used in solar collector applications should be highly absorptive to solar radiation and are usually "flat-black." Paints must be able to tolerate UV radiation, continuous temperatures of 140°F, intermittent temperatures of from 200-300°F, and diurnal expansion and contraction.

They must have good adherence to the absorber surface. Manufacturers' recommendations for surface preparation, priming, and applications of the paint should be carefully followed. Evaporation of the solvent during drying of paints (outgassing) causes a film to be deposited on the glazing, decreasing transmittance and collector efficiency. For this reason, it is essential that the paint be fully dry before the collector glazing is added.

Acrylic enamels and oil base paints are widely available, easy to apply, and durable. However, solvent evaporates during drying and at least two full days should be allowed for drying before the glazing assembly is installed. Epoxy paints consist of two components which must be mixed prior to application. The paint cures by chemical reaction, and outgassing is minimized. Epoxy paints should be used if the construction schedule does not allow several days for drying.

Paints identified as "selective" have recently been introduced. In fact, they are only partially selective. For example, Sun-In has an emissivity of 0.68, compared to an emissivity of 0.10 for an electrochemically deposited selective surface such as "black chrome."

WOOD. Good, straight, dry wood should be used for interior battens; spruce or fir are recommended. Pine should not be used due to the resin which may be given off in outgassing. Redwood is also not recommended since redwood forests are being decimated by over-production.

The outer battens on the wall collector can be constructed from wood or aluminum. Wood is less expensive but requires more maintenance and has been observed to warp and crack. Wood is recommended only if dictated by aesthetic requirements.

GLAZING. The most important properties sought in a glazing system are: 1) resistance to degradation from heat, light and weather, 2) high transmittance to solar radiation and low transmittance to infrared, 3) attractive appearance, 4) ease of handling and fabrication and 5) low cost.

Glass is clearly the best material for glazing a solar collector. It is unaffected by heat, ultraviolet radiation, and weather; properly installed, it should last indefinitely. Glass is optically flat, and is generally regarded as the most attractive glazing.

Since collectors may be subjected to severe thermal stresses, wind and snow loads, and impact from hail and other missiles, only fully tempered glass is acceptable. The use of double glazed, insulating glass units simplifies the installation of two layer glazing systems. Insulating glass units, 46 in. x 96 in., constructed with two panes of 3/16 in. glass and a 1/2 in. air space are specified in the construction drawings for the wall collector. ASG Industries, Inc., markets insulating glass units available with three types of low iron glass: Solatex, Sunadex, and Lo-Iron. The best choice appears to be "Solatex." Its transmittance (0.90) is slightly less than that of "Sunadex" (0.915), but its cost is at least 20% less. Both materials have textured surface which diffuses reflected light, eliminating glare and mirror-like reflections. The elimination of these reflections is an important aesthetic factor for solar collectors; it makes the collectors less noticeable and avoids troubling neighbors with the glare. The overall effect of textured glass with a black absorber underneath, is a smooth, dull, near-black surface. A third glass, ASG "Lo-Iron", has a normal flat surface, resulting in both glare and perfect reflections for situations where that is desired. This material has a transmittance of only 0.88, and it costs approximately 10% more than "Solatex." "Lo-Iron" is only available in the 76" height, and not in the 96" height shown on the drawings.

The cost of ASG insulating glass units is strongly dependent on the quantity purchased. The purchase of less than one standard case of nineteen 34 x 96 in Solatex units will cost $4.90/ft^2$; purchase of a standard case costs only $2.99/ft^2$. Since it is unlikely that nineteen units could be used on a single building, it will be necessary to purchase glass for two or three buildings to achieve the substantial discount.

An alternative is to purchase standard insulating glass units from local suppliers. Only insulating glass panels with an edge detail that allows the inner pane to expend relative to the outer panes is acceptable. Insulating glass with metal or glass edges have a tendency to crack in solar applications and must not be used. It is advisable to consult with the manufacturer regarding the maximum temperature to which the unit can safely be subjected (it should be at least 300°F). The price of these units ranges from \$2.75 to \$5.00/ft^2, depending on the supplier. However, they are not low iron glass, and they will reduce collector effeciency by about 6%. This is worth about \$1.25/ft^2 in fuel over a 20 year period. It should also be noted that most standard units are only available in 34 x 76 in units. Their use will require a modification in the construction plans and result in a smaller collector area per length of wall.

Another alternative is to purchase and install two individual panes of glass. However, this approach is more difficult and is unlikely to result in as durable and as attractive a system; it probably will not provide a savings.

Several manufacturers have developed fiberglass-reinforced polyester (FRP) glazing materials for use on solar collectors. The materials are formulated to provide resistnace to ultraviolet and thermal degradation. Although FRP glazings appear cloudy, their solar transmittance (0.84 - 0.90) is only slightly less than low iron glass. Kalwall's "Sun-lite" and Vistron's "Filon" are two commercially available fiberglass-reinforced polyester glazings.

Sun-lite is available in 4 and 5 foot wide rolls in thicknesses of 0.025, 0.140 and 0.060 inches. It is a popular material for site-built collectors since it is easy to cut, drill, and install. There are, however two problems inherent with Sun-lite. The most noticeable is one of appearance: when applied from rolls, it does not lie flat, resulting in a wavy appearance. This is aggravated as the collector heats up, due to Sun-lite's relatively large co-efficient of thermal expansion. TEA is concerned that the appearance will get progressively worse as the material continues to undergo thermal cycling. In order to minimize this problem, Kalwall has developed double glazed panels where the Sun-lite is "stretched" onto an aluminum frame. The theory is that since aluminum and Sun-lite have nearly the same coefficient of thermal expansion, the glazing will be tight regardless of the temperature. TEA has used the panels and finds that the wavy effect is reduced, but not eliminated.

The second problem relates to thermal degradation at high temperatures. Kalwall notes that Sun-lite experiences losses in transmission of 1%, 3% and 11%, when exposed to temperatures of 150°F, 200°F, and 300°F, respectively for 300 hours. Since summer stagnation temperatures are between 200 and 300°F, some method of ventilating excess heat is required to protect Sun-lite. This is not necessary with glass.

Filon is an acrylic-fortified polyester reinforced with fiberglass. The panels are clad with a layer of Tedlar polyvinylfluoride to provide protection from ultraviolet reduction and weathering. Filon is available in flat or corrugated sheets 4 ft. wide and up to 16 ft. long, in various thicknesses. Use of the corrugated materials may minimize the wavy appearance problem; however, TEA has had no experience with this material. Filon, like Sun-lite, must be vented to protect it from thermal degradation under stagnation conditions. Sun-lite and Filon sheet are not recommended for glazing either the wall or roof version of the MODEL-TEA collector due to their wavy appearance and concerns about the long term effects of thermal cycling.

Rigid plastic glazings have high impact and fracture resistance, good ease of handling and fabrication, and attractive appearance. Most of the products can be categorized as either acrylics or polycarbonates.

Acrylics have a slightly higher transmittance than tempered water-white glass, and exhibit good resistnace to ultra-violet light and weathering. They are usually clear and are as attractive as glass if they are not scratched.

There are several major disadvantages of acrylics in solar applications. Acrylics begin to soften at 180°F and melt at 250°F; they must not be used without fail-safe stagnation protection. Further, they have a very large coefficient of expansion and tend to "bow-in" on the hot side. TEA tested Acrylite SDP, a double wall acrylic glazing, on a collector module. Supported on four foot centers using the manufacturer's glazing system, the material bowed in 3/4 inch, touching the absorber plate and exerting considerable stresses on the glazing supports at normal collector operating temperatures.

Polycarbonates are stronger than acrylics and have a somewhat higher melting point. However, they have lower transmittance and suffer from ultraviolet degradation. Polycarbonates also have a high coefficient of thermal expansion and bow inward toward the absorber plate.

Acrylics and polycarbonates are not recommended for site-fabricated collector applications because of their low melting points and their high thermal expansion at collector operating temperatures.

Plastic films offer high transmittance and are relatively inexpensive. Two common materials are Dupont's Teflon and Tedlar. Teflon has excellent resistance to temperature. However, it has a high coefficient of expansion and tends to sag when installed as an inner glazing. It is also difficult to handle, bowing between supports and sticking to surfaces due to its tendency to acquire a static charge. In addition, it is relatively transparent to infrared radiation from the absorber plate, which reduces its effectiveness. There are similar problems with Tedlar; in addition, Tedlar becomes brittle with thermally accelerated ultra-violet degradation. Plastic films are not recommended for glazing the MODEL-TEA collector.

GLAZING SYSTEM. The glazing system chosen to fasten glass to the MODEL-TEA collector consists of two layers of EPDM strips and an aluminum bar cap. Such a system is sold by CY/RO Industries as their Universal Glazing System (UGS). This can be purchased directly from CY/RO.

It may also be possible to site-build a similar glazing system by purchasing flat EPDM strips from a manufacturer (such as Tremco), and buying aluminum bar stock separately. For a vertical wall collector, wood could be used for this outer batten, instead of aluminum. The wood will not be as durable, but it may be more aesthetically pleasing.