JUNE 1980

FOREST SERVICE U.S. DEPARTMENT of AGRICULTURE
SAN DIMAS EQUIPMENT DEVELOPMENT CENTER

INSTALLATION, MAINTENANCE, and TROUBLESHOOTING for SOLAR-POWERED VAULT TOILET VENTING

INSTALLATION, MAINTENANCE, AND TROUBLESHOOTING FOR SOLAR-POWERED VAULT TOILET VENTING

ED&T 0329
PHOTOVOLTAIC VAULT VENTING

FOREST SERVICE, U.S. Department of Agriculture
Equipment Development Center, San Dimas, California 91773

JUNE 1980

8023 1601

CONTENTS

INTRODUCTION

This manual provides step-by-step procedures for installation, maintenance, and troubleshooting of solar-powered venting systems on vault toilet structures having single vaults and roofs covered with wood or tar composition shingles or fiberglass and vent stacks of either Transite or sheet metal material.

Installation sites should have been preselected based on the practicality of using the system considering:

- **Type of structure and materials**
- **Orientation of the roof to sun exposure**
- **Obstructions such as trees, mountains, buildings, etc., that could cause shadowing over the array.**

Vault toilets with north/south facing roofs require installation of only one array module on the south slope of the roof to have an effective system. East/west facing roofs require installation of two array modules; one on each side of the roof.

NOTE

One array module may be installed on the west slope of an east/west facing roof to have a workable system. However, the system will not be as effective or reliable as a east/west installation because of a power degradation caused by the angle of incidence to the sun during the morning hours.

The required components and tools (as necessary) for installation of the systems are as follows:

- **Array module(s) with a package of assorted nuts, bolts, and washers**

NOTE

The array module has been completely assembled at the factory and contains a 20-Watt array, frame, electrical box with wire bundle, and a lexan cover. The array may be covered with an opaque covering that must be removed after installation to permit the array to absorb the sun's energy to generate electricity.

- **DC motor, 3-in ccw fan blade, and mounting bracket assembly (one 14-in bracket, one 4-in bracket, and two 10-in hangers)**
- **Hammer**
- **Circular saw**
- **Cats paw or nail puller**

- Wire cutters and strippers
- Drill motor with 5/8-in chuck
- Drill bit set—1/8-in through 5/8-in
- Extension cord, 25- to 50-ft
- Portable generator, 110 Vac
- Assorted screwdrivers
- Adjustable countersink bit, 1½-in minimum diameter
- Open end wrenches, 5/8-in and 11/16-in
- Pliers and vise grips
- Tin snips
- Hacksaw
- Weatherproof caulking or sealant
- Electrical wire staples
- One box 8 d galvanized nails
- One box 16 d nails
- One box fiberglass nails with rubber washers
- Lumber, 2 x 4's—8 ft
- Corrugated molding, 10 ft

Component and system manufacturers are listed in the appendix.

INSTALLATION

North/South Facing Roof

Wood or Tar Composition Shingles

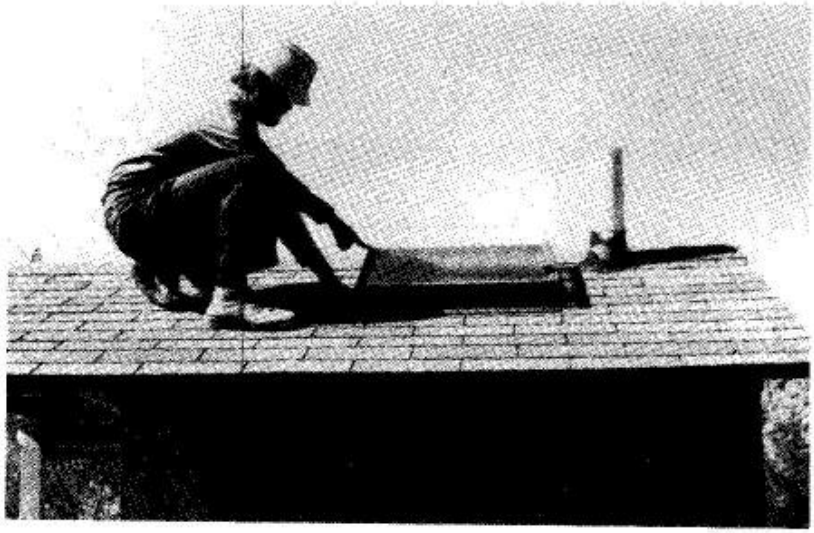
PROCEDURE: **The system is installed as follows:**

WARNING

Array module temperature can be nearly 200° F when exposed to bright sunlight. If the array module does not have an opaque protective covering, cover the module with cardboard, paper, wood, or other suitable material to stop the generation of electrical energy during installation.

1. If the structure has an attic cover, remove the cover and set it aside for replacement after the installation and wiring have been completed.

2. Position the array module on the south slope of the roof approximately 1 ft from the top of the roof ridge with the mounting holes oriented along the top and bottom of the roof and with the electrical box closest to the vent stack.



Position the array module so that the mounting holes are oriented along the top and bottom of the roof.

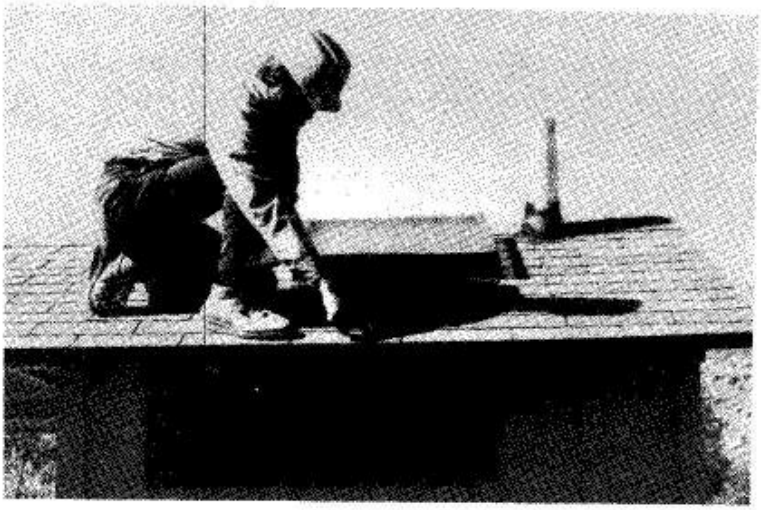
NOTE

If the stack protrudes through the south roof, locate the edge of the array module approximately 1 ft to the right or left of the stack. If the stack protrudes through the north roof, center the array module on the south roof in line with the stack on the north roof.

If the structure has both a south and north roof stack, plug the stack that will not contain the fan motor and bracket assembly; otherwise, the system will not serve the purpose for which designed.

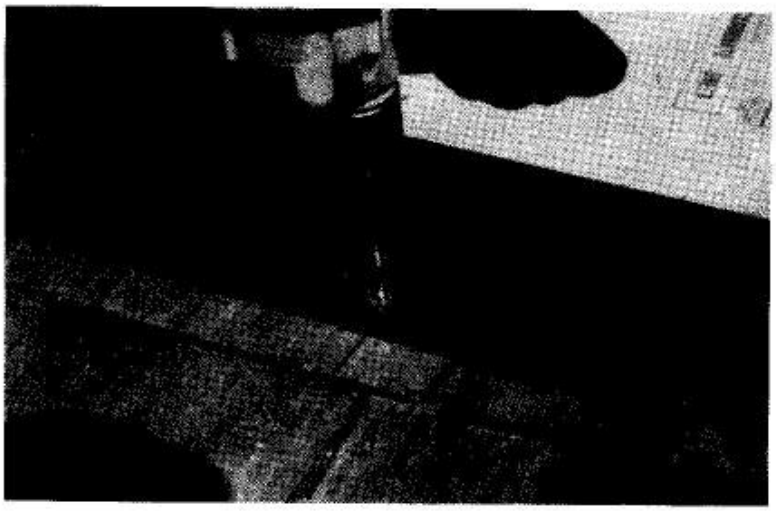
CAUTION

Make certain that the mounting holes of the array module are not positioned over the roof overhang nor any rafters within the structure.



Before drilling the installation holes, ensure that the mounting holes are not positioned over the roof overhang nor any rafters.

3. Using the holes of the module as a template, drill six holes through the roof with a 1/2-in drill bit. Drill the holes slowly so the roof material will not split around the drilled holes from the underside.



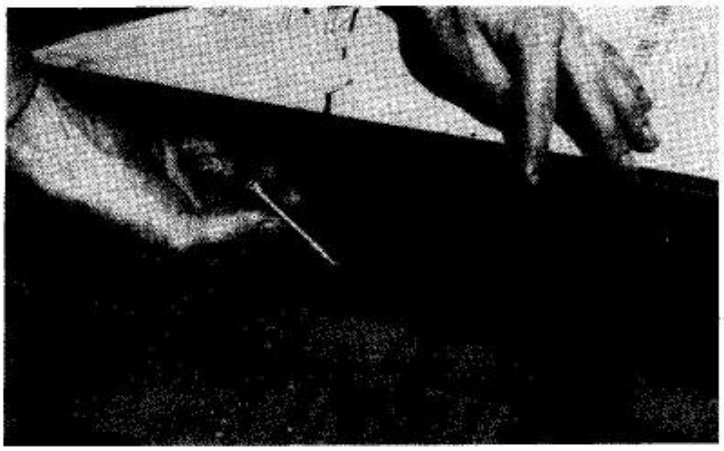
Use the mounting holes of the module as a template and drill six 1/2-in holes through the roof.

4. With the module still in place, locate the protruding wire from the electrical box and mark a location on the roof just below the opening of the box.

5. Remove the module and drill a 3/8-in hole through the roof at the marked location. Again, drill the hole slowly.

6. String the protruding wire from the electrical box through the 3/8-in hole and replace the array module over the six 1/2-in holes. From inside the structure, gently pull the wire through leaving only a slight amount of slack.

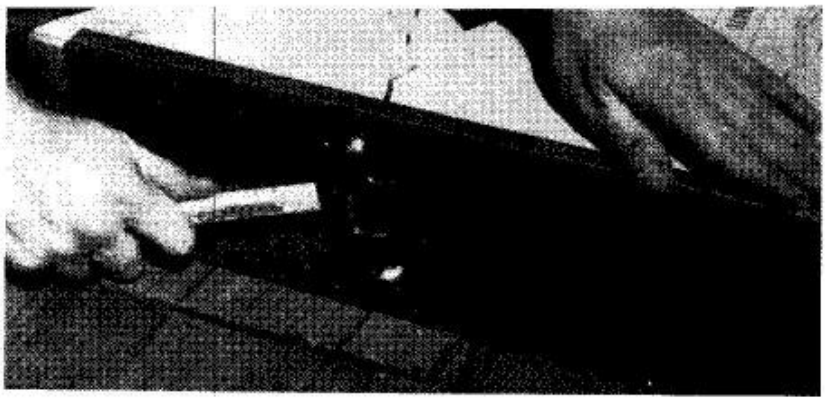
7. Insert six carriage bolts through the holes of the module from the outside if the structure has an attic. If no attic, insert the bolts from the inside using a large fender washer.



Insert carriage bolt through the mounting hole from the outside if the building has an attic.

NOTE

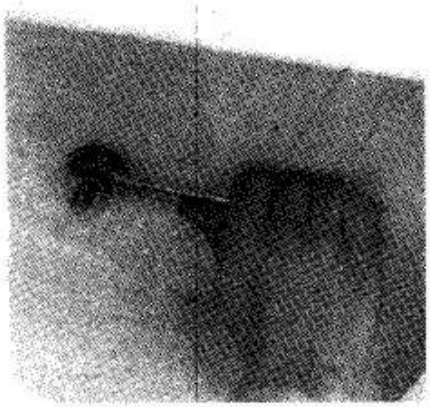
When the bolt is inserted from the outside, the bolt head may or may not fit flush to the module frame because a portion of the head is square and the hole in the module is round. Use a hammer and strike the bolt until the head is flush with the module, but do not damage the module frame in the process. This will prevent the bolt from turning and deter removal by vandals.



If carriage bolt does not fit flush to module frame, use a hammer and strike the bolt until flush with the frame.

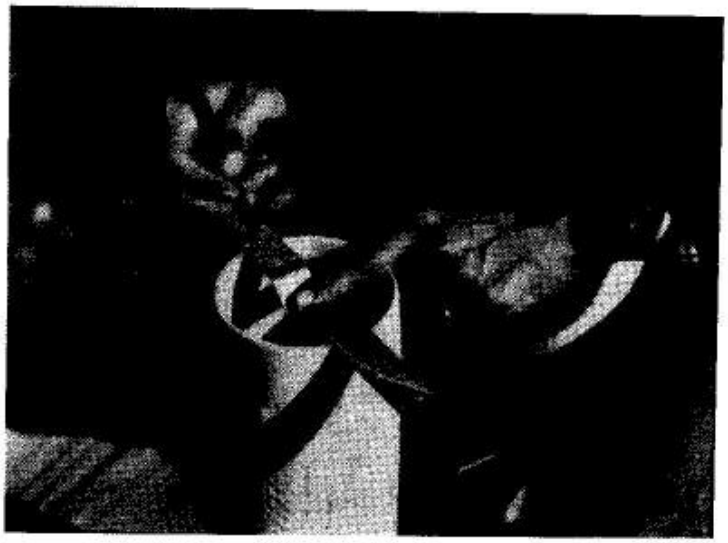
8. Secure the module by attaching six Tufnuts (vandalproof nuts) to the carriage bolts. If the bolt heads are on the outside, use six large washers on the inside between the roof and the nuts.

Thread the Tufnut onto the bolt using the base side of the nut first and thread until flush with the roof surface or washer. Hand-tighten the nut as much as possible. Thread another nut onto the bolt, this time starting with the smaller end of the nut first and thread down to within one to one half threads of the previous nut. Align the nuts so that their faces are directly in line with each other. Insert a 5/8-in wrench between the nuts and tighten. After tightening, remove the second nut. If the Tufnut is mounted outside (or inside and there is no attic), hacksaw the carriage bolt within three threads of the nut.



Use a 5/8-in wrench to tighten Tufnut and hacksaw the bolt within three threads of the nut after tightening.

9. The next steps are to mount the fan assembly in the stack. Center the 14-in bracket over the stack and mark two locations on the bracket where the bracket touches the inside of the stack. Then, make a mark on each end of the bracket 1-in outside the marks made for the inside diameter. Use the hacksaw or tin snips and cut the bracket at the outside marks. The bracket should now be 2-in longer than the inside diameter of the stack.



Center the 14-in fan assembly bracket over the stack and mark the location of the inside diameter of the stack on both ends of the bracket and then make an additional mark on both ends 1-in outside the inside diameter marks. The latter marks are where the bracket will be cut for further installation.

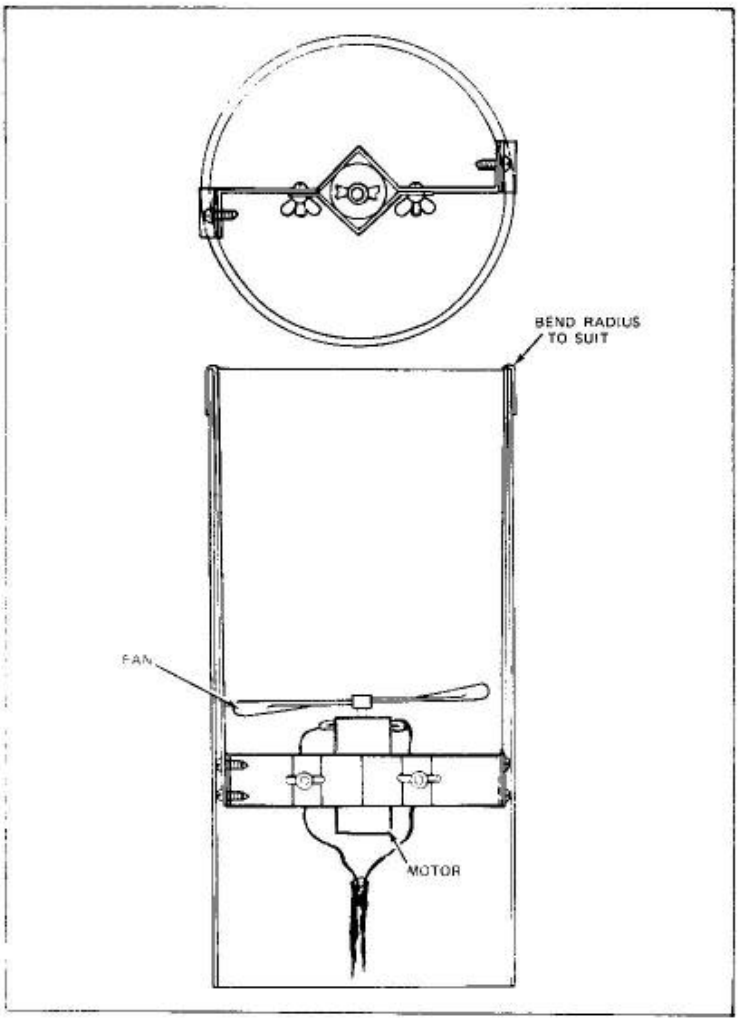
10. Use pliers or vise grips and bend one side of the bracket 90 degrees perpendicular to the bracket at the mark located for the inside diameter. Bend the other side 90 degrees in the opposite direction at the marked location for the inside diameter. Check the fit of the bracket by placing it down the stack. The bracket should fit easily without touching the sides of the stack.

11. Use the vise grips and clamp one 10-in hanger to the bracket perpendicular to the width of the bracket on one side at the 90-degree bend. Use the holes in the hanger as a template and drill two holes through the bracket with a .128 drill bit. Screw a No. 8 sheet metal screw into each hole and remove the vise grips. Repeat this procedure for the other hanger.

12. Position and center the DC motor in the V of the bracket and make sure that the motor shaft is facing in the same direction as the hangers. (When the fan motor and bracket assembly are installed in the stack, the fan blade will be facing the top of the stack.) Place the 4-in bracket over the motor with the predrilled holes aligned with the holes in the other bracket. Insert an 8-32 screw through each hole in the brackets and use wing nuts as fasteners. Finger-tighten the wing nuts to the point where the motor will not slide out of the bracket.

13. Slide the motor and bracket assembly down the stack leaving 1-1/2-in of the hangers sticking out of the stack. The assembly should fit snugly into the stack. Use pliers or vise grips and bend the protruding ends of the hangers over the edge of the stack. Try to bend the ends so that they will fit closely to the side of the stack to permit installation of a vent cap later.

Bend the ends of the motor and bracket assembly hangers over the edge of the stack so that a vent cap can be installed.



Cross-section of fan-motor assembly in vent stack.

14. The next steps are to complete the wiring of the system. Remove the motor and bracket assembly from the stack. Drill a 3/8-in hole in the stack from inside the structure about 2-in from the top of the roof and in a general direction towards the ridge rafter and the array module.

NOTE

The wire from the module will be strung through this hole and the route from the module to the stack will be along the inside roof. The hole should be located so that the wire will not have to be wrapped around the stack.

15. Route the wire from the module to the stack by stapling the wire to the roof and/or rafters using electrical wire staples.

NOTE

Thought should be given as to routing of the wire. For installations without an attic, the wire will be exposed to possible vandalism and selecting a route near the ridge of the roof will help to obscure the wire from detection.

A suggested method is to route the wire to the nearest rafter in a direction towards the stack; then route the wire up the rafter towards the ridge rafter. Continue stapling the wire every 5-in along the ridge rafter towards the stack. When rafters are encountered, drill a 3/8-in hole through the rafter and string the wire through.

16. String the wire through the hole in the stack and then pull the wire out the top of the stack.

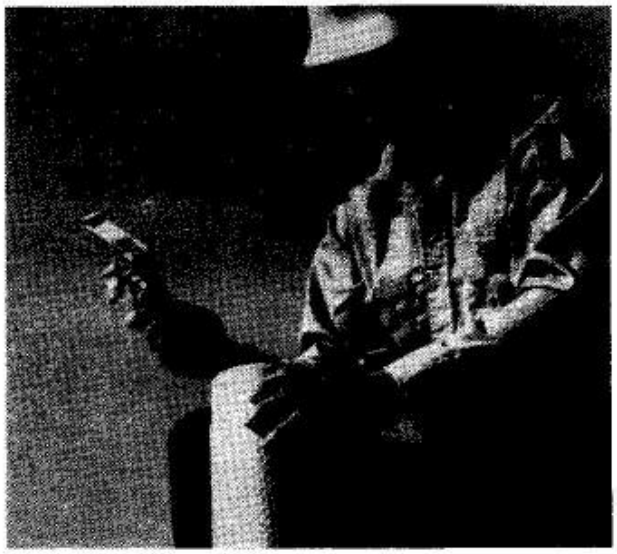
17. Attach the wires to the DC motor—the red wire from the cable to either connector of the red-banded connector and the black wire from the cable to either connector of the black-banded connector. The wires should be connected so that they will hang below the motor.

18. Press the 3-in fan blade onto the motor shaft just to where the shaft protrudes through the blade. The slip-ring or hub portion where the fan blade secures to the motor shaft should be positioned up. This fan operates in a counterclockwise manner.

NOTE

Apply a small amount of graphite or WD-40, or equivalent, to the motor shaft to prevent binding. This procedure should only be accomplished at the time of initial installation, since the motor has been permanently lubricated at the factory. Applying additional lubrication after installation will shorten the life of the motor.

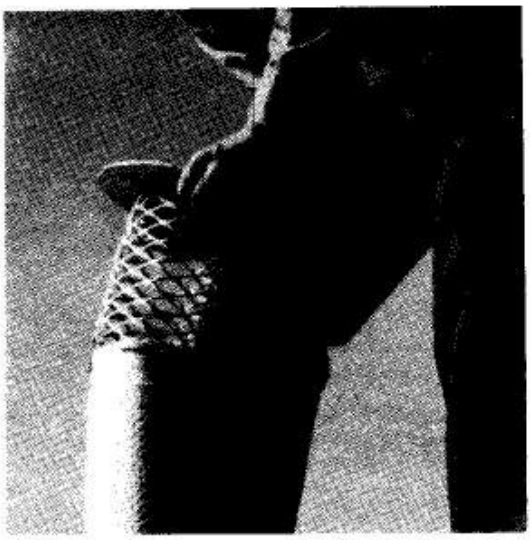
19. Insert the fan motor and bracket assembly down the stack. Ensure the wires hang freely below the motor.



Before inserting the fan motor and bracket assembly into the stack, make sure the electrical wires hang freely below the motor.

20. Remove the opaque material that is over the array module. If the sun is shining, the fan should begin turning. If nothing happens, recheck the wiring hookup and/or refer to the troubleshooting section of the manual. If the system is operating, check to see that air is circulating out of the stack and that the fan is turning in a counterclockwise manner. If the fan is turning too fast to indicate direction, stand over the module in a manner to cast a shadow over the array to reduce the power and slow the fan. If the fan is turning in a clockwise manner, recheck the wiring hookup.

21. Install a vent cover over the stack to protect the fan assembly from vandalism, precipitation, and debris accumulation.



After installation of the fan and motor assembly in the stack, place a vent cover over the stack for protection against vandalism, precipitation, and debris accumulation.

CAUTION

Do not use a turbine ventilator or a vacuum cap ventilator as a substitute for a vent cover. Substitution will hamper the effectiveness of the system.

22. Caulk the two holes where the wire was inserted through the roof and into the stack.

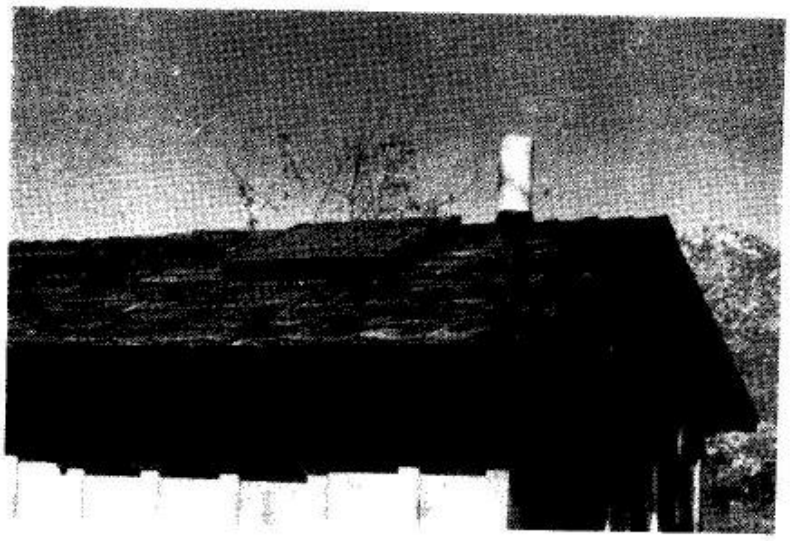
23. Replace the attic cover if the structure was so equipped. If not, paint over the wires with a color similar to the interior of the structure.

24. Clean the lexan cover of the module with a mild detergent and water followed by a water rinse. Use a damp cloth or squeegee to wipe the surface.

WARNING

Never use paper products to wipe the lexan cover. Paper products tend to scratch the surface of the cover causing the lexan's transparency to be obscured and in turn, causes the sun's rays to be deflected resulting in degradation of power to the system.

Installation of the solar-powered venting system is now completed.



Outside view of completed solar-powered venting system.

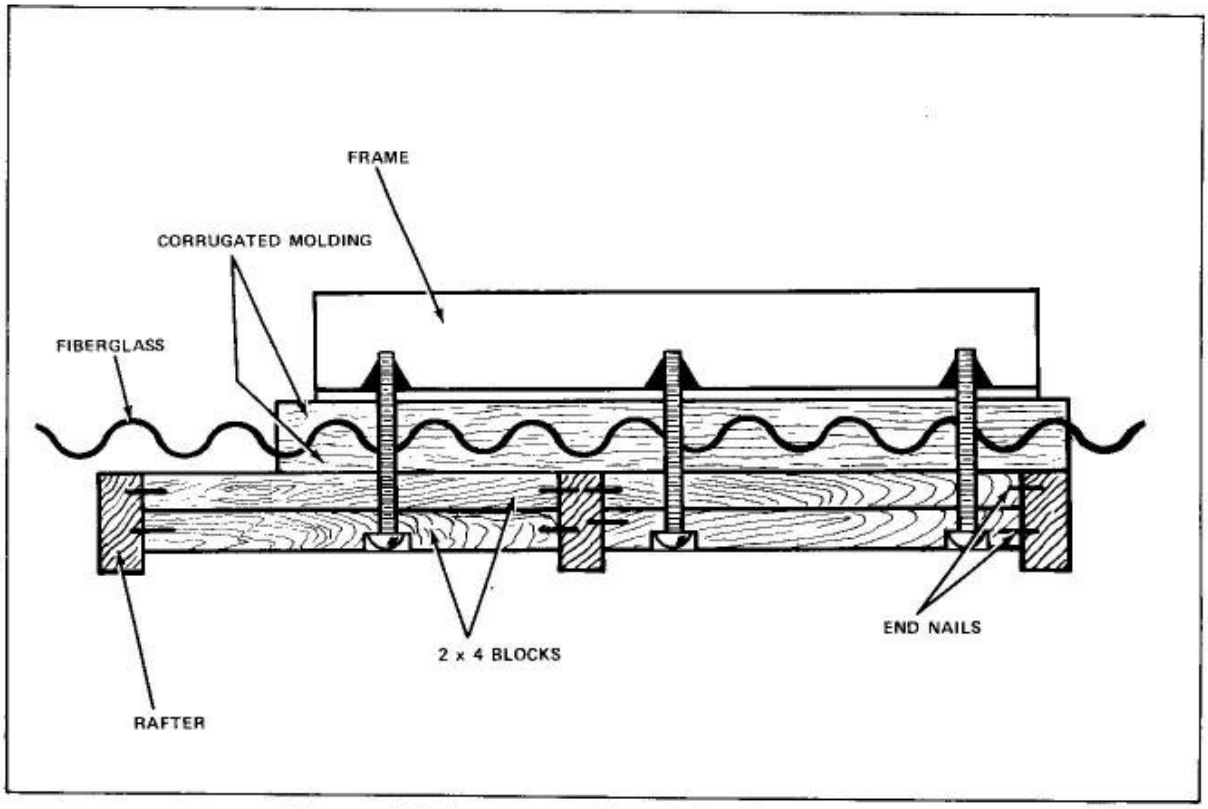
Fiberglass

PROCEDURE: The system is installed as follows:

WARNING

Array module temperature can be nearly 200° F when exposed to bright sunlight. If the array module does not have an opaque protective covering, cover the module with cardboard, paper, wood, or other suitable material to stop the generation of electrical energy during installation.

1. Follow steps 2 through 5 for the wood or tar composition shingled, north/south facing roof.



Solar module frame assembly on fiberglass roof.

2. Cut four or more pieces of 2 x 4 lumber the same length as the distance between the rafters to use as backing blocks. As many as eight pieces may be required to ensure that every mounting bolt will be mounted into a pair of blocks. Use two 8 d nails and nail the blocks together as pairs. Position the blocks directly under the centerline of the holes drilled in step 1. The blocks should be placed with the 4-in face flush against the fiberglass and end-nailed with 16 d nails.

3. Use a cats paw or nail puller and remove all nails holding down the fiberglass panel in the immediate area of the array module position. Enough nails must be removed to allow the fiberglass to be pushed up easily from inside the structure. Cut two pieces of corrugated molding the same length as the array module's mounting hole side frame. Push the fiberglass up from inside the structure and slide the molding on top of each block. Centerline the molding under the drilled holes in the fiberglass. Drill a 1/8-in hole 6-in from each end of the molding through the fiberglass and molding. Drive an 8 d nail through each hole and into the blocks to hold the molding in place.

4. Use the holes in the fiberglass as a template and drill 1 2-in holes through the molding and the blocks. Use fiberglass nails and renail the fiberglass back into place.

5. Cut two additional pieces of corrugated molding the same length as the previously cut molding and apply caulking or sealing compound on the curved side of the molding. Center these moldings against the fiberglass over the drilled holes. At each end of the molding, drill a 1 8-in hole through the molding and fiberglass and drive an 8 d nail through the holes and into the blocks to hold the molding in place.

6. From inside the structure using the holes in the blocks as a template, drill 1/2-in holes through the top molding and then countersink a 1-1/2-in diameter hole 3/4-in into each of the holes in the blocks.

7. String the protruding wire from the electrical box through the 3/8-in hole and replace the array module over the six 1/2-in holes. Gently pull the wire through leaving only a slight amount of slack.

8. Have an assistant push a carriage bolt with a washer attached into each of the holes in the blocks from inside the structure. Thread a Tufnut onto each bolt using the base side of the nut first and thread until flush with the module. Hand-tighten the nut as much as possible. Thread another nut onto the bolt, this time starting with the smaller end of the nut first and thread down to within one to one-half threads of the previous nut. Align the nuts so that their faces are directly in line with each other. Insert a 5/8-in wrench between the nuts and tighten. After tightening, remove the second nut and hacksaw the end of each bolt to within three threads of the nut. After securing the module, caulk the countersunk holes in the blocks.

9. Complete the system installation by following steps 9 through 22 and 24 for the wood or tar composition, shingled, north/south facing roof.

East/West Facing Roof

Wood or Tar Composition Shingles

PROCEDURE: **The system is installed as follows:**

WARNING

Array module temperature can be nearly 200° F when exposed to bright sunlight. If the array module does not have an opaque protective covering, cover the module with cardboard, paper, wood, or other suitable material to stop the generation of electrical energy during installation.

1. Position an array module on each side of the roof approximately 1 ft from the ridge and 1 ft south of the vent stack with the electrical box of each module closest to the stack. Ensure that the mounting holes are oriented along the top and bottom of the roof and that the holes are not positioned over the roof overhang nor any rafters within the structure.

NOTE

If the modules cannot be mounted south of the stack, mount them north of the stack but at least 3 ft away to prevent the stack from overshadowing the modules. Shadowing will reduce the effectiveness of the system.

If the structure has more than one stack, plug the stack that will not contain the fan motor and bracket assembly; otherwise, the system will not serve the purpose for which designed.

2. Follow the installation procedures for the north/south facing roof for both modules and the following additional procedures.

3. Drill a 5/8-in hole in the stack from inside the structure about 2-in from the top of the roof and in a general direction towards the ridge rafters and the array modules.

4. Attach the wires to the DC motor—the red wire from each cable to the double-ended, red-banded connector and the black wire from each cable to the double-ended, black-banded connector. The wires should be connected so that they will hang below the motor. Continue with the installation procedures for the north/south facing roof.

Fiberglass

PROCEDURE: **The system is installed as follows:**

WARNING

Array module temperature can be nearly 200° F when exposed to bright sunlight. If the array module does not have an opaque protective covering, cover the module with cardboard, paper, wood, or other suitable material to stop the generation of electrical energy during installation.

1. Follow the installation steps for the north/south facing fiberglass roof and the additional installation and wiring instructions for the east/west facing wood or tar composition shingled roof.

MAINTENANCE

Generally, the solar-powered vault venting system is trouble-free. However, periodic inspections should be performed to reveal problems such as motor malfunction, shorts, vandalism, and debris accumulation on the array module. Foreign materials coming into contact with the module surface will tend to fall away due to the mounting angle or will be washed away during a rain. Some sources of module soiling are:

- **Airborne emission particles**
- **Bird droppings**
- **Leaves and pine needles**
- **Rocks**
- **Snow.**

If soiling buildup becomes excessive, the system's performance will be degraded. Soiling may be removed with either plain water or a mild detergent solution followed by water rinse. Use a damp cloth or squeegee to wipe the module's surface. Never use paper products to wipe the array module cover, nor use solvents or strong detergents.

For problems associated with the performance of the entire system or individual components, refer to the troubleshooting section.

TROUBLESHOOTING

Always perform troubleshooting on a sunny day, preferably during mid-day when the sun is at its peak. The first step in troubleshooting is to determine that the module is not obscured by shadowing and that the fan is turning; if not, cover the module with an opaque material to stop the generation of electrical energy and proceed to troubleshoot the fan assembly in the stack.

1. Check for objects that may be preventing the fan from turning, such as debris, rocks, or a broken motor bracket and broken or disconnected wires.

2. If step 1 is not the problem, remove the fan motor and bracket assembly from the stack and spin the fan blade on the motor; it should turn freely. If not, remove the fan blade by gently but firmly pulling it off the motor shaft. Disconnect the wires from the motor and connect a 12-V power source to the motor. If the motor is not functioning properly, go to step 3. If the motor is functioning properly, reconnect the wires and insert the fan motor and bracket assembly back into the stack. Remove the opaque covering from the module; the fan should then start turning in a counterclockwise manner blowing air out of the stack. If not, go to step 4.

3. To replace the motor, loosen, but do not remove, one wing nut on the motor bracket. Grasp the motor body and pull the motor out of the bracket. Install the new motor making certain that the black wire is connected to the black connector and the red wire to the red connector. Install the fan blade on the motor and insert the fan motor and bracket assembly back into the stack.

NOTE

Before installing the fan motor and bracket assembly back into the stack, apply a small amount of graphite or WD-40, or equivalent, to the motor shaft to prevent binding. This procedure should only be accomplished one time—at initial installation or replacement—since the motor has been permanently lubricated at the factory. Applying additional lubrication after installation will shorten the life of the motor.

Remove the cover from the module; the fan should then start turning in a counterclockwise manner blowing air out of the stack. If not, go to step 4.

4. To check the module performance, remove the fan motor and bracket assembly from the stack and disconnect the wires from the motor. Put the motor aside and connect an ammeter across the black and red wires coming from the module through the stack. The ammeter's resistance should be such that the voltage drop across the ammeter is less than 0.3 volt. Measure the current output from the array. On a clear sunny day current output should be approximately 1.0 amp or more. Disconnect the ammeter and connect across the same wires a voltmeter having an impedence of at least 1,000 ohms/volt. The voltmeter

reading should be at least or greater than 13.0 volts. If these readings are not obtained, remove the module from the roof and remove the electrical box service plate. Perform the same ammeter and voltmeter tests by connecting the equipment to the wire connectors in the electrical box.

NOTE

When performing these tests, make certain that the array module is facing towards the sun.

If the module is functioning properly, the wires and connections between the module and motor have malfunctioned and should be replaced. If the module is defective, then replace the module or return the module to the manufacturer for repair.

If the system still malfunctions after troubleshooting procedures have revealed no reason for the malfunctioning, then the component or system manufacturers should be contacted. Manufacturers are listed in the appendix.

APPENDIX

MANUFACTURERS

Array Module, 20 W, Model No. 4200J

Solarex Corp.
1335 Piccard Drive
Rockville, MD 20850
Telephone: (301) 948-0202

DC Motor, Serial No. 650, Stock No. 6517-000

Rowe Industries, Inc.
9571 Pan American Drive
El Paso, TX 79927

Fan Blade, Celcon Plastic, Sizes 1-1/2-in to 10-in CCW

Glenn M. Stevenson Co.
20331 Coulsen Street
Woodland Hills, CA 91364
Telephone: (213) 458-5506

Solar-Powered Venting System

North/South Facing Roof, Stock No. E2000
East/West Facing Roof, Stock No. E4000

Solarex Corp.
1335 Piccard Drive
Rockville, MD 20850
Telephone: (301) 948-0202

Tufnuts, No. F29(7)

Ojo Caliente Craftsmen, Inc.
P. O. Box 67
Ojo Caliente, NM 87549

EQUIPMENT DEVELOPMENT AND TEST

The Forest Service's Equipment Development and Test (ED&T) program, conducted by two Equipment Development Centers (San Dimas, Calif., and Missoula, Mont.), provides systematic application of scientific knowledge to create new or substantially improved equipment, systems, materials, processes, techniques, and procedures that meet the objectives of advanced forest management and utilization in the United States. The ED&T effort, featuring Mechanical Engineering activities, encompasses projects in forest engineering, aviation and fire management, recreation, timber, range, wildlife, occupational safety and health, forest insect and disease, and forest residues to enable forest work to be performed more efficiently, at less cost, with minimum hazard.

As needs for field development services are identified and defined, the Centers determine if already available commercial products are suitable as is or if they require modifications necessitated by the forest environment. On the other hand, sometimes needs can only be met by the Centers taking advantage of the latest technology to create new concepts through a step-by-step product development program. These developments are typically achieved by active ED&T involvement with disciplines found throughout the Forest Service. The new equipment is field tested and demonstrated and user feedback is obtained to evaluate results. The role of the Centers is not considered complete until project output is implemented in the field.