Other Techniques

In addition to the previously discussed design approaches, there are a number of other special energy efficient techniques which can be applied to tropical island homes. Some of these have only efficient application on specific sites, such as wind turbines, while others are not currently common or readily available, but are signposts of upcoming developments in this area of energy efficient residential design.

Solar Water Heater (or Pre-Heater)

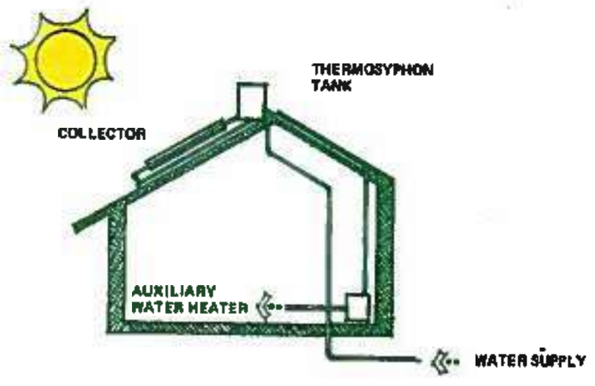
Water heating accounts for 30 percent of residential energy use in a non-air-conditioned house, so major savings are possible. A solar water heating system replaces an existing water heater with a solar collector and an insulated storage tank.

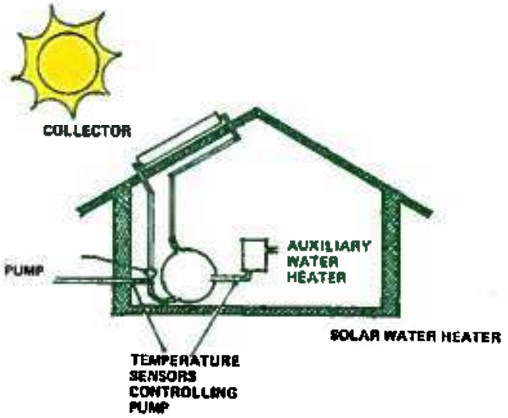
The most common collector is the flat plate type, which is basically a group of waterways connected to a sheet or plate that collects solar radiation. The sun warms the plates, heating the waterways and the water that is circulating through them. A transparent cover increases the efficiency of the unit by trapping heated air in the space above the absorber plate. Insulation prevents the loss of heat from the back.

As a general rule a family of four would need 40 to 50 square feet of collector and 60 to 80 gallons of water storage.

Collector slant from the horizontal should be approximately the same number of degrees as the latitude for maximum year round absorption and no less than a five degrees slope for proper venting of the system. Orientation should be within 25 degrees of due south.

There are two basic systems: thermosyphon and pumped. In a thermosyphon system the top of the collector is at least one foot below the bottom of the storage tank, thus the physical law that hot water rises causes a flow, and the hottest water can be drawn off the top of the tank and be replenished by water from a supply line feeding into a low point of the tank.





A pumped system uses a pump to move the water through the collector, allowing the storage tank to be located below the collector, avoiding problems of a heavy storage tank atop a structure, yet allowing the collector to be on the roof, away from vandal damage.

A small standard electric or gas heater can be used as the storage tank with the solar collector to assure an adequate supply of hot water. If the users can schedule most of their hot water usage in the late afternoon or evening, and accept temperatures of around 110F (43.3C), the conventional heating element in the tank can be avoided or set not to be activated above 110F.

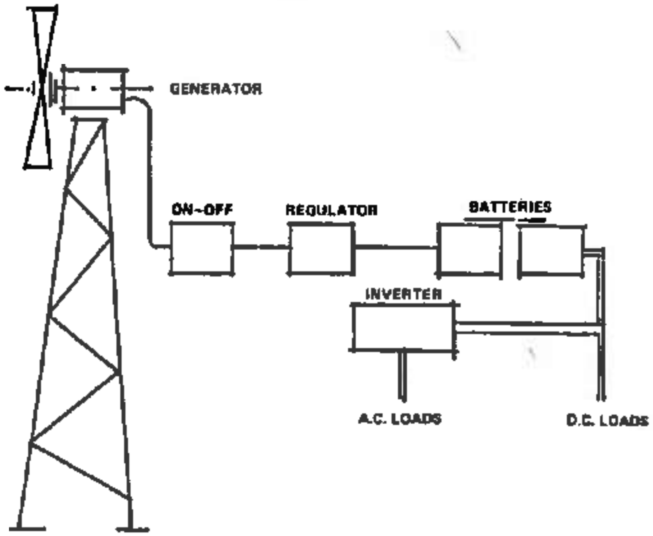
Whether solar water heating systems are economical involves studies of several factors. A system is generally assumed to have a 20-year life, thus its resale value as part of the house would need to be considered. The federal tax credits of 40 percent also need to be considered. These reduce the first year cost. Federal energy conservation tax advantages are reviewed in the appendices. Of consideration to some individuals are also the moral responsibility of reducing consumption of limited non-renewable energy resources and the status of being a part of current technological concerns.

Wind generation of electricity on a residential scale is highly dependent on the site. The cut-in wind speed where useful electricity is produced is generally around 8 to 10 miles per hour, with some units this is as low as 6.7 miles per hour. The power of the wind is proportional to the cube of the wind speed; there is 73 percent more energy in a 12-mile per hour wind than at 10 miles per hour. An average family of four will use 1000 kilowatt hours of electricity per month (without air conditioning) for which most small wind turbines would require an average 22-mile per hour wind speed.

Wind generation can be an economic alternate where the site is remote and you may have to provide a mile or more of power line at your own cost.

At lower wind velocities, between 20 and 14 miles per hour, it would be more logical to have two smaller rated units (i.e., 2000 watts at 22 miles per hour) rather than one unit (i.e., 4000 watts at 22 miles per hour) because at lower speeds both units generate approximately the same kilowatts, thus the two smaller systems would generate twice the kilowatt hours of this larger unit. Having two smaller units would also allow for a back up during maintenance or emergency repairs.

An inverter is usually used to convert the 12-volt DC, direct current, to 115-volt, 60 cycle, alternating current. These are costly and consume electricity themselves, thus it is desirable to run as many appliances as possible on direct current, allowing for a reduced size of inverter. Some appliances can accept either alternating current or direct current (such as vacuum cleaners, shavers, sewing machines and food mixers. Others such as stereo, TV, clock, refrigerator and washer need the alternating current. However, manufacturers recommendations and warranty restrictions should be checked prior to usage.



Most people want the wind system to supplement their existing electric utility service. The wind turbine is tied into the power line, drawing power from the utility company when needed and feeds excess power back into the power line, (reversing the meter) when the power is not needed.

To eliminate the cost of the inverter the present trend is toward induction turbines. They can be tied directly into the power lines without the inverter, thus providing a cheaper system. However, the speed at which they run must be closely controlled.

The wind turbine is generally supported on a pole, either freestanding or guyed.

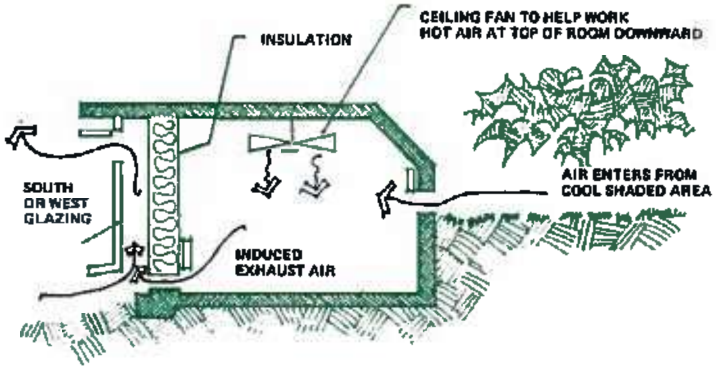
To study a particular site before purchasing a wind turbine data should be collected for at least three months with an odometer for measuring long-term average wind speeds.

Trombe or Cavity Walls

A Trombe (pronounced tromb) wall is a concrete wall used to store heat located behind glazing material.

Sunlight is trapped behind south or west glazing, heating a wall or sloped roof mass; as air between the mass and glazing is heated it rises to be vented to the outside at the top. Interior house air is drawn into the space at the bottom of the wall. New air is thus pulled into the house, preferably entering the house at low shaded spots on the north or east sides. Insulation is necessary on the interior room side of the Trombe wall to keep the heated mass from heating the room.

Caution should be applied not to use acrylic plastic glazing as the temperatures generated will cause warping and cracking. Gaskets or mullions which allow for sufficient thermal expansion must be used. Consideration must also be made for typhoon protection of the glazing. This could be done with hinged panels or shutters that could be employed to reflect additional sunshine onto the wall.



TROMBE OR CAVITY WALL

Wall thicknesses of up to 18 inches of concrete are beneficial for the mass storage. The more heat stored the longer the system will work after the sun is no longer shining on the wall. The spacing from the glazing to the mass should be a minimum of 3/4 inch. The total cross-sectional area of the bottom vent openings should be equal to one-half the plenum cross-sectional area between the masonry wall and the glazing. Since the air to be exhausted enters the chamber low on the wall, this system does not exhaust the hotter air near the ceiling. Ceiling fans can assist by pushing the warm air down, or the chamber could be located on a second floor wall to exhaust air from the first floor ceiling.

Coolth Tubes

It is possible to use earth's mass for cooling by conducting incoming air through long tubes buried underground, in earth berms, or laid in the bottom of ponds. This method uses the stable temperature of the earth's mass to absorb heat from air passing through the tubes.

This also has the potential for removing humidity from the air. As the temperature of the air reaches the dewpoint of its moisture contents, water condenses out. Tubes sloping downward allow this moisture to drain out near the bottom end of the tube before the air enters the house, or perforated pipes could be used on a ground bed so moisture drains from the pipe immediately. To remove humidity the ground temperature needs to be below the dewpoint, which, based on our island's averages runs between 69-77 degrees F (20.6-25C) but on an extreme day would be 85 degrees F (29.9C). The ground temperature is believed to be only approximately 78F (25.6C), so this system would only work occasionally in the capacity of dehumidification.

Tubes can be made of concrete, clay tile or plastic, but currently they are usually ABS plastic corrugated pipe, which has a higher conductance than the ground. Inlets must be protected from rain entry, screened and placed in well-shaded areas. The tubes should be between 8-inch and 18-inch diameter, with 12-inch diameter being preferred.

The available data indicates these tubes are effective for only about 60 foot runs; after that distance the temperature difference between the ground and air is too small. Insulation in the soil above the tubes may be necessary to keep the earth cool around them, depending on the depth of the tubes. Normally the tubes are placed at six feet or more below the surface and they can be expected to stay at the average annual air temperature, 79F (26.1C). Pipes should be no closer than four feet apart, so they do not heat the earth in between.

Coolth tubes can also be used in what is called a closed loop system. In this system the air-conditioning fan circulates the warm return air through the tubes to be cooled by the ground. If the air is sufficiently cooled by the ground, then the air conditioner condenser does not turn on.

The amount of cooling from this type of system can be estimated by the following equation:

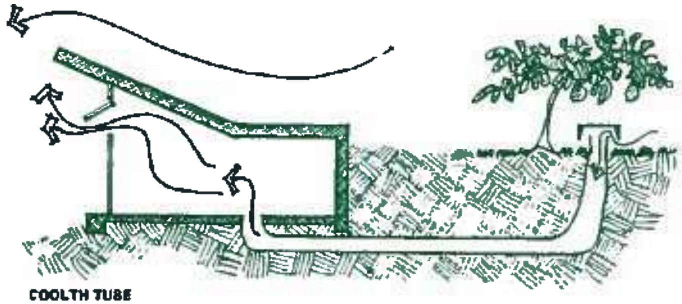
Cooling (BTU x 10^6) = 0.00463 x cubic feet per minute
air flow + 0.022 x pipe diameter (inches) +
0.0168 x pipe length (feet) +
0.168 x soil conductivity +
0.0580 x soil heat capacity

local soil conductivity is:

Coral	1.3
Clay soils	0.75

local soil heat capacity is:

Coral	0.20
Clay soils	0.22

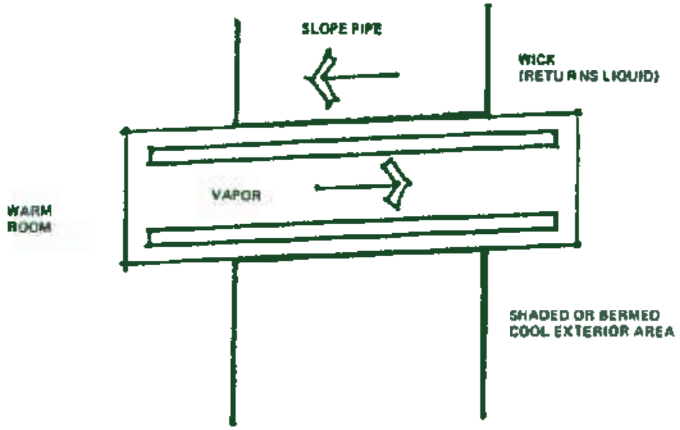


COOLTH TUBE

Heat Pipe

A heat pipe is a passive device for transferring heat from one point to another. It consists of a sealed tube that is evacuated and partially filled with a working fluid such as Freon. When heat is applied to the low end of the tube some of the fluid evaporates and expands, flowing to the unheated end where it releases heat by condensing and flows to the low point again. The system is self-balancing; the more heat applied the faster it works.

This could be used to quickly remove heat from a space that cannot otherwise be easily opened for air flow; such as earth sheltered or tightly enclosed normally air-conditioned spaces.



HEAT PIPE

Convection Air Conditioning

Air-conditioning systems are available that use convection air currents rather than the typical blower and ductwork systems. These use approximately 40 percent less electrical power, but cost double for the initial installation investment.

These systems have cold Freon circulating in finned tubing at valance level along at least all outside walls. The air in contact with the fins is cooled, becomes heavier and falls down the wall pulling warmer air from the ceiling in behind it, thus setting up the natural convection air current. Due to the slow air current motion, the air is in contact with the finned tubing longer allowing approximately 25 percent better dehumidification action than typical air-conditioning systems. A continuous drain pan under the coiling coils is required and is a part of the overall system. This type of system reduces the noise inside the space since blowers are not used, but would have a longer start-up cool down period. This could be easily installed in existing buildings where low ceilings make typical ductwork difficult.

The roof-top heat exchanger and the water heater reclaim option qualify this system for the energy income tax credit. This brings their break even period down to three to four years in comparison to typical central air-conditioning systems.

Desiccants

Desiccant salts in solid form absorb tremendous amounts of water vapor from the air. During this water-vapor absorption, heat energy is released, so insulation from the space would be required in conjunction with the desiccant panel, and perhaps a heat sink.

If the absorbent materials were placed in the east and west walls of a building, the morning sun could heat the east wall, regenerating the material which had absorbed moisture the previous afternoon and evening. At the same time the west wall could dehumidify the incoming air. In the afternoon the process would reverse as the sun moved on to the west wall.

Earth Sheltered or Bermed Structures

A sod roof over a structural roof can provide extra insulation from the direct sun. The soil acts as a dense mass of heat absorbing material to inhibit and delay heat transfer to the interior. The vegetation provides shading and evaporative cooling. Dew that condenses on the vegetation provides evaporative cooling during the morning. In calculations coral gravel would have an R of 2.04 and clay an R of .48 per foot. Up to 10 inches of soil cover on a 6-inch concrete slab would be beneficial for a tropical area and will provide a thermal time lag of approximately 12 hours.

There are three basic concepts: The "elevation" type that includes one or more exposed walls for access, natural light, and view; the "atrium" type has the earth-covered home surrounding a central open court-area or atrium; with light and access provided through this central area; and the "penetrational" type has a totally covered house except for skylights and access doors punched through the roof.

Earth-sheltered houses not only can take advantage of the insulation value of the soil, but also experience some cooling by the ground absorption of heat load from the house. This system will hold the walls at a mean radiant temperature of 78F (20C) on our island.

This technique is undesirable alone as it does not have sufficient exposure to the air to maintain humidity control and the house's interior air still needs to be exchanged at least once every two hours to maintain adequate oxygen and prevent accumulation of carbon dioxide and toxins. Air conditioning or coupling with some other system, such as coolth tubes, for humidity control should be anticipated. At least the heavy damp air that is near the floor must be ventilated out.

Construction should be kept above any ground water level or flood plain. Overall site drainage must be seriously studied. Soil percolation should be checked where sunken courtyards are to be used. Such areas need percolation beds or floor drains to prevent flooding.

The level of the sewer line should also be checked to insure gravity flow from the house.

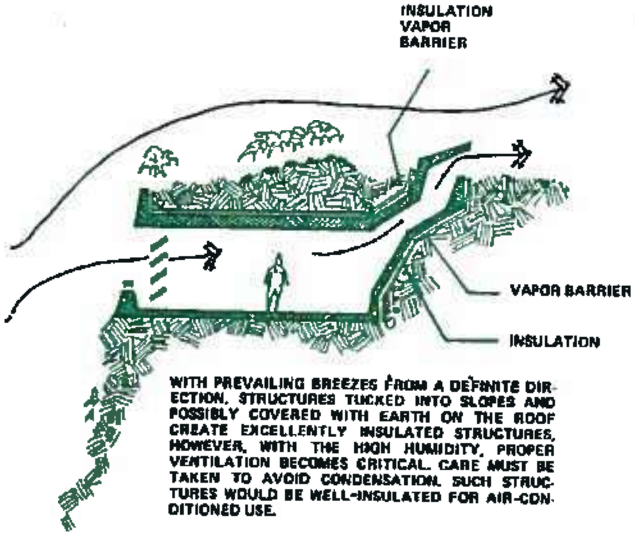
Building codes require an openable window in every sleeping room for fire safety exiting. This can be done with windows on the side of a hill, in an open sky-well or into a sunken courtyard. These windows must have a sill height no more than 44 inches above the floor, and a clear opening of a minimum 20 inches wide, 24 inches high and 5.7 square feet.

A vaporproof barrier is required to block the flow of moisture from the earth through the construction materials into the house. Recommended for the roof is 1/32-inch butyl sheeting completely bonded to the surface, to avoid side movement of water in a rip or seam break. Walls can be a trowel-grade mastic or spray-on elastomeric vaporproof treatment. All penetrations need to be sealed, including around conduits and pipes.

Windows on the east and west that let in the most solar energy should be protected or small, close up seating will provide the equivalent to normal viewing. Sliding or folding indoor insulating window covers should be provided to seal in coolness during the hottest days, or when a room is not in use.

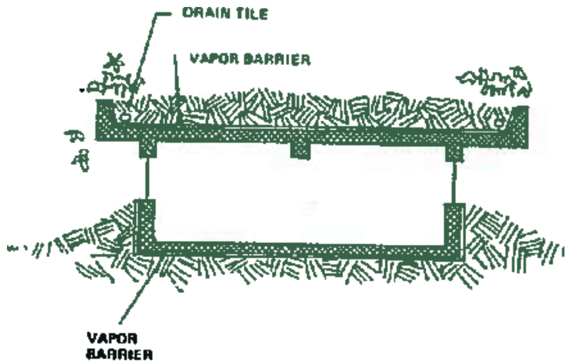
Landscaping on the roof should include native plants for their drought resistance, such as ground covers from open grassland areas. Barriers of thorny bushes, such as bougainvillea or fences hidden in shrubs will be needed at roof or open sky-well edges to prevent accidental falls.

Existing structures cannot easily be converted to earth shelters, since the structural design probably did not consider the additional loads.



WITH PREVAILING BREEZES FROM A DEFINITE DIRECTION, STRUCTURES TUCKED INTO SLOPES AND POSSIBLY COVERED WITH EARTH ON THE ROOF CREATE EXCELLENTLY INSULATED STRUCTURES. HOWEVER, WITH THE HIGH HUMIDITY, PROPER VENTILATION BECOMES CRITICAL. CARE MUST BE TAKEN TO AVOID CONDENSATION. SUCH STRUCTURES WOULD BE WELL-INSULATED FOR AIR-CONDITIONED USE.

EARTH BERMED STRUCTURE



AIR-CONDITIONED STRUCTURE EARTH BERMED STRUCTURE

Passive Water Cooling

A passive water cooling system will cycle water through a cool mass like the deep ground and then through the building structure.

If the water supply lines to a house are first run through the roof or wall structure this will provide reverse radiant cooling and avoid heat build-up in the structural materials. When occupants are present, normal use of water for any function, including washing clothes, dishes, cars, flushing the toilet or showering, would remove warm water in the living space ceiling or wall and replace it with ground temperature water. This daily usage averages 200 gallons per person. The pipes in the living area ceiling or wall could be laid at a slope and in a grid system that allows the warmest water to be removed first upon any use of water. For example, if the main water temperature is 72F (22.2C), the roof slab maximum temperature is 127F (51.1C) with a maximum still air temperature below the slab of 92 degrees F (33.3C), normal water usage during the hottest weather condition could absorb up to 91,400 BTU per day per user. A portion of this cooling capacity is used to cool the roof and the remainder is available to cool the occupants. If the roof is painted white and the roof area is not too extensive, only a small portion of cooling capacity is used to offset the roof heat gain. Because occupant cooling is the major function, instead of roof slab heat removal, the pipes should be near the inside surface of the structure and the ceilings kept low.

PASSIVE WATER COOLING

Residences Using Other Energy Conserving Techniques

Residence for Steve Lander

A portion of an existing duplex was reroofed and remodeled for a small residence. The site is a typical flat lot within a compact village, yet incorporates many design techniques to provide a comfortable living environment in the Guam climate.

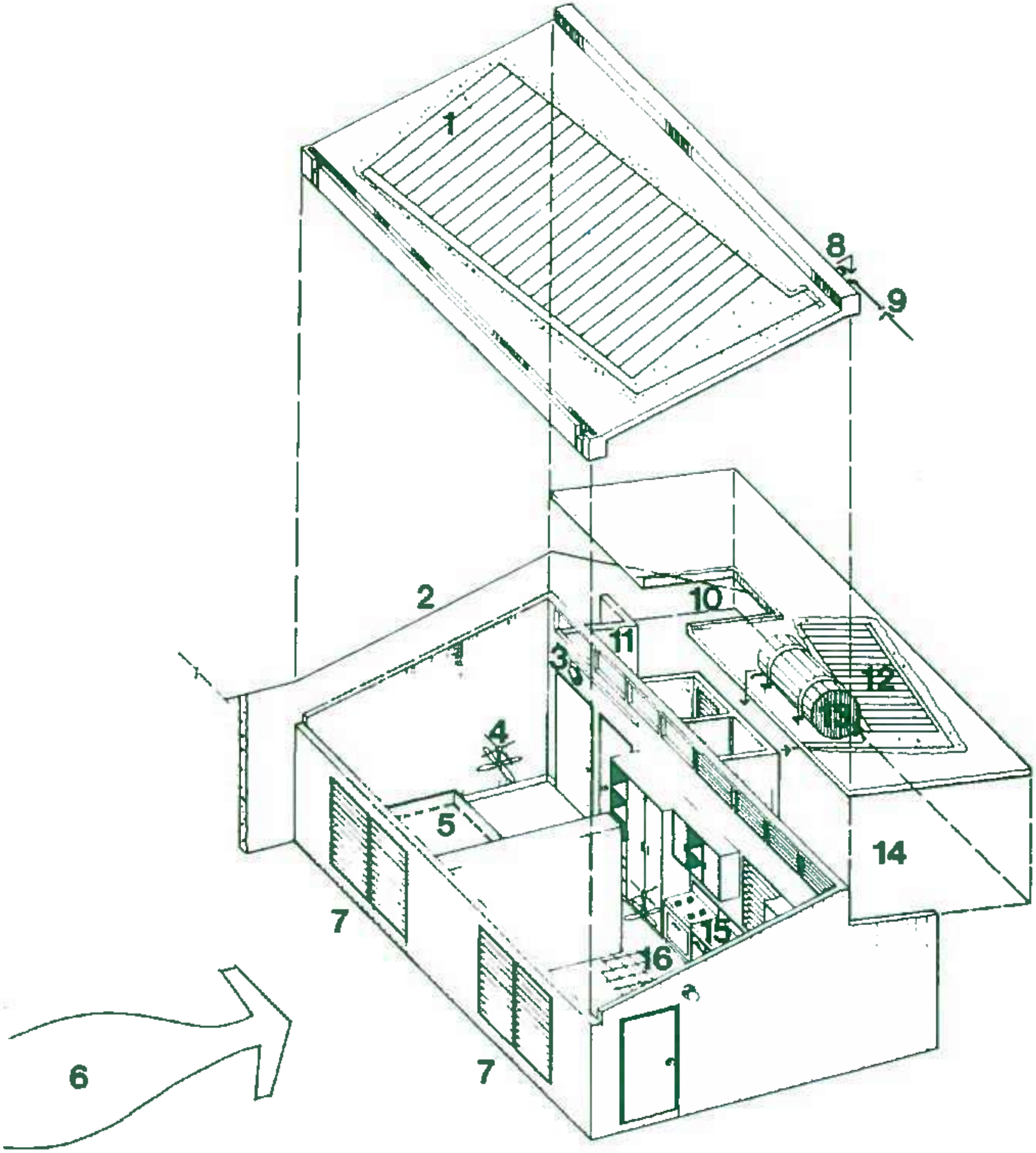
Natural breezes are accepted across an open front yard with windows running the full height range of inside occupants. Clerestory windows and a shower roof opening use the rising warm air to induce additional ventilation.

All the water used in and around the residence is first passed through the roof slab over the living areas. This removes the sun heatload from the concrete roof slab and creates a cool ground temperature slab, to cool the occupants.

Water heater solar collector pipes are cast in the concrete slab to be maintenance free and safe from typhoon related damage. The required oversized collector area is located over the seldom inhabited laundry area and covered clothes drying space.

Project: Residence for Steve Lander
Piti, Guam
Architect: Stephen F. Lander, AIA
Contractor: Vic Reyes Construction Co.
Construction Date: 1980

1. Heat collector pipes cast in living area ceiling slab
2. South side protected by adjacent duplex unit
3. High light fixtures near clerestory heat exhaust
4. Ceiling fans
5. Waterbed in contact with cool floor slab-on-grade
6. Prevailing east breezes
7. Windows on windward side, low for full room circulation
8. Preheated water to house fixtures and hot water solar collector
9. Inlet water from cool street main
10. Humidity and hot air exhaust hole over shower
11. Exhaust clerestory leeward of living spaces
12. Water heater solar collector pipes cast in roof of laundry/workshop area
13. Thermosyphon hot water tank
14. Exterior protected laundry/workshop area
15. Kitchen appliances below clerestory for immediate heat exhaust
16. Brick paving floor to provide cool slab-on-grade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Appendix

Glossary

Ambient Temperature: Temperature of the air

Air Velocity: Movement of air through space, expressed in feet per minute (fpm) or miles per hour (mph)

10 fpm equals approximately (stagnant)	0.1 mph
20	0.2
40	0.5
60	0.7
100	1.1
200 fpm	2.0 mph
300	3.4 (disrupts paperwork)

Berm: A mound or small hill of earth, man-made

BTU: British Thermal Unit: Amount of heat necessary to raise the temperature of one pound of water one degree Fahrenheit.

cfm: Abbreviation for cubic feet per minute.

Comfort Zone: The ranges of indoor temperature, humidity and air movement under which most persons enjoy mental and physical well-being.

Conduction: Process of heat transfer whereby heat moves through a material.

Convection: Transfer of heat by movement of a fluid or gas.

fpm: Abbreviation for feet per minute.

Heat Gain: Increase in the amount of heat contained in space, resulting from direct solar radiation and the heat emitted by people, lights, equipment, machinery and other sources.

Infiltration: Uncontrolled flow of air into and from a building through cracks, openings, doors or other areas which allow air to penetrate.

Insulation: Any material high in resistance to heat transmission.

k value: Conductivity of a 1-inch thickness of a material; k times thickness involved = U value

Kilowatt Hour (KWH): Unit of electrical energy consumption; equal to about 3,400 British Thermal Units (BTU)

Latent Heat: Heat required to change the state of a substance without changing its temperature; i.e., it takes approximately 1,000 BTU to change 1 lb. of 212 F (100C) water to 212F (100C) steam. In building, increases in relative humidity change comfort conditions but not the temperature.

Latitude: The measurement in degrees of a given position on the earth perpendicular to the equator.

Mass: The property of density of a material; the existence of mass causes building materials to to store energy or heat.

Mean: The average or expected value.

R Value: The resistance of a material to the flow of heat or energy; expressed in hours per square foot of surface per degree Fahreheit per BTU or hrs/ft^2/BTU; reciprocal of heat transfer; can be added or multiplied.

Radiation: The transfer of heat by electromagnetic waves; the energy is transferred directly and is uneffected by the temperature of the surrounding air.

Relative Humidity (RH): The percent of moisture in the air compared to the maximum amount that can exist at that temperature.

Sensible Heat: Energy that can be measured by a change in temperature (see latent heat).

Shading Coefficient: Fraction of the incident solar energy that is transmitted through a shading device (such as an awning or tree).

Thermal Lag: The time between the heat being applied at one side of a material until the heat is transmitted to the surface on the other side.

Ton of Air Conditioning: Energy required to melt one ton of ice; equals 12,000 British Thermal Units (BTU)

U Value: Coefficient that indicates the energy that transfers through a building component for every degree Fahrenheit; expressed in BTU per hour per square foot of surface per degree Fahrenheit or BTU/hr/ft^2/F; reciprocal of heat resistance; $U = 1/R$

Weatherstripping: foam, metal or rubber strips used to form a seal around windows, doors or reduce infiltration.

Typical Construction for walls

Metal stud wall without insulation	R Value
outside surface (15 MPH wind)	0.17
½" plywood sheathing	0.62
air space 3½"	1.01
½ gypsum wallboard	0.45
inside surface (still air)	0.68
TOTAL R =	2.93

Concrete block wall without insulation	
outside surface (15 MPH wind)	0.17
¾" cement stucco	0.15
8" concrete block with cells filled	2.05
inside surface (still air)	0.68
TOTAL R =	3.05

Precast concrete wall without insulation	
outside surface (15 MPH wind)	0.17
5" precast concrete wall panel	0.40
inside surface (still air)	0.68
TOTAL R =	1.25

Example with insulation:

Concrete block wall with insulation	
outside surface (15 MPH wind)	0.17
8" concrete block with cells filled	2.05
*1" polystyrofoam board	5.00
5/8" gypsum board	0.57
inside surface (still air)	0.68
TOTAL R =	8.47

*A wide variety of other insulating materials can be used. For polystyrene and polyurethane boards check for compliance with manufacturer's recommendations and codes prior to installation.

Typical Construction for roofs

Wood frame with tin	R Value
outside surface (15 MPH)	0.17
metal decking on wood trusses	0.00
air space	1.14
5/8" gypsum board ceiling	0.57
inside surface (still air)	0.92
	2.80

Concrete without insulation	
outside surface (15 MPH)	0.17
5" concrete deck	0.50
inside surface (still air)	0.92
	1.49

Concrete slab with waffle insulation (Urethane waffle)	
outside surface (15 MPH)	0.17
concrete 2½"	0.24
2½" polyurethane waffle	19.25
inside still air surface	0.92
	20.82

Sprayed Urethane Foam	
outside surface (15 MPH)	0.17
white roof paint	—
1" sprayed foam insulation	6.25
6" concrete deck	0.48
inside surface (still)	0.92
	7.82

Coefficients for Heat Flow

	Thickness (in.)	K Conductivity 1-in. thickness	U for given thickness	1/K Resistivity per 1-in. thickness	R or 1/U Resistance for given thickness
Insulating Materials:					
Cellular glass		0.40		2.50	
Glass-fiber		0.25		4.00	
Mineral fiber batt	2¾		0.14		7.00
	3½		0.09		11.00
	6½		0.05		19.00
Mineral fiberboard		0.35		2.86	
Mineral or glass-fiber wool		0.27		3.70	
Styrofoam		0.26 to 0.20		3.8 to 5.00	
Vermiculite, 4 to 6 pcf		0.44		2.27	
Perlite		0.37		2.70	
Urethane Board		0.14 to 0.13		7.1 to 7.7	
Sprayed on Urethane		0.17 to 0.16		5.8 to 5.2	
Hardwood		1.10		0.91	
Insulating fiberboard	25/32		0.49		2.06
Lapped siding, plywood	½	0.80	1.60	1.25	0.62
Softwood		0.80		1.25	
Stucco		5.00		0.20	
Wood shingles			1.06		0.94
INTERIOR:					
Carpet on foam rubber underlay			0.81		1.23
Cement plaster with sand aggregate	½	5.00	10.00	0.02	0.10
Gypsum board	½		2.25		0.45
	5/8		1.75		0.57
Plywood	½	0.80	1.60	1.25	0.62
Tile: asphalt, vinyl, or rubber			20.00		0.05
Wood subfloor	¾		1.06		0.94
Cement mortar		5.00		0.20	

	Thickness (in.)	K Conductivity 1-in. thickness	U for given thickness	1/K Resistivity per 1-in. thickness	R or 1/U Resistance for given thickness
Concrete:					
sand and gravel aggregate 140 pounds/cubic food		12.00		0.08	
Concrete block:					
filled	4		0.98		1.02
	8		0.49		2.05
	12		0.33		3.07
Sand and gravel aggregate-hollow	4		1.40		0.71
	8		0.90		1.11
	12		0.78		1.28
BUILDING MATERIAL:					
Stone, lime and sand		12.50		0.08	
Stucco		5.00		0.20	
Terrazzo		12.50		0.08	
MISCELLANEOUS:					
Aluminum		1536.00		negligible	
Asphalt 15-lb felt, two layers			8.35		0.12
Glass, average		6.00		0.17	
Sheet metal		456.00		negligible	
Soil, dry, loose		3.00		0.33	
Coral gravel		6.00		0.17	
Soil and clay mix		4.00		0.25	
Steel		312.00		negligible	
Water		5.50		0.18	

Coefficients for Heat Flow

Air Films & Air Spaces

AIR FILMS		Aluminum-coated Paper		Ordinary Building Materials	
Position of Surface Inside (or Still) Air:	Heat Flow	U	R or 1/U	U	R or 1/U
Horizontal	Down	0.37	2.70	1.08	0.92
Slope, 45°	Down	0.60	1.67	1.32	0.76
Vertical	Horizontal	0.74	1.35	1.46	0.68
Horizontal	Up	0.91	1.10	1.63	0.61
Slope, 45°	Up	0.88	1.14	1.60	0.62
Any Position for Outside (or Moving) Air:				U	R or 1/U
15 mph wind	Any			6.00	0.17
7-1/2 mph wind	Any			4.00	0.25

AIR SPACES			Aluminum-coated Paper		Ordinary Building Materials	
Position of Air Space	Heat Flow	Thickness (in.)	U	R or 1/U	U	R or 1/U
Horizontal	Down	3/4	0.48	2.08	1.19	0.84
		1-1/2	0.36	2.76	1.07	0.93
		4	0.30	3.38	1.01	0.99

			Aluminum-coated Paper		Ordinary Building Materials	
Slope, 45°	Down	3/4	0.48	2.09	1.19	0.84
		4	0.40	2.50	1.11	0.90
Horizontal	Up	3/4	0.61	1.63	1.32	0.76
		4	0.53	1.87	1.25	0.80
Slope, 45°	Up	3/4	0.53	1.90	1.24	0.81
		4	0.51	1.98	1.22	0.82

Heat flow through roofs and ceilings is generally down.
Heat flow through walls is generally horizontal.
Heat flow through floors is generally up.

Recommended Materials for the Tropics

MATERIALS	NATURALLY VENTILATED	AIR CONDITIONED	PARTIALLY AIR CONDITIONED
Paint	Synthetic/water base avoid organics (oils)	Either water base or organic base	Synthetic/water base
Carpet	Because of frequent air conditioning breakdowns and results of typhoons, synthetic backed carpets are recommended for all three types of spaces. Organic backed carpet, hemp, is subject both to mildew and insect infestation.	same	same
Carpet Pad	Synthetic material pad	Synthetic material throughout; whether a direct glue down is used may depend on the floor or slab condition. Moisture will transfer through an on-grade slab which lacks a vapor barrier (Polyethylene sheet)	
Floor Material	Cooling radiating materials, quarry tile, ceramic tile, marble, other stones are recommended. Wood flooring material can be used throughout but unless it is treated or a termite resistant species such as the traditional Ifil, will be subject to termite damage.	Carpet, resilient tile	Same as the naturally ventilated house. Carpet is satisfactory in permanently air conditioned.
Ceilings	Lay-in ceilings other than fiberglass are prone to absorbing moisture, and sagging. Non-ferrous supporting system.	Same as naturally ventilated spaces because of potential air conditioning breakdowns.	Same as naturally ventilated spaces.
Misc. Metals	Aluminum and non-ferrous metals should be used to avoid rust.	Either ferrous, or non-ferrous metals.	Same as naturally ventilated spaces.

MATERIALS	NATURALLY VENTILATED	AIR CONDITIONED	PARTIALLY AIR CONDITIONED
Glass Mirrors	No difference. Care must be taken to have properly sealed edges and backs to avoid "fogging" due to moisture penetration.	same	same
Reflective Films	The films require more careful maintenance in naturally ventilated spaces due to increased dust.	See naturally ventilated	Same as naturally ventilated.
Furniture	Synthetics/rattans, hardwood. Heavy upholstery is more subject to mildew if organic. Open weave for ventilation.		Similar to naturally ventilated spaces.
Window/Door Seals	Adequate for rain protection	Proper seals to reduce air infiltration is important in air conditioned and partially air conditioned spaces.	Same as air conditioned spaces except interior wall between air conditioned and non-air conditioned spaces also need sealing.
Vapor Barriers	Recommended for slabs for future conversion capability. Sealing of exterior surfaces and below grade surfaces still important.	Important between air conditioned and non-air conditioned spaces whether interior or exterior.	

Guam Climate

The following climatological data has been included for Guam where the majority of the residences illustrated are located. For other areas, pertinent local data and charts similar to those shown on the following pages should be used.

As immediately recognized by the multitude of tourists and residents alike, Guam has the potential for being quite comfortable. The fresh air, lush foliage and surrounding beaches, reefs and ocean all contribute to a nearly year-round vacation atmosphere. Taking advantage of the breezes and controlling the solar radiation and humidity are very important for insuring comfort.

Climatologically, Guam is one of the world's most stable locations. The average daily temperature differential is only 10F (5.6C) and the annual variation is less than 13F (7.2C). During the dry season, December through June, the average temperature fluctuation is between 71F (21.7C) at night and 85.6F (20.8C) at the hottest time of the day. From mid-July through mid-November the average temperature and average fluctuation increases slightly, so that the temperature varies from 72.2F (22.3C) to 86.2F (30.1C). The hottest officially recorded local temperature is 96F (35.6C) and the coldest is 54F (12.2C). The majority of these temperatures are near the upper comfort zone for humans.

NORMALS, MEANS AND EXTREMES

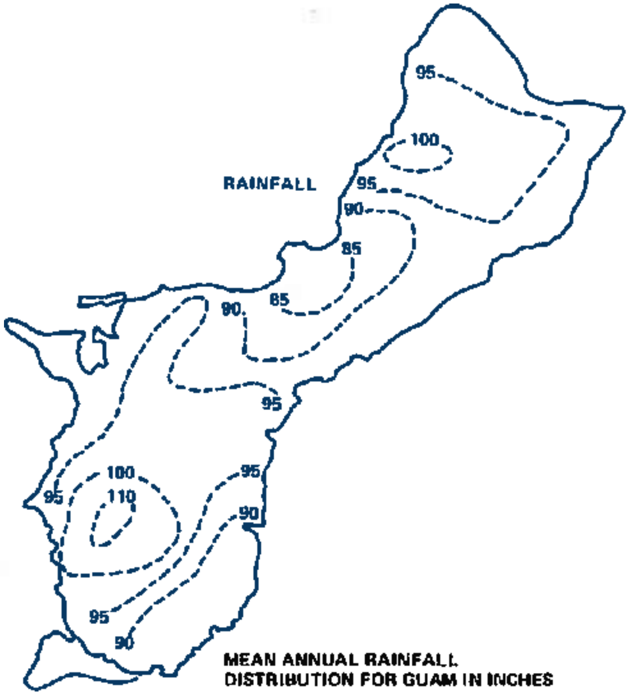
Month	Temperatures F					Normal Degree Days	Precipitation in Inches				Relative humidity pct.				Wind		Pct. of possible sunshine	Mean sky cover, tenths, sunrise to sunset
	Normal			Extremes			Rain				(Local time)							
	Daily Maximum	Daily Minimum	Monthly	Record highest	Record lowest	Cooling	Normal	Maximum Monthly	Minimum Monthly	Maximum in 24 hrs.	Hour 04	Hour 10	Hour 16	Hour 22	Mean Speed m.p.h.	Prevailing direction		
(a)																		
J	83.2	71.5	77.3	87	56	381	5.16	20.38	1.09	6.28	88	77	76	86	8.2	E	65	7.5
F	83.3	71.3	77.3	88	59	344	4.26	14.78	0.67	9.24	88	76	74	86	10.2	NE	60	8.0
M	84.5	71.0	77.7	89	54	394	2.94	16.94	0.59	3.55	88	75	74	86	9.0	E	66	7.5
A	85.6	72.5	79.0	90	59	420	4.00	19.65	0.50	6.37	90	74	73	87	8.9	E	68	7.8
M	86.4	73.1	79.4	91	62	446	4.49	40.13	0.80	27.00	92	73	73	89	8.3	E	64	7.5
J	86.7	72.9	79.8	91	63	444	6.18	11.53	1.82	4.86	92	76	78	90	8.4	E	61	8.0
J	86.2	72.6	79.4	90	66	446	9.59	20.00	4.74	5.17	94	79	78	93	5.1	E	49	8.5
A	86.1	72.2	79.1	91	67	437	12.16	26.66	3.87	7.81	96	81	80	94	4.8	E	45	8.9
S	85.8	72.4	79.1	95	61	423	14.08	24.34	6.79	7.48	96	81	81	94	4.7	E	42	9.0
O	85.6	72.3	78.9	91	66	436	14.40	28.06	6.63	10.14	95	80	80	93	6.2	E	44	8.2
N	85.3	73.2	79.2	88	62	426	8.51	18.14	2.08	7.26	91	80	81	91	7.8	E	49	7.9
D	84.1	72.9	78.5	89	61	418	6.85	16.18	2.22	6.09	88	78	78	88	9.1	E	62	7.5
YR	85.1	72.3	78.7	95	54	5014	80.68	40.13	0.50	27.00	92	78	77	90	7.4	E	56	8.0

METEOROLOGICAL DATA
WEATHER DATA FINEGAYAN, GUAM MI

Islands to the north of Guam will experience slightly lower average temperatures and islands closer to the equator slightly higher temperatures and humidity.

The attached graphs and information indicate the following local information:

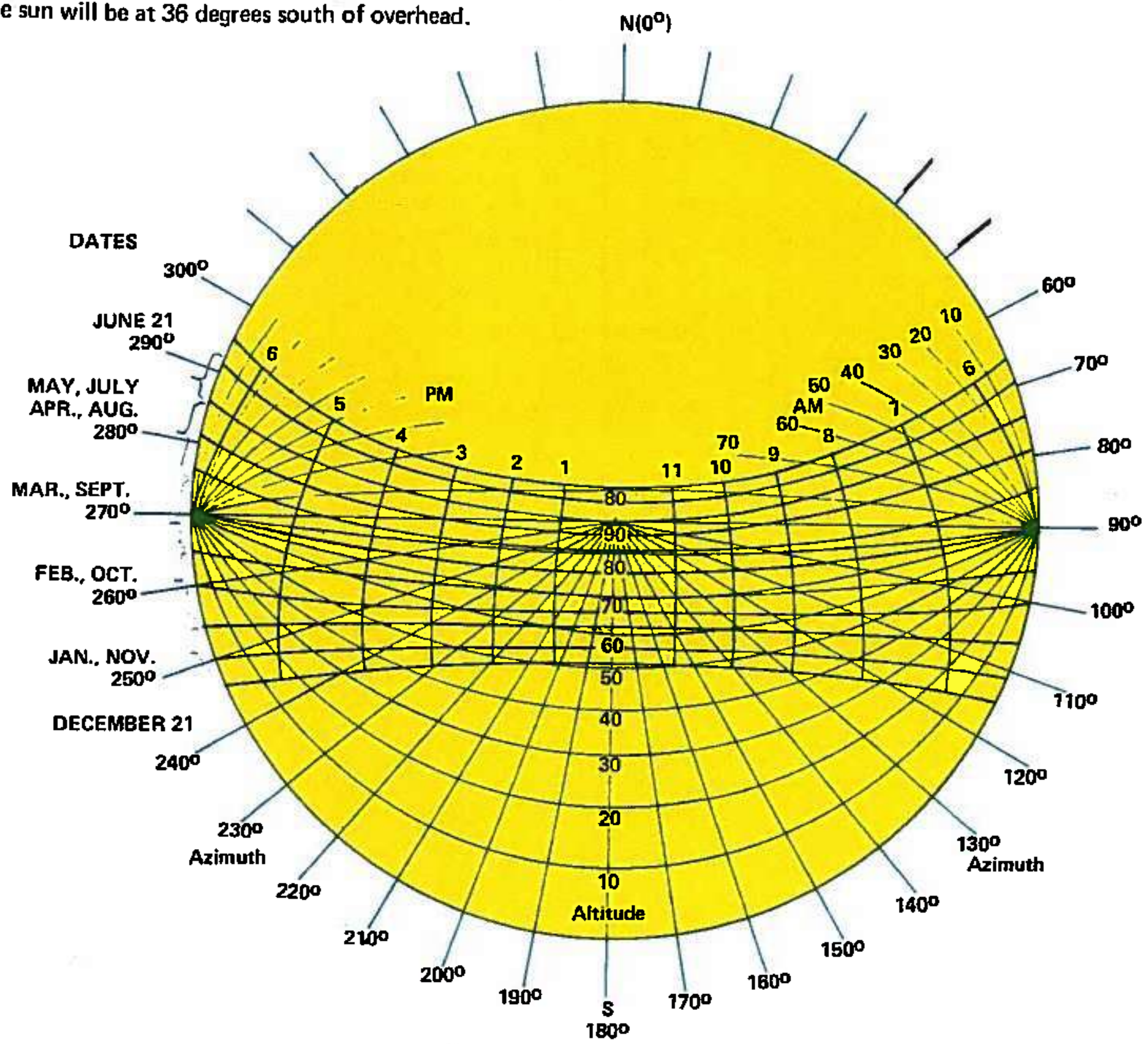
- Temperatures
- Relative Humidity
- Rainfall
- Sun Angles
- Wind
- Heat Gain Factors



MEAN ANNUAL RAINFALL DISTRIBUTION FOR GUAM IN INCHES

Sun

Guam is located at latitude 13.5 degrees north; at noon on June 21, the sun will be located at 10 degrees north of overhead; at noon on December 21, the sun will be at 36 degrees south of overhead.



SUN CHART 13° 30° 00° North Latitude

SUN ANGLES — **SUMMER June 21**

Hour Angle	Altitude	East Asthmeth	Due North = 0	West Asthmeth
0 (Noon)	80°	0		0
1st Hour	72°	52°		308°
2nd Hour	60°	66°		294°
3rd Hour	46°	70°		290°
4th Hour	32°	71°		289°
5th Hour	19°	69°		291°
6th Hour	5°	67°		293°
Sunrise	0°	66°		
Sunset	0°			294°

SUN ANGLES — **WINTER December 21**

0 (Noon)	54°	180° (Due South)	180° (Due South)
1st Hour	51°	158°	202°
2nd Hour	44°	141°	219°
3rd Hour	33°	129°	231°
4th Hour	21°	122°	238°
5th Hour	8°	117°	243°
Sunrise	0°	114°	
Sunset	0°		246°

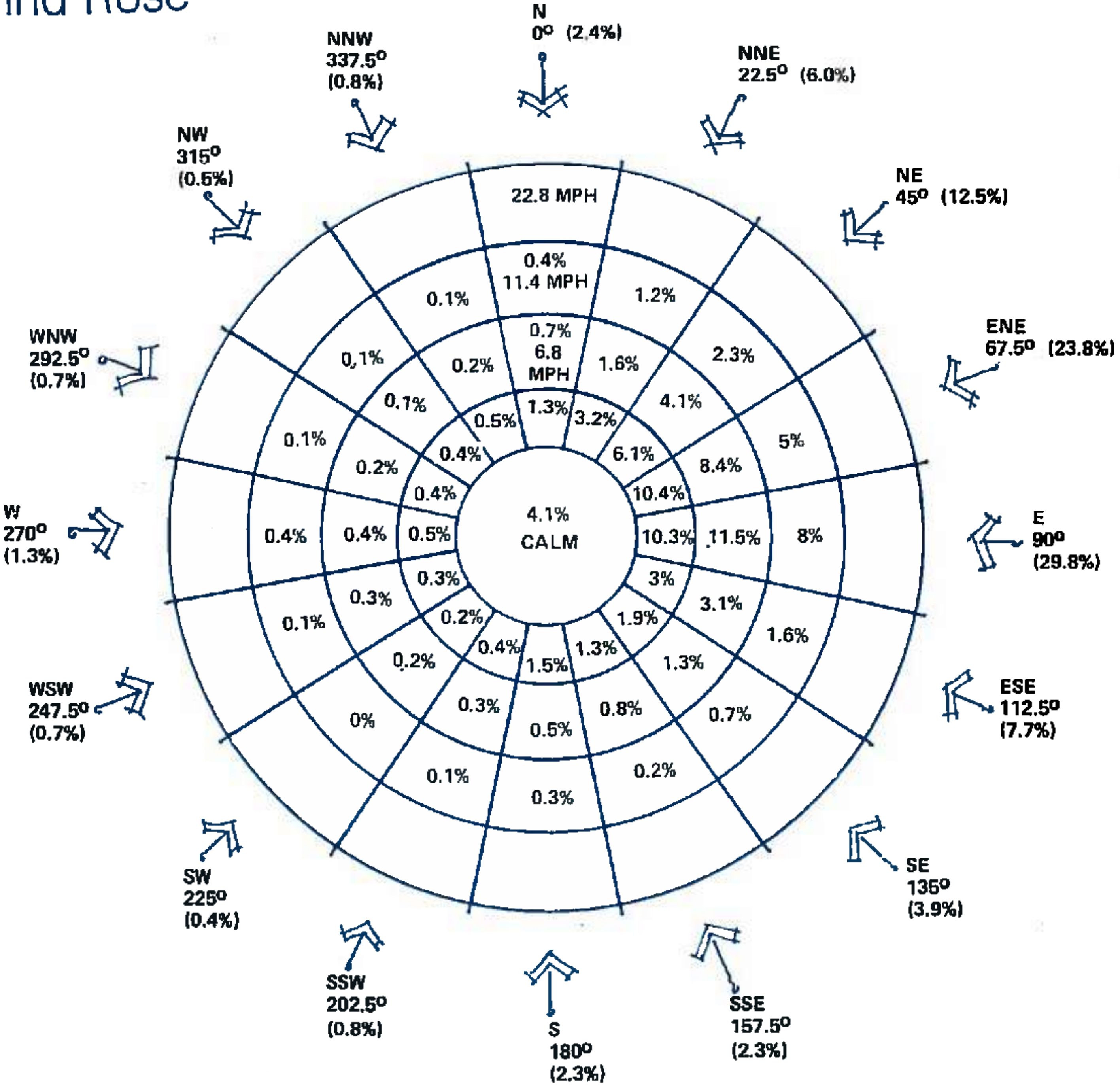
Wind

As shown in the windrose, approximately 80 percent of all winds come from the 112 degree section of NNE through ESE. Only 16 percent of the winds come from the other directions (a portion of these are from storms) and 4 percent of the time the air is still.

Major consideration must be given to typhoons and supertyphoons. Supertyphoons, Karen in November 1963 and Pamela in May 1976, rewrote the building design standards in our area. Design for 155 mile per hour winds is now a requirement for construction. This greatly affects the design of roof and wall materials, and protection of windows and glass.

AVERAGE WIND SPEED

Wind Rose



WIND ROSE - AGANA, GUAM, MARIANA ISLANDS
GUAM INTERNATIONAL AIR TERMINAL

Federal Energy Conservation Tax Advantages

Currently the federal government encourages energy conservation by allowing a decrease in personal taxes owed, or an increase in personal tax refund, by 40 percent of the first $10,000 invested in a solar water heater or windmill, and 15 percent credit of the first $1,000 spent for energy conserving improvements to a home or apartment existing before April 1977 such as:

weatherstripping of an air-conditioned space

insulation

white exterior paint coating to reflect heat

window film

timers for lights and water heaters

These must be expected to last five years and cost can include on-site preparation and installation costs.

Economic Analysis

$$\text{present value} = nMe^{-r} - e^{-rn} (Sr - Ss) = PV$$

where:

n = life span in years = 30 years for most construction.
r = inflation rate = 10% assumed = growth rate of savings.
M = 1-1/3 cost savings in first year (assumes 25% tax bracket).
e = 2.71828
Sr = first cost (-) any tax credit
Ss = Salvage value after n years = 0 assumed

When present value calculation exceeds cost then it makes economic sense to purchase:

$$PV > Sr$$

$$PV = (30 \times M \times 2.71828^{-.10}) - 2.71828^{-3} (Sr)$$
$$(30M \times .90483748) - 04978717\ S$$

thus with the above assumptions:

$$PV = 27.145M - 0.049787\ Sr$$

thus it's logical to make the investment when:

$$M \geq 0.01867\ Sr.$$

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Charts

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