DOE/NASA CONTRACTOR REPORT

DOE/NASA CR-150730

DESIGN PACKAGE FOR INSTRUMENTATION OF THE DECADE 80 HOUSE IN TUCSON, ARIZONA

Prepared by

Copper Development Association, Inc.
405 Lexington Avenue
New York, New York 10017

Under Contract NAS8-32244 with

National Aeronautics and Space Administration
George C. Marshall Space Flight Center, Alabama 35812

For the U. S. Department of Energy

(NASA-CR-150730) DESIGN PACKAGE FOR INSTRUMENTATION OF THE DECADE 80 HOUSE IN TUCSON, ARIZONA (Copper Development Association, Inc.) 58 p HC A04/MF A01 CSCL 10A G3/44

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U.S. Department of Energy

Solar Energy

CONTENTS

* Drawings only included in three copies. One (sepia) set of drawings is reproducible.

Proposed Installation Plan
for the Decade 80 Solar House

1.0 **Site and System Description**

1.1 Site Contractor

Copper Development Association Inc.
405 Lexington Avenue
New York, New York 10017
(212) 953-7315

Field Office:
34 E. Madrid Place
Tucson, Arizona 85704
(602) 297-7020

1.2 Site Address

7779 N. Via Piccolina
Tucson, Arizona 85704

1.3 Purpose of Site

Single family residence.

1.4 Building Description

See brochure enclosed as Appendix A

1.5 System Descriptive Summary

1.5.1 Type:

Heating, absorption air-conditioning, and domestic water heating.

1.5.2 Collector area:

Gross area = 1923 sq ft

Clear aperture = 1766 sq ft

1.5.3 Collector description:

The collector is the Revere Copper and Brass Inc. Laminated Panel Collector, integral with the building roof. The collector is glazed with two panes of 1/8-inch glass preassembled in a frame. The glass is PPG Herculite K tempered glass as the outer pane, and annealed glass as the inner pane.

Flow through the collector is 25 gpm; mass flow is about 6.5 lb/sq ft-hr . Flow is through a grid-sinuous pattern of 22 parallel tubes. Each tube is folded back-and-forth in a sinuous path of about 200 ft with a balancing cock in each flow path.

1.5.4 Storage:

The storage medium is tap water, treated with soda ash and sodium sulfite to inhibit rusting in the storage tank.

The storage container is a steel tank of 3000 gallon capacity. The tank contains about 2700 gallons of water, with the remaining space for expansion.

The tank is built of 1/4-inch steel plate formed into a cylinder; the ends of the tank are domed. The cylinder stands vertically, about 8 1/2 ft in diameter. It was delivered to the site assembled.

The tank has an epoxy lining.

1.5.5 Space heating method:

The zoned heating system is a forced-air type, with two units, one serving the east zone and one serving the west zone. Air is heated by fan coils containing solar-heated water. Water is delivered to the fan coils at 5 to 11 gpm directly from the storage tank.

In the event that there is not sufficient heat in the storage tank to satisfy the demand, heat is provided to the fan coils by an auxiliary natural-gas-fired boiler.

1.5.6 Hot water subsystem:

Domestic water is heated through a heat exchanger and stored in a 66-gallon electric water heater, Rheem model 666H-660. The water heater electric elements are wired so they are in-circuit only when the main storage tank is below a preset temperature.

Hot water is circulated continuously to faucets throughout the house.

1.5.7 Energy transport:

Fans - All are 120 V AC, Single phase, 60 Hz.

East zone uses one 3/4-HP blower.

West zone uses one 1/2-HP blower.

There is a duct booster-fan that controls air flow to the guest cabana. The fan is operated by the homeowner when he desires.

Ducts - All ducts are rigid fiberglass, in diameters from 6" to 16". The duct layout is shown in Drawing 1, enclosed as Appendix B.

Air flow through the east system is 1750 cfm; air flow through the west duct system is 1500 cfm.

Pumps - All pumps are 120 V AC, single phase, 60 HZ, listed in Table 1, page 20.

Some modifications of the pumps will be required due to the increased head imposed by the instrumentation. Specifically, pump P-1 will have to be replaced, the motor and impeller of pump P-2 will be replaced and larger replacement impellers will be needed for P-3, P-4, P-5 and P-6.

Pipe details - Drawing 2, The Heating-Cooling Water Piping Diagram (Appendix C) gives a detailed description of each pipe size and identifies all pumps, valves, heat exchangers, etc.

All tubes between the collector and HE-1 and HE-2 are 1-1/2 inch. All tubes into and out of the storage tank are 1-1/2 inch.

Tubes to and from the Arkla generators and condensers, and tubes to each heating fan coil, are 1 inch.

All tubing is Type L copper. Fittings are copper, brass, or bronze. All joints are brazed with "Sil-Fos" silver-phosphorous-copper brazing alloys.

Fluid type - All fluids are tap water.

The collector water has about 35% propylene glycol antifreeze added to it. It is inhibited with phosphate.

The storage tank water has sodium nitrite and sodium sulfite added to it as rust inhibitors. About 10 lbs of each were used. The sodium sulfite is periodically replenished. This water circulates through the heating fan coils and the Arkla generators.

The cooling tower water has a polyphosphate stabilizer metered into it at about 1 to 10 ppm. An algaecide is added to the water once a month. The algaecide is consumed in a few days. The cooling tower water is bled off whenever the air conditioners are operating; bleed rate is 10.5 gal per hr for each of the two Arkla air-conditioners.

1.5.8 Space cooling method:

Air-conditioners are three-ton Arkla lithium bromide absorption units, model XWF-501. Two are used; each cools one zone, or about half the living space. They are direct expansion types.

1.5.9 Auxiliary energy source:

Auxiliary energy for the heating and cooling subsystems is provided by a natural-gas-fired boiler: Teledyne Laars model HK--250--CN01A. The labelled input is 250,000 Btu per hr; output is 200,000 Btu per hr.

The boiler has been modified by the removal of its two-stage gas valve, and replacement of it by a modulating valve and a partial bypass. Maximum output is now expected to be about 150,000 Btu per hr, with minimum continuous output about 50,000 Btu per hr.

Auxiliary energy for domestic water heating is provided by the two electric heating elements within the domestic water storage tank. Each element is 4500 watts, wired to operate one at a time. Auxiliary electric power is allowed to come on only when the main storage tank temperature drops below a preset temperature.

1.5.10 Operational control sequence:

The operational control sequence is described in detail in <u>Section 2.3 Operating and Control Modes</u>

1.5.11 Energy conversion efficiency:

<u>Collection efficiency</u> - The collector efficiency has been measured continuously for over a year. Typical summertime day-long efficiency, integrated over the total run-time of the collector (about 10:30 a.m. to 3:30 p.m.) is about 24 to 26%. Typically 650,000 to 850,000 Btu are delivered to storage on a normal clear day.

Typical wintertime day-long efficiency, integrated similarly, is 30 to 40%. Up to 1,100,000 Btu are collected on a clear December or January day. Recall also that the collector is sloped at 26^{o} above the horizontal, to emphasize collection of heat during the summer.

<u>Storage losses</u> - Heat delivered from storage to the HVAC system has been measured. On a typical day the air conditioning system draws from storage about 200,000 Btu less than was delivered to storage by the collector.

About half the 200,000 Btu appears to have been used for domestic water heating. The other half is attributed to losses through the storage tank insulation, plumbing insulation, and to measurement error.

Storage losses in the heating mode have not yet been analyzed.

Domestic water heating losses - The domestic water storage tank/heater is wired to its own watt-hour meter. Domestic water heating energy consumption can therefore be measured by forcing the heater to remain in the electric heating mode. (It is set to the same temperature, 135 F, that the solar water heating system.)

Typically the domestic water heating system will consume about 25 Kwh per day, with two occupants living in the house. Of this amount, about 8 Kwh per day is dissipated because of the continuous-circulation feature of the plumbing system. In addition, the circulator pump itself consumes about 2 Kwh per day.

Additional insulation was added to the domestic water storage tank during the past summer. Before it was added energy consumption by the subsystem was about 6 to 10 Kwh per day higher.

These measurements of electric energy consumption by the domestic water subsystem do not, of course, account for any losses that occur in the domestic water heat exchanger, HE-3 or its associated plumbing.

Arkla C.O.P. - Air-conditioner Coefficient of Performance has been measured approximately. Under steady-state operating conditions the COP of the Arklas has been measured at about 0.8 ± 0.1.

Day-long COP varied, of course, with the amount of cooling required throughout the day. During the summer it was about 0.8. Early and late in the cooling season it was lower, about 0.3 to 0.6. During the summer both air-conditioners ran continuously from early morning till late night, typically 16 to 20 hours per day. Early and late in the cooling season the machines cycled rather frequently, lowering their effective coefficients of performance.

2.0 Instrumentation Definition

2.1 Instrumentation Locations

The Heating-Coooling Water Piping Diagram (Appendix C) shows the proposed location of each sensor. Duct sizes are shown in Appendix B. The location of the two air duct flow rate sensors cannot be shown conveniently on the diagram. For the east zone,the sensor will be located in the vertical air return in the basement energy room. For the west zone, it will be located in a horizontal section of the air supply duct as it leaves the Arkla unit. In both cases flow straighteners will have to be used with the sensors.

The pyranometer will be mounted on a parapet wall near the ridge-line as shown in Figure 1, page 22.

It is proposed to mount the outdoor dry bulb temperature sensor a few yards west of the west wall of the house, behind a five foot high redwood fence.

2.2 Instrumentation Parts Schedule

This listing appears in Table 2, page 20. It is keyed to the drawing in Appendix C by the measurement numbers shown in the left-hand column of the table.

2.3 Operating and Control Modes

There are six basic operating modes in the Decade 80 Solar House energy system:

- Energy collection
- Space heating from storage
- Space heating from auxiliary energy
- Space cooling from storage
- Space cooling from auxiliary energy
- Domestic water heating

The heat transfer fluid flows for each of the six operating modes are shown schematically in the six drawings (Drawings 3 through 8) that make up Appendix D, and are described below.

2.3.1 Energy collection:

Energy collection is controlled by two differential thermostats (Rho Sigma Model 12 modified units). When the collector surface temperature exceeds the temperature at the bottom of the storage tank pump P-1 is turned on, circulating the water-antifreeze solution from the collector to heat exchangers HE-1 and HE-2, and back to the collector.

A second differential thermostat turns pump P-2 on when the temperature of the antifreeze solution, as measured near the inlet of HE-1, exceeds the temperature at the bottom of storage by about 3 F.

Pump P-2 circulates water from the bottom of the storage tank through HE-2 and HE-1, and back to the top of the storage tank.

All energy that is collected is delivered directly to the storage tank; there is no provision for bypass from the collector directly to the heating and cooling equipment.

2.3.2 Space heating from storage:

Upon demand for heat by either of the two room thermostats,pump P-3 draws water from the solar storage tank. Warm water is provided to both fan coils, but admitted only to the one for which a demand was registered. Heat can be provided to either or both heating zones.

Water flow to each fan coil is set at 6 gpm. Each fan coil has a water bypass, so that its status (on or off) does not effect the rate of water flow to the other fan coil.

2.3.3 Space heating from auxiliary energy

Auxiliary heat, when required, is provided by a natural gas boiler. During the winter of 1975-1976 only 3% of the total heating Btu's were provided by the boiler. So far (January 1977) no auxiliary heat has been used during the current winter.

The heating system is controlled by a two-stage room thermostat in each zone. When the space temperature drops below the thermostat set-point, a stage-one demand is created. Heat is provided to the space from the storage tank. If the storage tank is too cold to satisfy the demand for heat, the space temperature will continue to drop.

When the space temperature drops 1.5 F below the set-point of the thermostat a stage-two demand is created. If this demand continues for seven minutes the auxiliary boiler will operate. The boiler will continue to operate, and provide heat to both fan coils, until the stage-two demand for heat is satisfied.

It has been found that the boiler might be needed during the coldest part of a morning, but as the day begins to warm there is sufficient heat still in storage to satisfy the smaller demand. Therefore the auxiliary heat source is load-dependent rather than supply temperature-dependent.

The seven minute time delay on the boiler was added to assure that the boiler does not operate unnecessarily. The occupant of the house might over adjust a thermostat upward or open a door on a cold, windy morning. This might create a sudden false stage two demand for heat that could actually be satisfied by stored heat.

For economy, water heated by the boiler should not be returned to the storage tank after passing through the fan coil. Therefore, whenever the gas boiler operates, proportioning valve V-2 moves to the full bypass position. In this position water travels from pump P-3 to the boiler, then to the heating coils, and finally through V-2 and back to the pump.

2.3.4 Space cooling from storage:

When the occupant of the house chooses to cool the house he sets a Summer/Winter switch to the Summer position. This causes valves V-3 and V-4 to deliver hot water to the Arklas instead of the fan coils.

For proper operation the Arkla air conditioners require hot water between 190 and 210 F. The storage tank may at times exceed 210 F; therefore the stored hot water must be tempered somewhat. This is done by valve V-2. If water from storage enters this valve too hot, cooler water returning from the air-conditioners is mixed with the hot water, until the proper temperature is achieved.

The Arklas also require a means to dissipate the heat extracted from the house. This is the purpose of the cooling tower. The tower delivers water to the Arklas between 70 and 85 F; the water is heated in the Arklas by 15 to 20 degrees and returned to the tower. At the tower some of the water is evaporated, causing the remaining water to be cooled. On a dry day the water may be cooled below 70 F; this is not desirable.

To maintain the cool water at no less than 70 F there is a proportioning valve, V-11, at the cooling tower. If the tower chills the water excessively, unchilled water is delivered to the bottom of the tower, instead of the top, from which it returns, unchilled, to the Arklas. Valve V-11 mixes chilled and unchilled water to achieve the proper temperature.

Upon demand by either room thermostat for cooling,pumps P-3 and P-6 start, delivering hot water from storage and cool water from the cooling tower to the Arklas. Each Arkla has three-way valves and bypasses, so that cycling of one machine does not effect the water flow rates to the operating machine. The machines can operate alone or simultaneously.

As mentioned previously, the hot and cool water into the Arklas must be within certain temperature limits. If the cool water is too warm, or the hot water too cool, there is a danger of solidification, or crystallization, of the lithium bromide solution. To prevent the possibility of solidification there is a safety thermostat on each Arkla. This thermostat is a differential type; it allows air-conditioner operation only when the hot water is at least 110 F hotter than the cool water.

2.3.5 Space cooling from auxiliary energy:

The cooling system, like the heating system, is controlled by two two-stage thermostats, one in each of the two zones of the house. A first-stage demand for cooling from either thermostat will operate its air-conditioner, if certain conditions are met. The first condition, as described above, is that the hot water to the Arkla's generator must be at least 110 F hotter than the cool water to the machine's condenser. The second condition is that the hot water be at least 190 F. If the water in the storage tank is below this temperature, thermostat T-4, in the storage tank, signals valve V-2 to close to the recirculate position. This prevents the water in the storage tank from circulating uselessly and losing heat through pipe insulation.

A second stage demand from either room thermostat indicates that, that zone has warmed more than 1.5 degrees above the thermostat set-point. If the storage tank is above 197 F, the second stage demand has no effect. If the tank is below 197 F a second stage demand will first cause valve V-2 to close to the recirculate position. It then causes proportioning valve V-14 to respond to its temperature sensor T-16. As V-14 begins to operate to admit water to the boiler, the opening of an end-switch on the valve allows the boiler circulating pump, P-10, to start and sends a signal to the boiler gas valve. Flow through the boiler and P-10 trips a flow switch which then allows the boiler to begin operating.

to begin operating.

There is a modulating gas valve in the boiler. The valve's regulator is set to raise the incoming water temperature by about 10 to 12 degrees. The boiler also has an over-temperature thermostat, set to 230 F, which shuts off the boiler if the water becomes too hot.

Modulating valve V-14 regulates the temperature of the water flowing from the boiler to the Arklas, holding the water to about 205 F.

The boiler will come on and operate both Arklas whenever there is a second-stage cooling demand from either thermostat. There is no time delay in the cooling mode, as there is in the heating mode.

If the storage tank temperature is between 190 and 197 F, the Arklas will operate from solar storage upon first-stage cooling demands and from the auxiliary boiler when either thermostat registers a second demand.

2.3.6 Domestic water heating:

The final mode of operation is domestic water heating. Water is received from the city supply between 50 and 90 F, and heated to 135. Domestic hot water is stored in a 66-gallon commercial electric water heater, whose electric heating elements are normally disabled.

The hot water is circulated continuously through the house past all faucets. The water temperature is sensed by thermostat T-7 as the water returns to the base of the storage tank.

When the water temperature drops below 135 F, T-7 causes pump P-4 to start. This pump draws hot water from the solar storage tank and sends it through the shell side of HE-3. After a 30-second delay (to allow the heat exchanger to warm up) pump P-5 starts sending domestic water from its storage tank to the tube side of HE-3. Both pumps run until T-7 is satisfied. During the summer, with the storage tank normally above 180 F, these pumps run for a one to two minute cycle every hour or two. During the winter the pumps run somewhat longer and more frequently.

Thermostat T-5 measures the storage tank temperature. If the main tank is below about 140 F pumps P-4 and P-5 would run excessively, or continuously. Thus T-5 disables the pumps below its 140 F set-point, and instead puts the domestic water heater's electric heating elements into circuit.

2.4 Architectural Rendering

An aerial photograph of the Decade 80 Solar House appears as Figure 1, page 22, showing pyranometer location and collector orientation. There are no interfering surrounding structures.

3.0 <u>Installation Cost Proposal</u>

Cost information deleted.

4.0 Instrumentation Installation Completion Schedule

The installation schedule visualized is as follows:

	Day
Receipt of instrumentation	zero
Begin installation	5
Complete installation	20
Installation checkout	24
System start-up and stabilization	28
Implementation plan complete	30

5.0 Additional Information

Junction Box modification - If it is feasible we would like to have the NASA Junction Box built so that the instrumentation sensor wires enter the bottom of the box, and the J-Box/SDAS Interface Cable connectors mounted on the top of the J-Box.

Collector surface temperature measurement - While we recognize that a measurement of collector surface temperature is not necessary for efficiency or heat balance calculations, we feel that such a measurement would be useful. Such a measurement would indicate the collector's freezing-temperature susceptability, and the temperature experienced by the collector/roof if the collector should experience "stall" conditions.

Natural gas flow - We find no suggestion for a transducer to indicate natural gas flow to the auxiliary boiler. The boiler has a pilot light which consumes about 1.5 to 2 cu ft per hr of gas; when the boiler ignites gas flow probably increases to more than 240 cu ft per hr.

We recognize that gas flow transduction is difficult; Colorado State University is understood to have worked for several months on this problem.

The auxiliary gas boiler at the Decade 80 House is, of course, served with a gas meter.

Outdoor wet-bulb temperature measurement - While wet-bulb temperature measurement is not necessary for heat balance purposes, it is a useful measurement to indicate the efficiency of a cooling tower.

Location of Site Instrumentation Interface Hardware - The mechanical room (basement) of the house can experience 110° temperatures in the summer, even though all equipment is well insulated and the room is ventilated by a fan. Therefore a closet on the west end of the house, formerly used to store swimming pool equipment, has been chosen for the site data acquisition equipment, as indicated on the floor plan, Figure 2, page 23. Sensor wires will reach the equipment closet via a 6-inch plastic conduit from the main mechanical room and a 3-inch duct brought in from the west Arkla room.

The CDA computer equipment has been moved to this room and has been operating successfully there.

During the winter the room temperature has been quite stable at 70 to 80 F, day and night. Power lines have been brought in to the room from the main breaker panel: one line for the computer equipment and one for an air-conditioner that may be necessary in the summer.

The main telephone entrance to the house is through this closet.

TABLE 1. PUMP SCHEDULE

Pump	Current draw, A Label	Measured	Manufacturer and Model	Size	Flow, gpm	Head, ft	HP	RPM
P-1	7.1	7.0	B&G 1522	1½AAB	25	30	½	1750
P-2	4.9	4.7	"	1¼AAB	25	15	¼	"
P-3	12	10-10.5	"	1¼AAB	22	47	1	3450
P-4	4.9	4.3	"	1¼AAB	25	12	¼	1750
P-5	4.9	4.6	"	1¼AAB	25	23	¼	"
P-6	12	12.7	"	1¼AAB	20-30	48	1	3450
P-9	0.85	?	Grundfos	UP-25-42SF			1/20	2620
P-10	4.9	4.9	B&G 1522	1AA	22	15	¼	1750

TABLE 2. INSTRUMENTATION PARTS SCHEDULE - PRIMARY MEASUREMENTS

Measurement	Nomenclature	Estimated Range	Sensor Model
I001	Total radiation at collector surface angle, Btu/ft^2 hr	0-320	Eppley PSP
T001	Outdoor DB temperature, F	15-125	S53-P24
T100	Collector inlet temperature, F	70-225	S53-P72
T101	HE-1, HE-2 inlet temperature, F	70-240	S53-P72
T102	Collector surface temperature, F	15-285	S53-P24
T200	Storage inlet temperature, from HE-1, F	80-220	S53-P72
T201	Storage tank, top temeprature, F	80-220	S53-P180
T202	Storage tank, middle temperature, F	80-220	S53-P180
T203	Storage tank, bottom temperature, F	80-220	S53-P180
T204	Storage load return temperatrure, F	80-205	S53-P80
T300	Storage water temperature to DHW HE-3, F	130-220	S53-P55
T301	DHW make-up water temperature, F	40-95	S53-P55
T302	Water entering DHW HE-3 from mains or DHW storage tank, F	40-135	S53-P55
T303	Delivered DHW temperature, F	120-140	S53-P55
T400	East fan coil water inlet temperature, F	80-210	S53-P55
T401	West fan coil water inlet temperature, F	80-210	S53-P55
T402	Auxiliary gas boiler inlet water temperature, F	70-200	S53-P72
T500	East Arkla generator inlet temperature, F	180-215	S53-P55
T501	West Arkla generator inlet temperature, F	180-215	S53-P55
T502	East Arkla condenser inlet temperature, F	65-85	S53-P55
T503	West Arkla condenser inlet temperature, F	65-85	S53-P55
T600	East duct temperature out of Arkla/fan coil, F	50-130	S53-P85
T601	West duct temperature out of Arkla/fan coil, F	50-130	S53-P85
T602	East zone living-space temperature, F	65-85	S54-P28
T603	West zone living-space temperature, F	65-85	S54-P28
TD100	Collector array differential temperature, F	0-25	S57-P72
TD101	Collector/HE-1 differential temperature, F	0-25	S57-P72
TD200	Storage/HE-2 differential temperature, F	0-25	S57-P72
TD204	Storage make-up/load differential temperature, F	0-30	S57-P72

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TABLE 2. INSTRUMENTATION PARTS SCHEDULE - PRIMARY MEASUREMENTS *(Continued)*

Measurement	Nomenclature	Estimated Range	Sensor Model
TD300	DWH HE-3 storage-side differential temperature, F	0-50	S57-P55
TD301	DHW load differential temperature, F	40-100	S57-P55
TD302	DHW HE-3 differential temperature, F	0-40	S57-P55
TD400	East fan coil water differential temperature, F	0-30	S57-P55
TD401	West fan coil water differential temperature, F	0-30	S57-P55
TD402	Auxiliary boiler water differential temperature, F	0-25	S57-P72
TD500	East generator water differential temperature, F	0-15	S57-P55
TD501	West generator water differential temperature, F	0-15	S57-P55
TD502	East condenser water differential temperature, F	0-20	S57-P55
TD503	West condenser water differential temperature, F	0-20	S57-P55
TD600	East duct H/C air differential temperature, F	0-60	S57-P85
TD601	West duct H/C air differential temperature, F	0-60	S57-P85
W100	Collector flow rate, gpm	0-25	MKV-1½-ss
W200	Collector-HX to storage flow rate, gpm	0-25	MKV-1½-ss
W201	Storage to H/C system flow, gpm	0-23	MKV-1½-ss
W300	DHW flow to load, gpm	0-10	MKV-¾-ss
W301	Storage to DHW HX flow rate, gpm	15-25	MKV-1-ss
W302	DHW to HE-3 flow rate, gpm	10-15	MKV-1-ss
W400	East fan coil water flow rate, gpm	3-11	MKV-1-ss
W401	West fan coil water flow rate, gpm	3-11	MKV-1-ss
W500	East Arkla generator flow rate, gpm	0-11	MKV-1-ss
W501	West Arkla generator flow rate, gpm	0-11	MKV-1-ss
W502	East Arkla condenser flow rate, gpm	0-10	MKV-1-ss
W503	West Arkla condenser flow rate, gpm	0-10	MKV-1-ss
W600	East air duct flow rate, cfm	1500-1900	Ellison 74/157A (20 in.)
W601	West air duct flow rate, cfm	1400-1750	Ellison 74/157A (20 in.)
EP300	DHW auxiliary electric power, watts	0-4500	PC5-29
EP500	P-10, cooling tower pump & fan & control, electric power, watts	0-3000	PC5-20
EP600	System operating power, watts P-1, P-2, P-3, P-4, P-5, P-9, air compressor, system control circuitry	0-9000	PC5-29
EP601	East Arkla blower and controls, watts	0-1450	PC5-19
EP602	West Arkla blower and controls, watts	0-1150	PC5-19
F400	Auxiliary H/C boiler natural gas flow, cu ft per hr	0-250	(not selected)

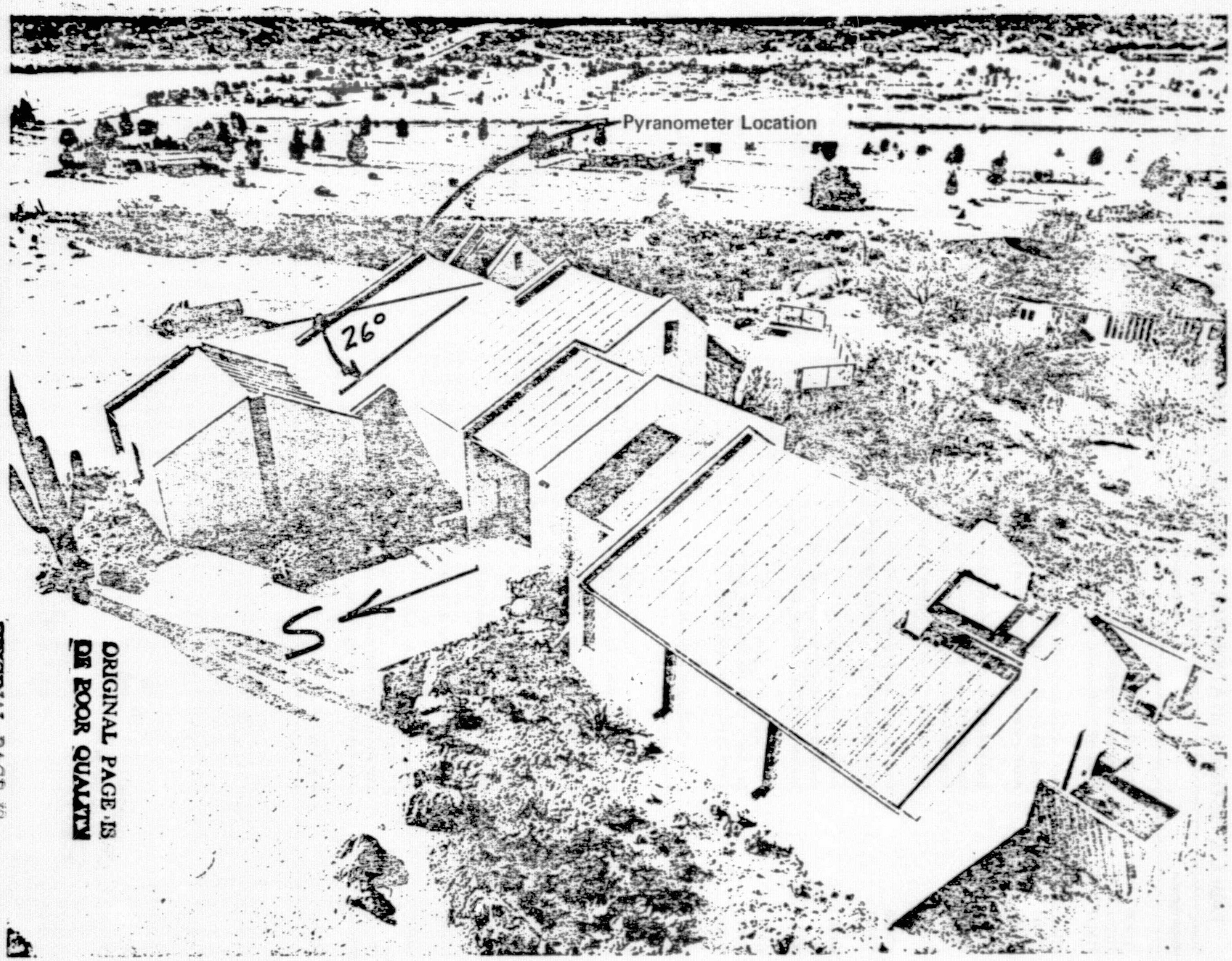

FIGURE 1. VIEW OF DECADE 80 SOLAR HOUSE SHOWING COLLECTOR ORIENTATION AND PYRANOMETER LOCATION

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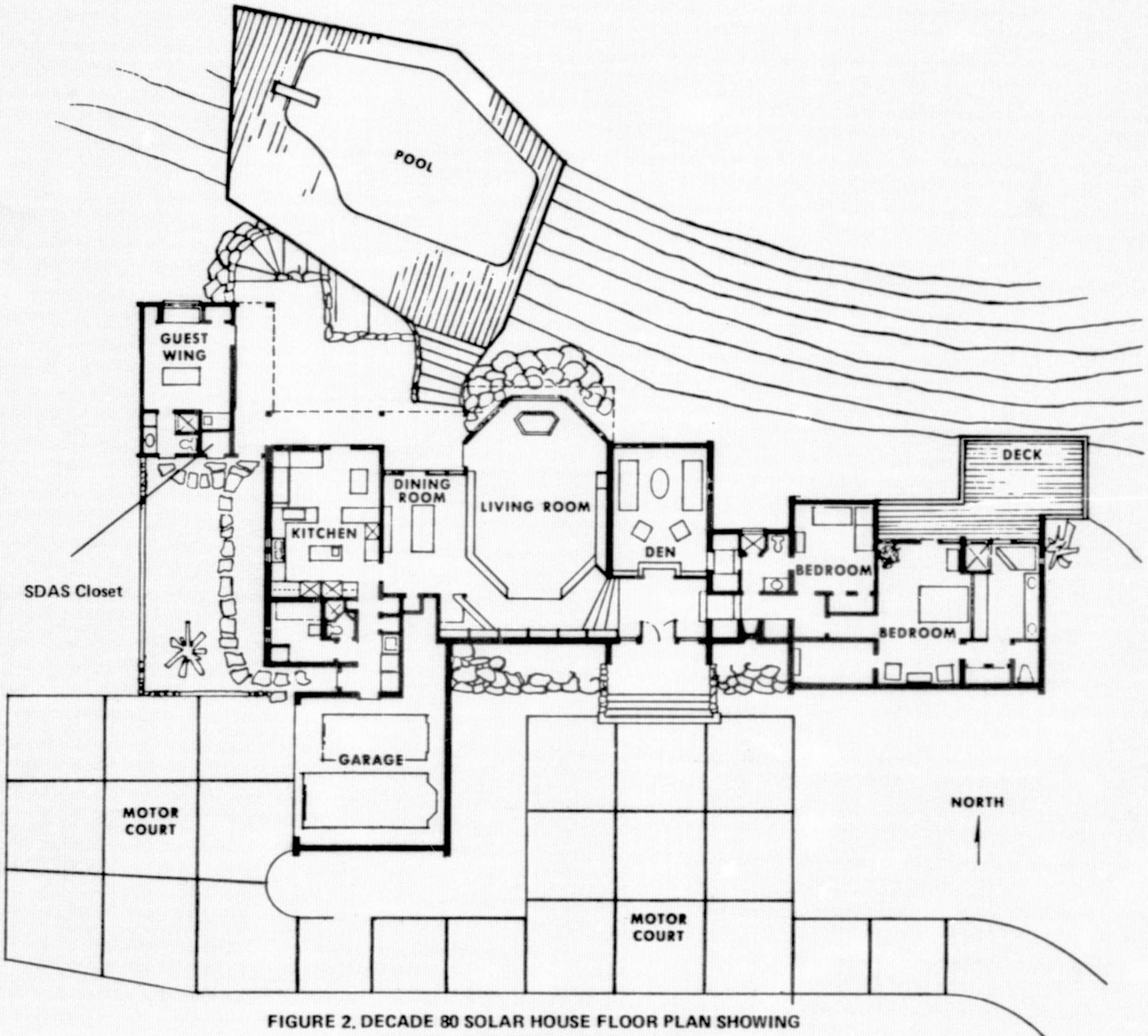
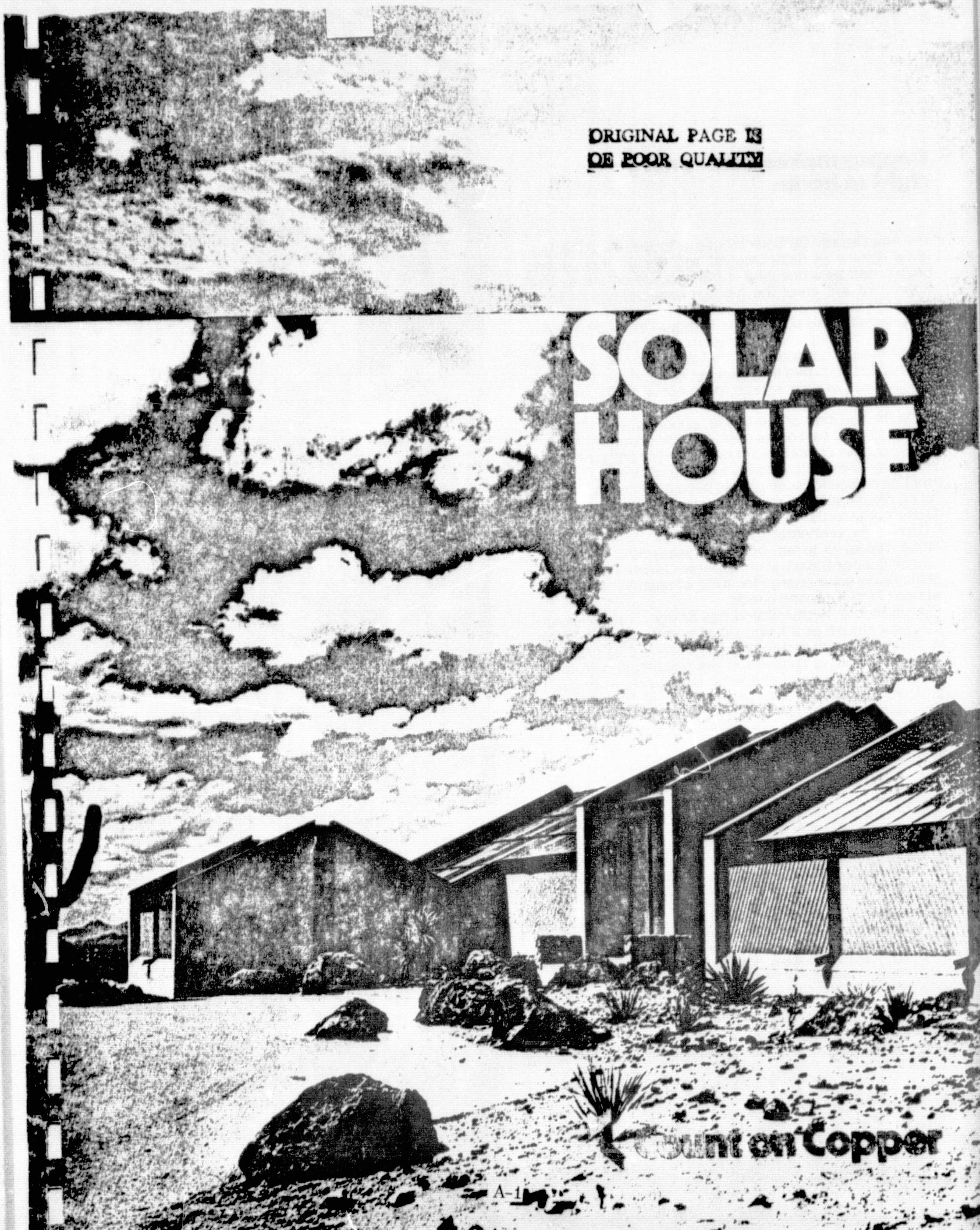


FIGURE 2. DECADE 80 SOLAR HOUSE FLOOR PLAN SHOWING LOCATION OF SDAS AND JUNCTION BOX.

APPENDIX A


SOLAR
HOUSE
Count on Copper

Copper makes solar energy right at home

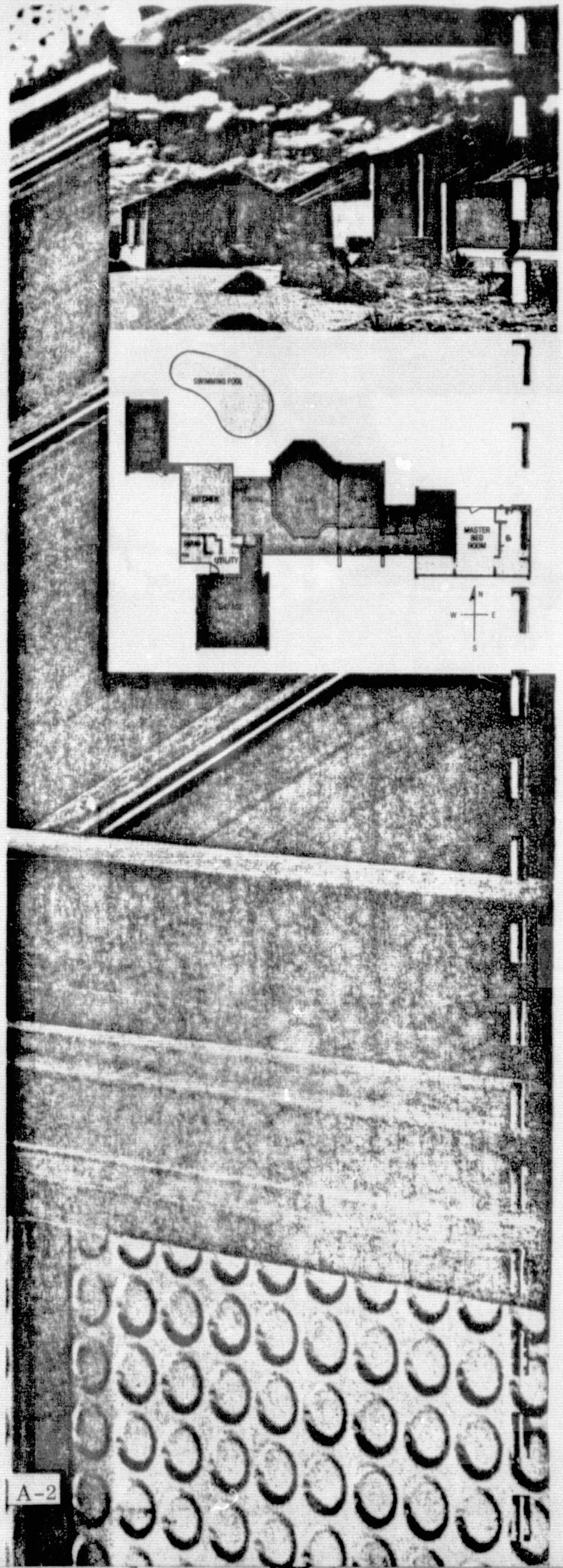
The new Decade 80 Solar House in Tucson, Arizona, features dozens of technological and design innovations highlighted by a beautiful copper roof to create a solar home that will meet the highest expectations of comfort and convenience.

Conceived and built by the Copper Development Association Inc., advanced market development arm of the copper and brass industry, the Decade 80 Solar House is designed to prove the practical value of sun power as an alternate energy source in an era of dwindling fuel supplies and rising energy costs.

On the sun side of the house, copper solar collectors are an integral part of the overall copper roofing system. These copper collectors are now commercially available and easy to install with today's tools and skills. Copper is the first choice for solar panels because it conducts heat more effectively and resists corrosion better than other feasible materials.

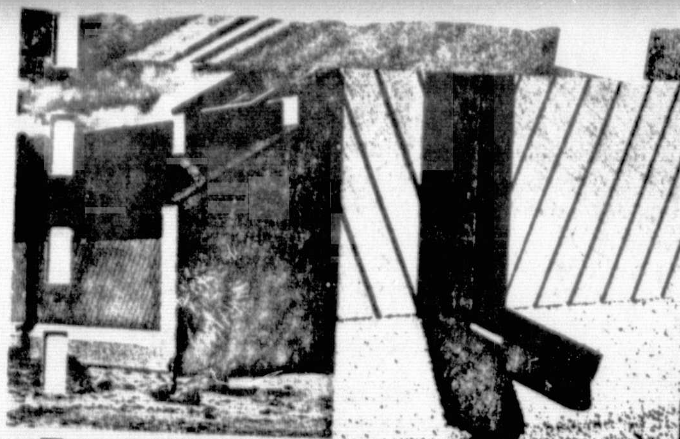
Unlike experimental solar structures, the Decade 80 Solar House is a real home—a year-round residence whose copper-based, solar-assisted climate control system utilizes solar energy for 100% of heating needs, and at least 75% of cooling needs.

Architect M. Arthur Kotch has designed the Decade 80 Solar House as a blueprint of bright ideas ahead in residential design and construction. Innovative products from participating sponsors in the building construction and home furnishing fields are everywhere. And so are copper, brass and bronze products that will continue to be hallmarks of high-quality construction—copper plumbing and wiring, copper metals for architectural and decorative uses, exterior and interior.



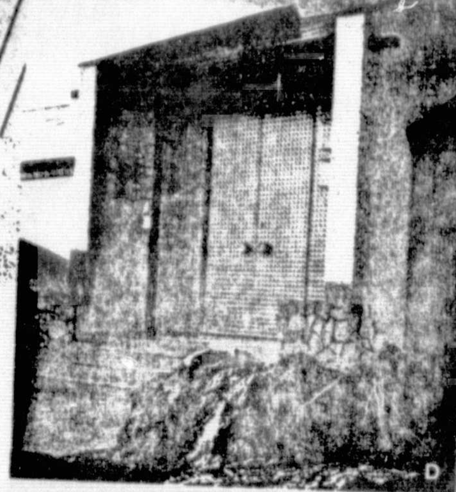
(A) The combination solar collector roof consists of 2 ft. by 8 ft. copper sheets and rectangular copper tubes fastened to them, both blackened for maximum absorbing power. Radiant heat is trapped in the collectors, transferred to water in the tubes and circulated by ITT Bell & Gossett pumps into a storage tank. This energy then is transferred as needed to Arkla Industries' absorption chiller or to a fan coil unit for cooling or heating the house. Fiberglas ducts from Owens-Corning Fiberglas provide noiseless distribution of warm and cool air from the Arkla units. The stored energy is used also for heating household water. PPG Industries "Twindow" double glass covers the blackened copper collector panels to trap energy that is radiated back from the collector surfaces. A separate copper collector heats the pool.

Architect: M. Arthur Kotch, A.I.A.
Interior Design: Ving Smith Interiors, A.S.I.D.
Contractor: McLoughlin Contractors & Engineers, Inc.

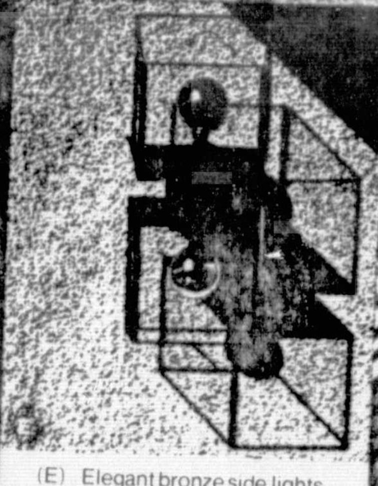


(B) The south side of the house is almost windowless to minimize the cooling load. Dramatic copper doors are fully insulated. Owens-Corning Fiberglas building insulation under the copper roof and in walls cuts heat gain and loss for maximum energy conservation. Grooved siding is U.S. Plywood's Roughtex T1-11 in desert-toned cedar.
(C) Practical, stylish burnished-copper downspouts continue theme of natural colors and textures.

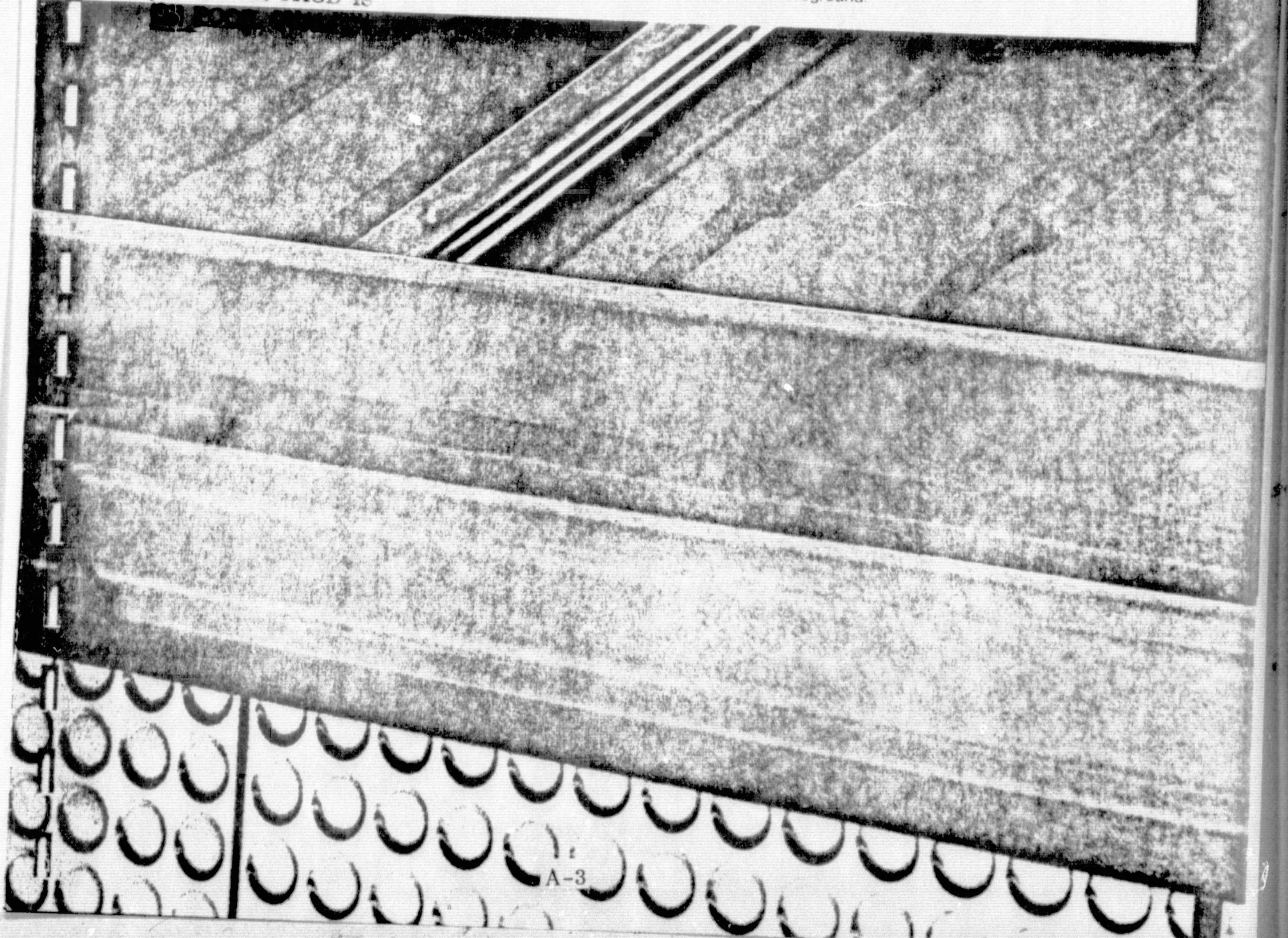
Floor plan fulfills desires of today's families for casual living and convenience. Openness of living areas sets a relaxed, informal mood.



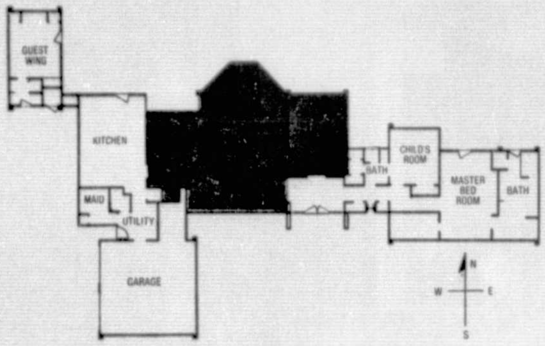
(D) Casting a warm glow of welcome are the main entrance doors, pulls and side panels of copper. Out-of-sight Schlage Electronics access system eliminates keys by sensing presence of a coded card held near sensor unit in wall. Side windows flanking doors are narrow heat-reflective Solarcool Bronze Twindow units from PPG Industries. Native Arizona copper ore is in the foreground.



(E) Elegant bronze side lights contrast beautifully with durable exterior cladding of U.S. Plywood's Sanspray, a factory-finished plywood panel coated with decorative stone chips in a protective epoxy resin.



Elegant, arefree living, solar-style



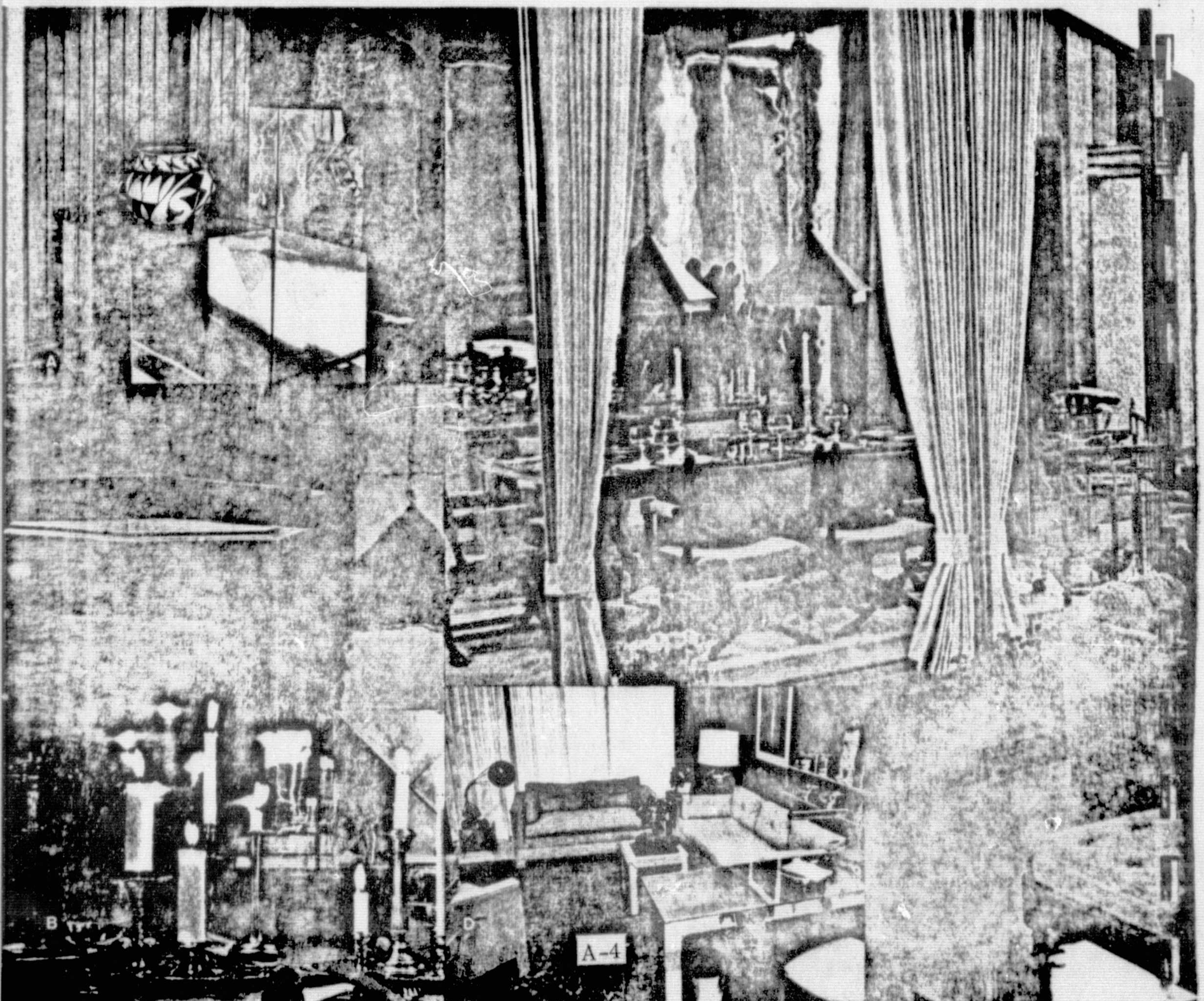
The sun-splashed living areas of the Decade 80 Solar House present a glowing showcase for today's emerging trend in home decor—"neutrals and naturals," enhanced by the warmth and beauty of copper, brass and bronze.

Every room is alive with decorative ideas and furniture designs for today's elegant yet informal lifestyles, coordinated by interior designer Ving Smith, A.S.I.D. Each room has a dramatic view overlooking the beautiful Tucson National Golf Course.

Colors and textures reflect the desert environment and the traditions of the American Southwest—subtle tones of sand, beige, sky blue and sagebrush. Woods display their natural finishes or are lightly stained. Floors

(A) Cubes and columns of mirrored copper and brass, enriched with an abstract, inlaid solar design, were created by Ving Smith as the house's "signature" and used here as sculpture in the foyer with a Navajo Indian bowl. The entrance hall and living room walls are distinctive light-hickory paneling from the elegant U.S. Plywood Weldwood Collection. Indian Artifacts: Navajo National Arts & Crafts Council.

(B) That special glow of a candlelight dinner is reflected by copper plates, serving dishes, brass candleholders and brass wall covering.



are of ceramic tile from member com ies of the Tile Council of America. And decorative accents are those of the warm-tone metals—copper, brass, bronze.

Most furnishings in the Decade 80 Solar House have been selected from the vast resources of Burlington Industries, the largest and most diversified manufacturer of these products for the home.

Styles are right in tune with today's eclectic tastes. In the dramatic sunken living room, contemporary pieces from the Burlington Stendig Collection contrast excitingly with prototype furniture designs in copper and brass, created specially for the Decade 80 Solar House.

Tying together living areas is the fresh look of ceramic floor tile. A rich, durable amber-tone tile sweeps from the front steps through foyer, living room and dining room to enhance the open plan and create a natural backdrop for an array of Lees carpets from Burlington.

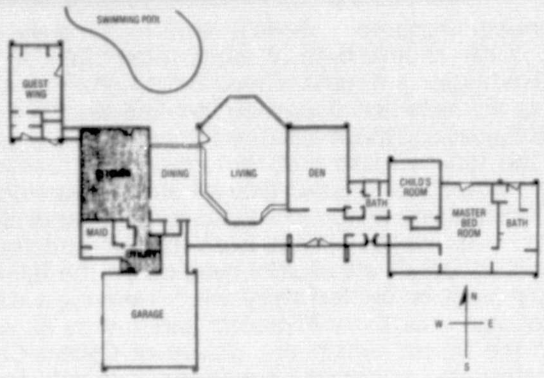
Beneath bronze c deliers, a mirrored brass dining table is the room's natural focus, beautifully at home with Burlington's director's-type dining chairs. Floor-to-ceiling windows and doors are thin-line bronze framed. Double glass and thermal-break frames conserve energy.

In the dining room and throughout the Decade 80 Solar House, Scotchgard* Brand Fabric Protectors from 3M Company are on the job, keeping upholstery, draperies and even wallcoverings fresh-looking and soil-free. If a spill occurs, it will usually bead up on the fabric and can generally be blotted away without leaving a stain.

Scotchgard Drapery Protector safeguards all draperies in the house which are woven of Owens-Corning Fiberglas yarn as are wall coverings. Fire-safe Burlington House draperies of Fiberglas in icy white dramatize windows. Versatile Fiberglas reproduces the look and feel of traditional fabrics.

(C) A soaring copper fireplace, copper and brass hearth equipment, decorative copper bowls and brass lamps reflect the warmth of the fireside. Shimmering mirrored brass wall sets the stage for gracious dining and entertaining. Brass pole system separates living and dining areas with Burlington's draw draperies for more privacy when desired.

(D) In the den/study, the mirrored-copper desk blends with the warmth of a patterned rug and flooring of glazed ceramic tile. Paintings, sculpture: Harlan Gallery. Copper cloisonne: Margaret Seeler.



Copper Kitchen: Everything new under the sun

Ultimate convenience with ultimate energy conservation was the design challenge posed by the Decade 80 Solar House's kitchen and utility rooms. The result is a "dream-come-true," step-saving environment built around the central food preparation island.

Every appliance in these bright, friendly copper-accented rooms was selected from among the most advanced energy-conserving designs available. Solar cells on the house's roof power the kitchen's TV set, wall clock and some small appliances.

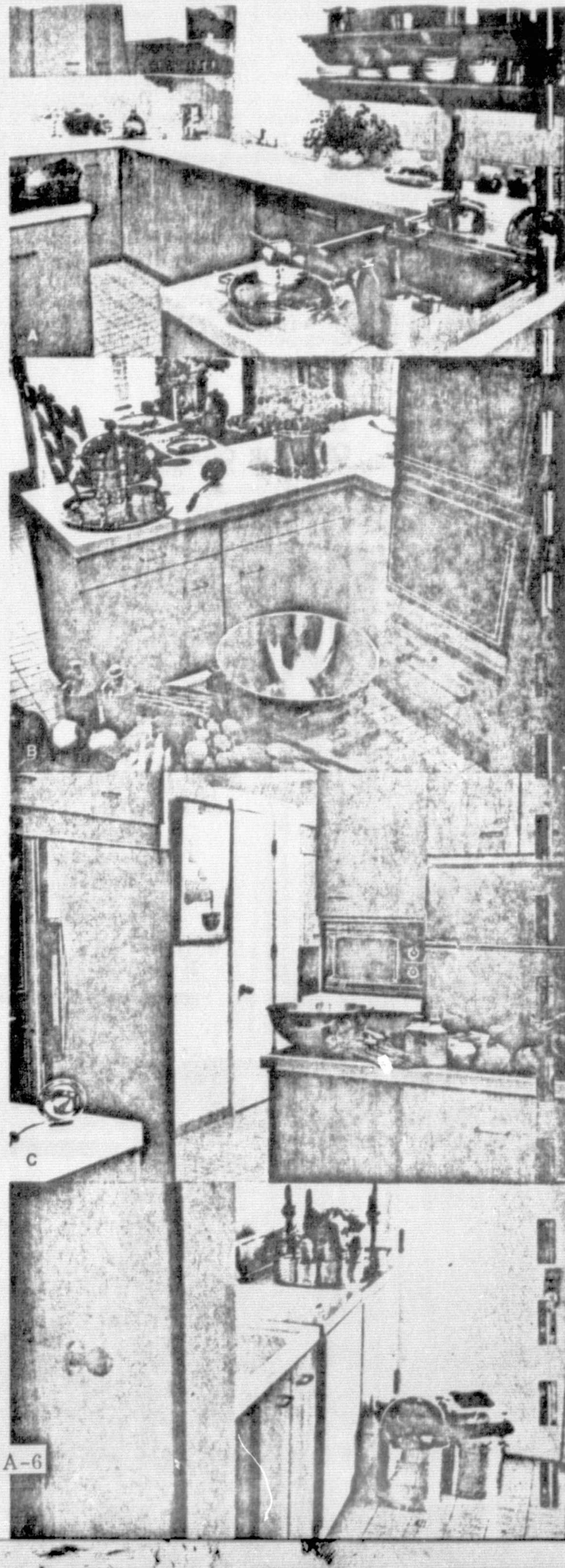
Amana's "Energy Saving Refrigerator" uses only 2.9 kilowatt hours of electricity per day—little more than a single 100-watt light bulb. Amana's companion "Free-O-Frost Freezer" stops any energy-wasting frost build-up before it starts.

An advanced-design Amana "Radarange" microwave oven also cuts energy consumption. With cool microwave cooking, there's no energy wasted heating the oven before cooking begins.

The novel Jenn-Air convertible grill-range offers the beauty of glass-ceramic cooktops in modules which unplug and convert into a single or double grill. Accessories transform the unit into a rotisserie, French fryer, griddle or shish kebab broiler. Built-in proximity ventilation eliminates overhead exhaust hood. In guest wing is a Jenn-Air deluxe single grill.

For cleaning up after mealtime or entertaining there's a Maytag food-waste disposer and a built-in dishwasher engineered for energy-saving operation and highlighted by a copper front. Its rinse-and-hold, crystalware and plastics cycles are important energy conservers.

Color-coordinated ceramic floors, countertops and backsplashes throughout are from the Tile Council of America. Cheerful canary yellow floor tiling has a slip-resistant glaze. Crisp white square-tiled countertops are perfect foil to the elegantly-styled American-Standard "Fiesta" triple bowl sink.



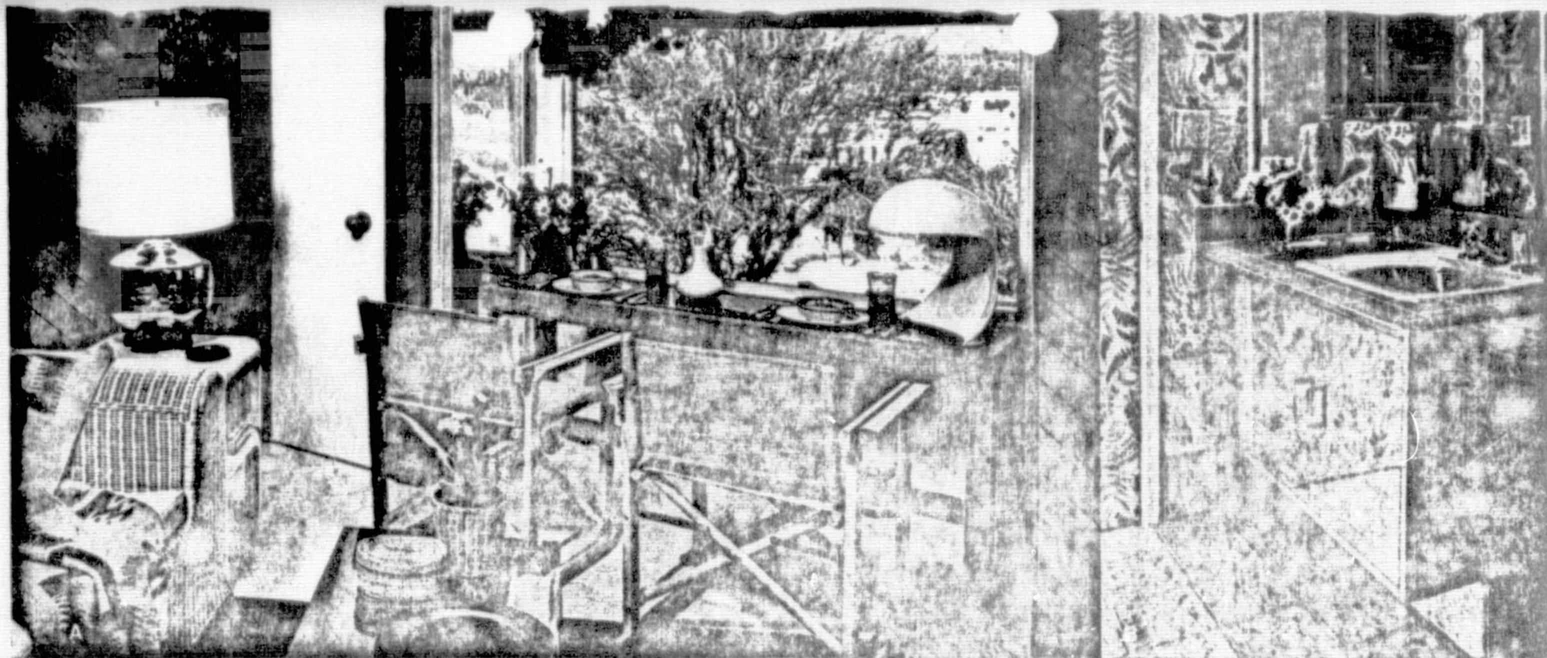
(A) Step-saving planning puts triple sink, copper fronted Maytag dishwasher, and countertop Jenn-Air grill-range all within easy reach. Under-cabinet lighting brightens tile work surfaces.

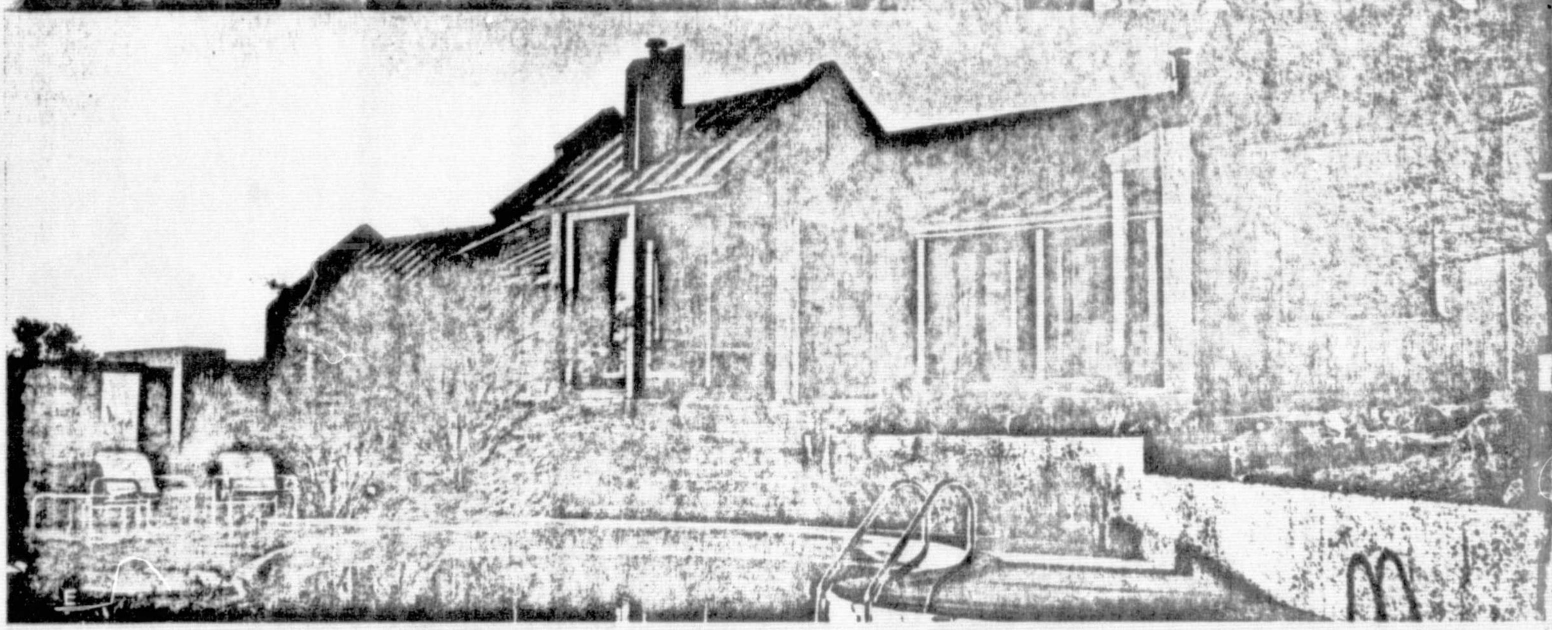
(B) For conventional baking, there's an extra-large Jenn-Air deluxe twin oven, with clock-controlled baking, energy-hoarding continuous-cleaning interior. Informal eating area beyond opens onto poolside.

(C) Copper-fronted Amana freezer and refrigerator are handy to energy-conserving Amana "Radarange" microwave oven. Central to all is butcher-block topped food preparation island.

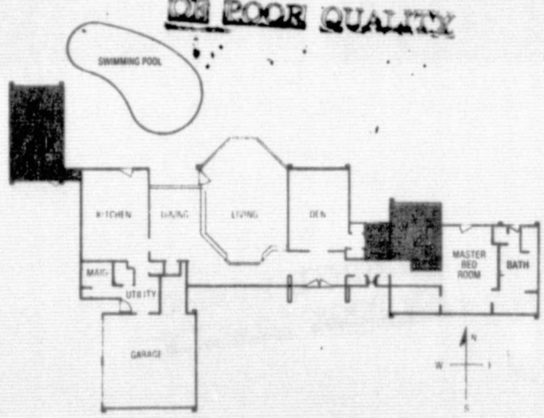
(D) Down corridor in utility area, two more energy-saving appliances. Maytag's automatic all-fabric clothes washer handles any time and temperature cycle. Maytag's electronic control dryer automatically measures moisture content of clothes, economically cutting off current as soon as load is properly dried. Utility sink by American Standard.

(E) Above in the Decade 80 Solar House kitchen are professional-quality copper pots, pans and kitchen tools—time-tested companions to fine cooking. In the 1980's, as always, gourmet cooks will be cooking with copper because of its even heating qualities. Beyond, charming family room with adobe-type corner fireplace and built-in banquettes covered in Burlington hot Mexican striped fabrics, made carefree by 3M Scotchgard Protectors. Copper-theme accents help make this a delightful area for breakfasts, snacks and informal entertaining. Copper wall hanging: Yvonne Forbath. Breakfast area paintings: Chabela





(A) Guest wing decorative motif is set by paneling of cinnamon brown California redwood lumber, dramatically applied on the diagonal to walls and ceiling. Accessories are in varying tones and textures of the copper metals: copper, brass and bronze.
(B) The mirrored copper sink enclosure and ceramic tile floor add touches of practical elegance to the child's bathroom. Unseen servants: efficient, lifetime copper and brass plumbing.
(C) Furniture and decor in child's bedroom reflect younger tastes. Walls and ceilings are of U.S. Plywood's Wayside Inn paneling in birch, with mismatched plank look accenting the natural knots and burls of real wood. RCA's solar-powered TV adds to room's enjoyment.
(D) Master bath features super-sized, 42-inch-wide "Ultra Bath Bathing Pool" by American-Standard, his and hers "Ovalyn" lavatories highlighting the expanse of cobalt blue mosaic tile on counter top.

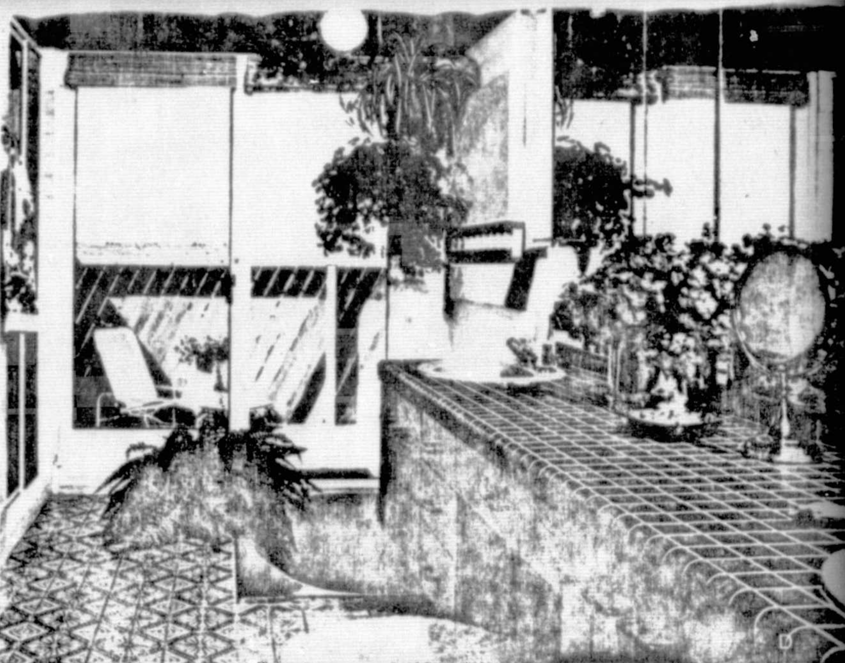


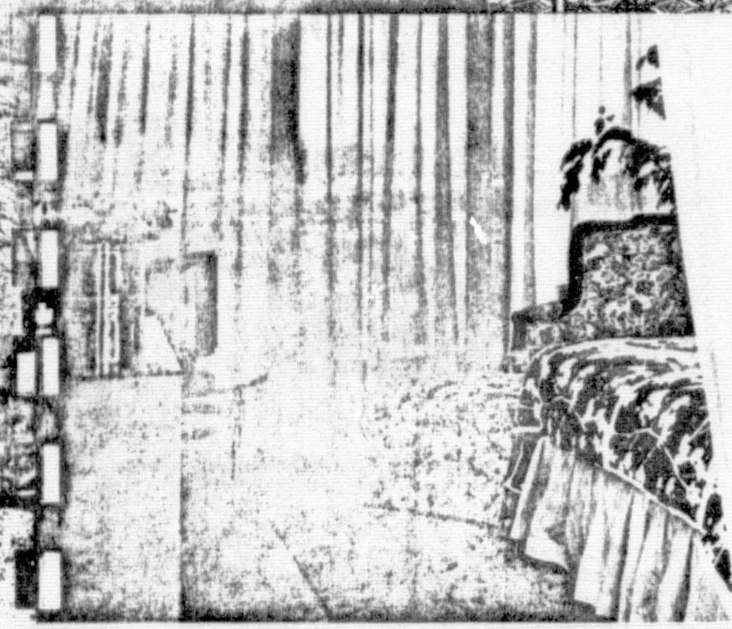
Solar-home sunning, bathing and sleeping

Sunning, bathing and sleeping areas in the Decade 80 Solar House continue the note of luxury appropriate to America's most innovative home.

Opening onto the poolside area is a guest wing, with its own private entrance, kitchenette and bath. Copper solar panels on the south-facing cathedral ceiling are part of a separate solar energy system for heating or cooling the pool.

The entire guest wing floor is surfaced with "Corsican" design, curvilinear white glazed tile. The guest wing's window wall, as with all north-oriented glass, is PPG tempered "Solarbronze Twindow" insulating glass units





Light cylinders are ordinary copper plumbing tube cut to desired length. Outside: private California redwood deck.
(E) Automatic poolside "servant" skims debris from water surfaces and continuously chlorinates water. California redwood is natural choice for pool decking and fencing and exterior siding of the guest wing. Copper roof. U.S. Plywood Sanspray cladding, complete natural look.

(F) Distinctive furnishings, linens and wall fabric from Burlington House create a mood of worldly sophistication and fashion in the Decade 80 Solar House's master bedroom. Decorative mirrored-brass pole system separates sleeping area from dressing area and bath. At left, an elegant mirrored-copper dressing table. Copper "life safety" fire sprinkler system protects master bedroom and all other rooms.

which reduce heat gain or loss to half that experienced with clear single glass.

Outdoor living in the Decade 80 Solar House is as enjoyable and carefree as technology can make it. The natural center for entertainment and recreation is the family-sized, kidney-shaped "Buster Crabbe" swimming pool by Cascade Industries. This solar-heated "Capri" design pool has a mosaic-patterned bottom of light-to-dark blue and blue sidewalls, perfect reflections of the Arizona sky.

In the child's bath, American-Standard fixtures reflect a casual style. Lavatory is the self-rimmed "Aqualyn," water closet the one-piece "Concord," both in blue. Fittings and faucets are gold-plated brass.

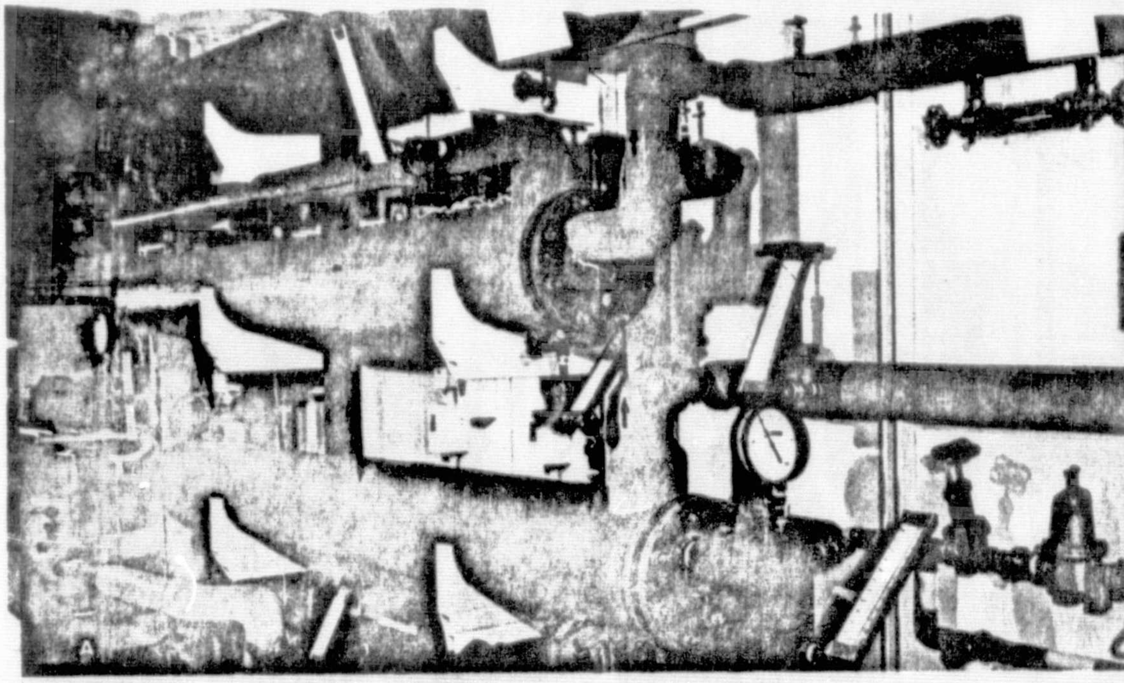
In the dramatic master bath, high-style American-Standard fixtures, faucets and fittings take center stage, with blues and copper metal hues predominating.

An oversized American-Standard bathing tub-pool gives extra room for relaxing. A built-up back support and beveled headrest make it a sybarite's delight.

Water closet and bidet are sleek new low-profile designs. Floors are of dramatic, Aztec-inspired ceramic tile. Faucets and fittings are again gold-plated brass. Closet doors are clad in mirrored copper.

Contrasting in color and texture are the walls and ceiling of natural all-heart California redwood. Redwood's superior insulating properties are important here and throughout the Decade 80 Solar House—it insulates better than gypsum board, plaster or cement block.

Accessible only from the master bath is a secluded sundeck for private sunbathing. Fencing and decking are of economical garden grades of California redwood, one of the world's most weatherable woods. Its rustic texture extends the house's theme of natural materials.



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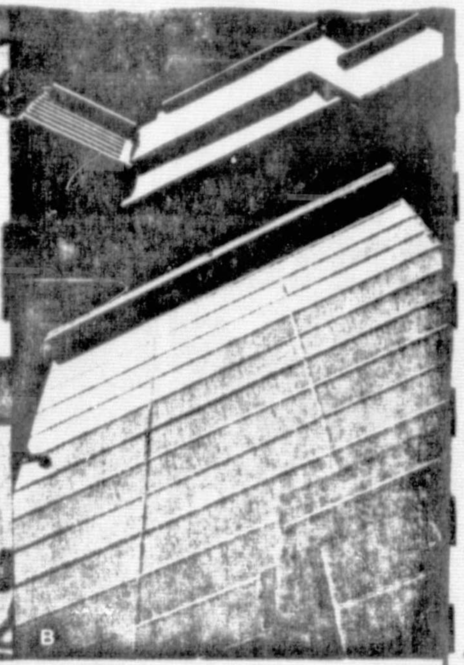

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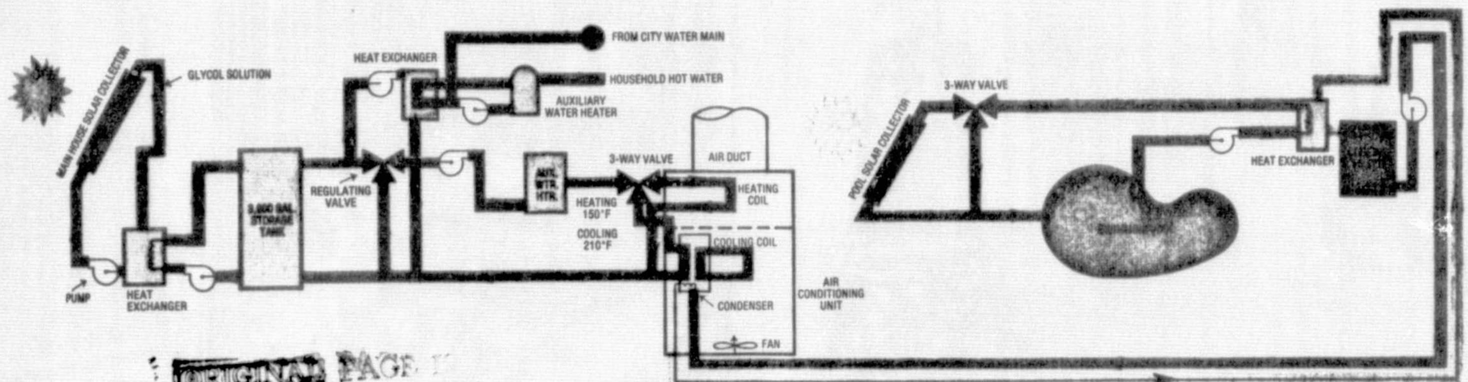


E

(A) Basement energy room houses solar-energy system components including B&G heat exchangers, pumps and control valves that transfer energy throughout the system.
(B) Copper makes beautiful, efficient solar roofing systems ready for builders today. Copper conducts heat more effectively and resists corrosion better than any other material feasible for solar panels. Roof-mounted silicon photovoltaic cells directly convert sun's energy to low voltage power for RCA TV and radio sets, clocks, decorative lighting and security system, safe from power interruptions.
(C) Inconspicuous all-copper "life safety" fire sprinkler system tied into household water lines protects the Decade 80 Solar House. Copper tube's fast, easy joining by soldering, plus ability to handle pressures reliably make this innovative system feasible for residences, apartments, nursing homes, hotels and office buildings.

Copper: The key to quality and performance reliability

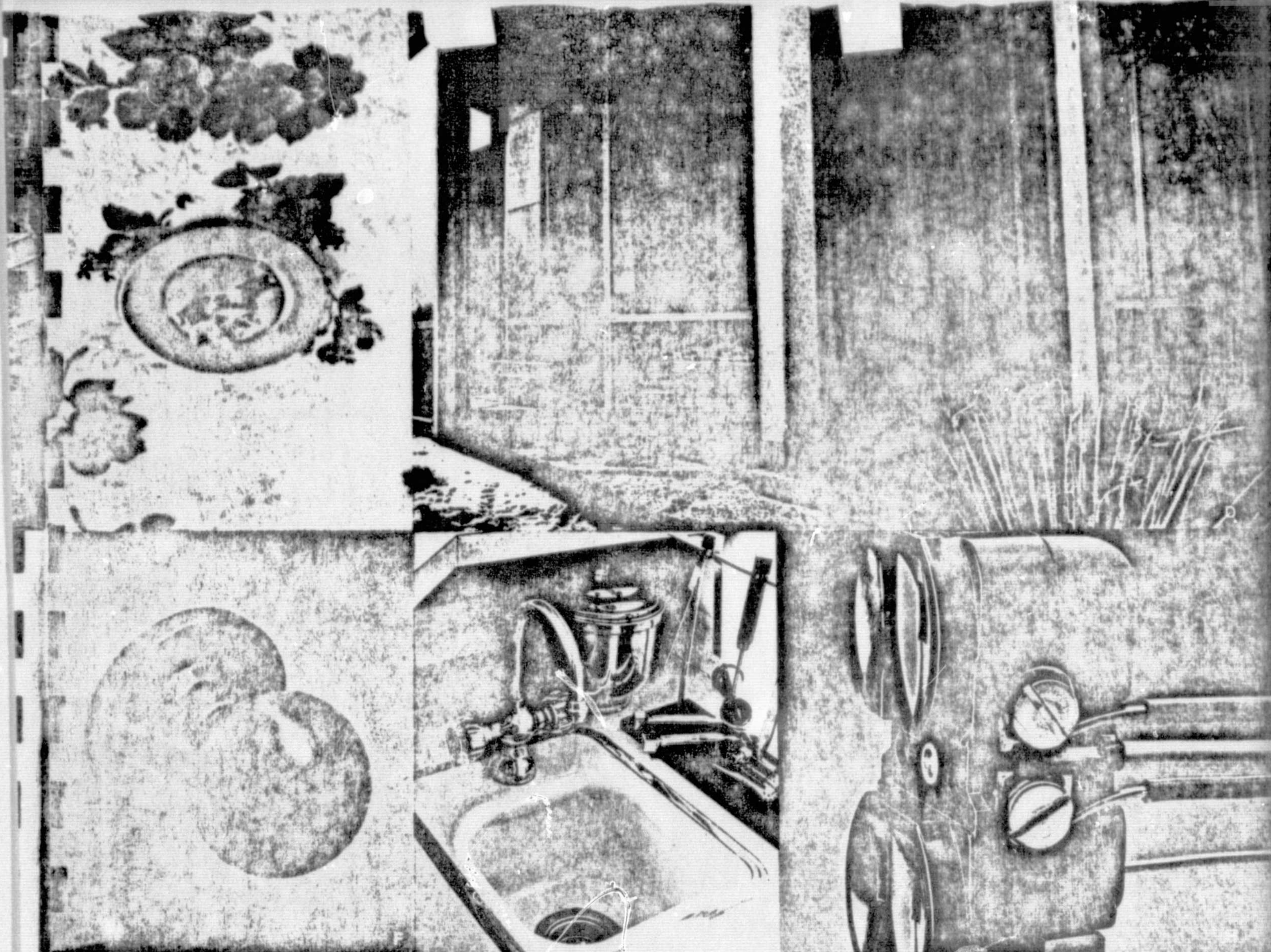
A thoroughly practical means for harnessing the sun's energy, the Decade 80 Solar House climate control system is built entirely of components commercially available today.

Nucleus of the solar energy system, basically an extension of the house's plumbing system, is the breakthrough integrated copper solar-collector roofing system. A blending of the best virtues of both copper roofing and copper plumbing, each 2 ft. by 8 ft. panel consists of rectangular copper tubes fastened to a 0.016-inch thick copper sheet (laminated to plywood) and glass covering over the copper tubes and sheet.

Solar heat absorbed by the collector panels warms a mixture of water and 10 percent propylene glycol antifreeze circulating through the copper tubes, which carry it to a 3,000-gallon underground thermal energy tank for storage and use.

ITT Bell & Gossett (Fluid Handling Division) heat exchangers, pumps and control valves play a vital role in the Decade 80 Solar House. The centrifugal pumps are of all-bronze construction, similar in design to B&G pumps proven in more than 8 million hydronic heating/cooling systems. B&G heat exchangers have been employed in a number of solar-energy applications. The B&G pumps and control valves work together with these compact heat exchanger units to accomplish the efficient transfer of energy throughout the system.

The air conditioning system employs two Arkla Industries Solaire® WF 501 units. These absorption-type units are remarkably compatible with solar-energy power because they use heat directly to produce cooling. For heating the home, the hot water goes directly from the storage tank to a copper fan-coil in the Arkla unit.



(D) Elegant new thin-line bronze door and window system features unique thermal break sandwich construction and PPG "Solarbronze Twindow" units for high insulating performance.
(E) Schematic heating/cooling system. Water, plus 10 percent propylene glycol, circulating through copper solar collector is heated by the sun, pumped to energy room and stored as thermal energy for use as required for space heating, air conditioning, and household hot water. Separate copper collector serves pool, which also uses waste heat from air conditioner condenser to help increase solar efficiency.
(F) Schlage's highly contemporary "Ball" lock in oil-rubbed bronze provides warmth and beauty throughout the house.
(G) American-Standard party sink in living-area bar features elegant look of solid brass gold-finished fittings.
(H) Copper wiring is sign of a quality home. Copper's installation ease and lifetime reliability are well-known. It is the standard for all types of buildings. Copper remains the only wiring approved by all codes.

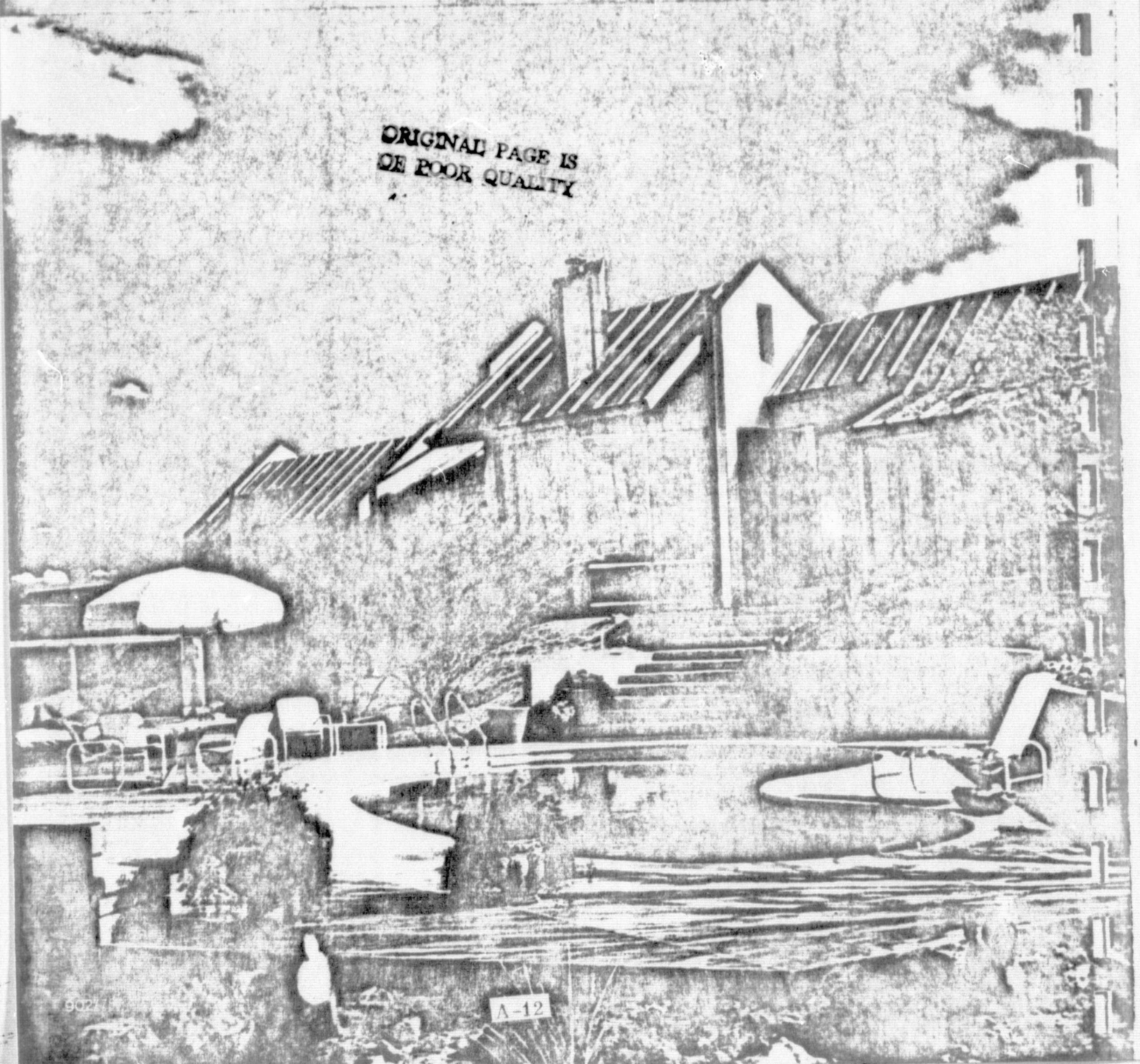
In addition to the sun-powered climate control system, the Decade 80 Solar House contains a small separate system directly converting solar energy to electrical energy. Silicon photovoltaic cells developed by Solar Power Corporation are mounted on the master bathroom roof, convert the sun's energy directly to low voltage power for selected uses. Electric power for lighting, cooking and appliances is utility-supplied.

Copper plumbing and copper electrical systems provide the Decade 80 Solar House with high performance reliability. For plumbing and electrical uses, copper is the standard of quality, accepted by more building codes than any other material. Architects and engineers also know that copper is more economical overall.

Copper systems for electricity, plumbing, fire sprinklers and solar energy are the lifeline of the Decade 80 Solar House built with materials and technology which are available today.

Decade 80 Solar House Participating Sponsors: Amana Refrigeration, Inc., microwave oven, refrigerator, freezer ☐ American-Standard Plumbing Products ☐ Arkla Industries, Inc., climate control system ☐ Burlington Industries, Inc., furniture, lighting, carpets, draperies, bed linens, towels ☐ California Redwood Association, interior paneling, fencing, decking and siding ☐ Cascade Industries Incorporated, swimming pool ☐ ITT Bell & Gossett, Fluid Handling Division, centrifugal pumps and heat exchangers ☐ Jenn-Air Corporation, cooking range, oven, and grill ☐ The Maytag Company, washer, dryer, food-waste disposer, and dishwasher ☐ Owens-Corning Fiberglas Corporation, Decorative and Homefurnishings Division, Fiberglas for the draperies, wallcovering, and bedspreads ☐ Owens-Corning Fiberglas Corporation, Home Building Products Division, Fiberglas insulation and Fiberglas duct system ☐ PPG Industries, glass for solar panels, windows, and doors ☐ Schlage Lock Company, electronic locking device, and locksets ☐ 3M Company (Scotchgard Products), supplier of Scotchgard Protectors for upholstery, draperies, and wallcoverings ☐ Tile Council of America, exterior and interior tiles ☐ U.S. Plywood, Division of Champion International, exterior cladding and panels, interior paneling

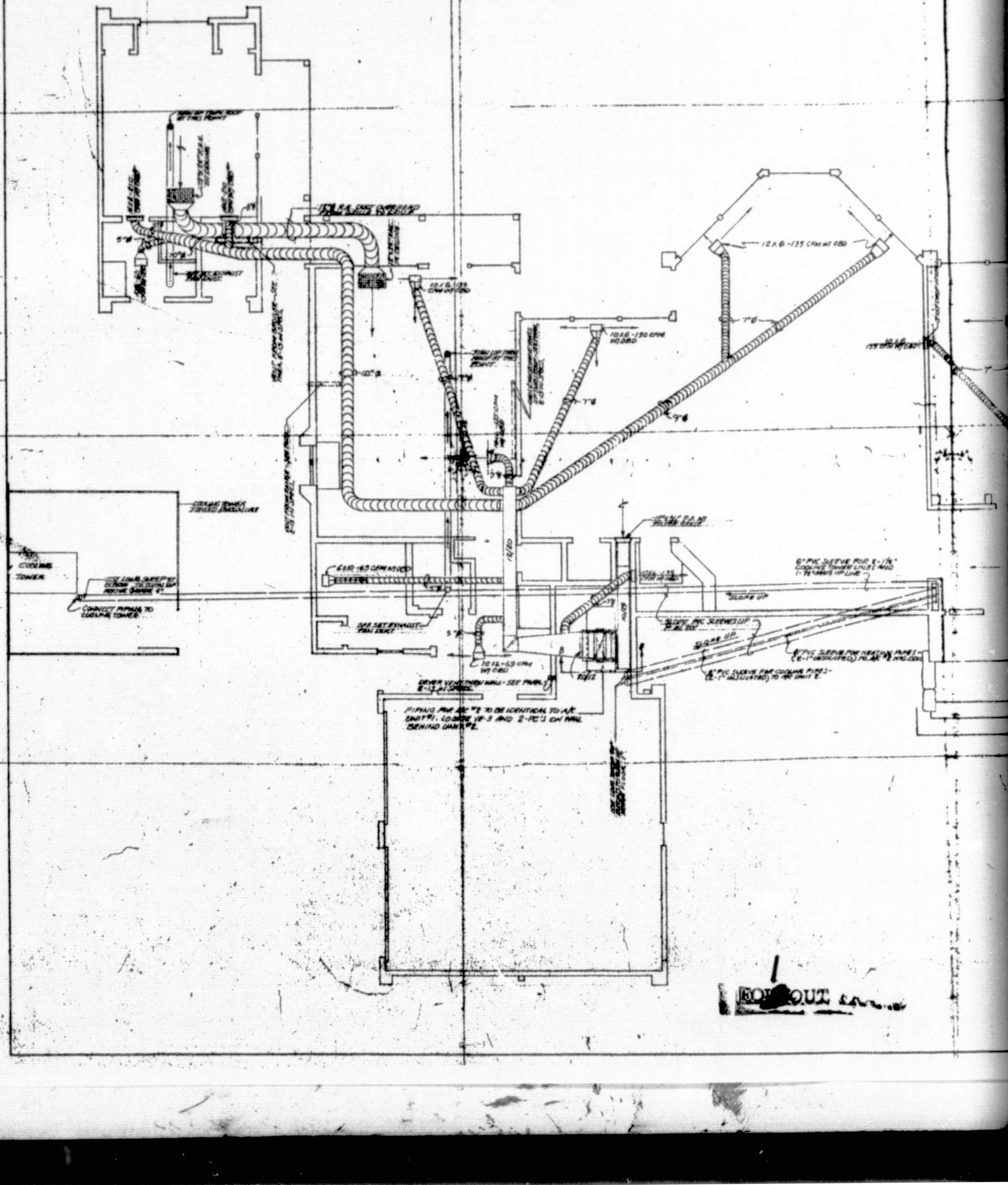
COPPER DEVELOPMENT ASSOCIATION INC.
405 LEXINGTON AVENUE, NEW YORK, N.Y. 10017

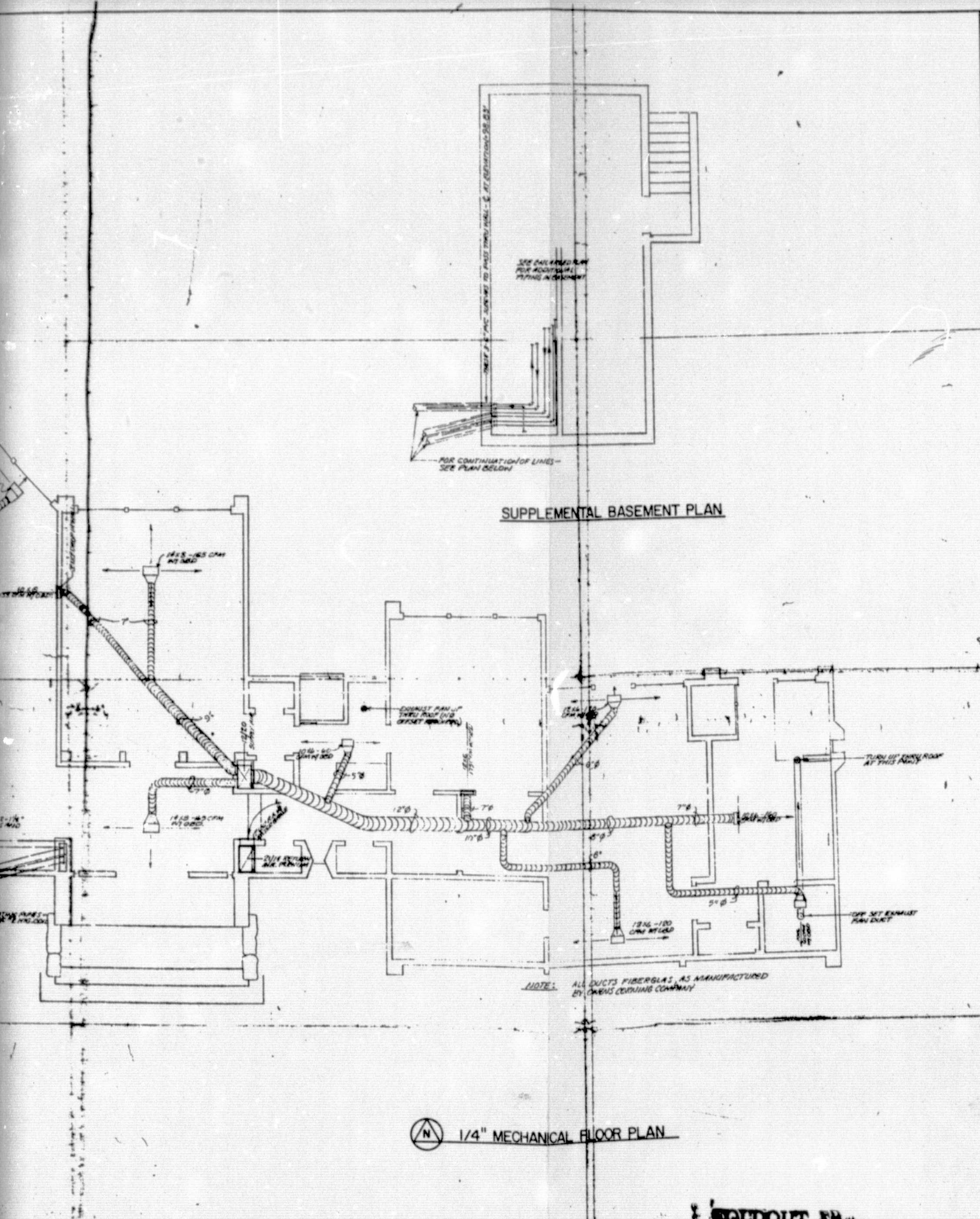


APPENDIX B

AIR CONDITIONING NOTES

1. TYPE 'M' COPPER TUBING SHALL BE USED FOR ALL A/C PIPING
2. ALL REGISTERS AND GRILLES SHALL BE KRUEGER OR EQUAL STEEL
3. SIDEWALL REGISTERS ARE SERIES 800V
4. RETURN GRILLES TO BE SERIES 80H
5. CEILING DIFFUSERS TO BE SERIES "S".
6. FILTER RETURN GRILLES TO BE FRAME 3 FA WITH 380H





A RESIDENCE FOR
GEORGE M. HARTLEY, TRUSTEE
TUCSON ARIZONA

B-1

DATE: 4-5-74 6-7-74
DRAWN BY:
APPROVED:

M. ARTHUR KOTCH
ARCHITECT
HOUSTON, TEXAS

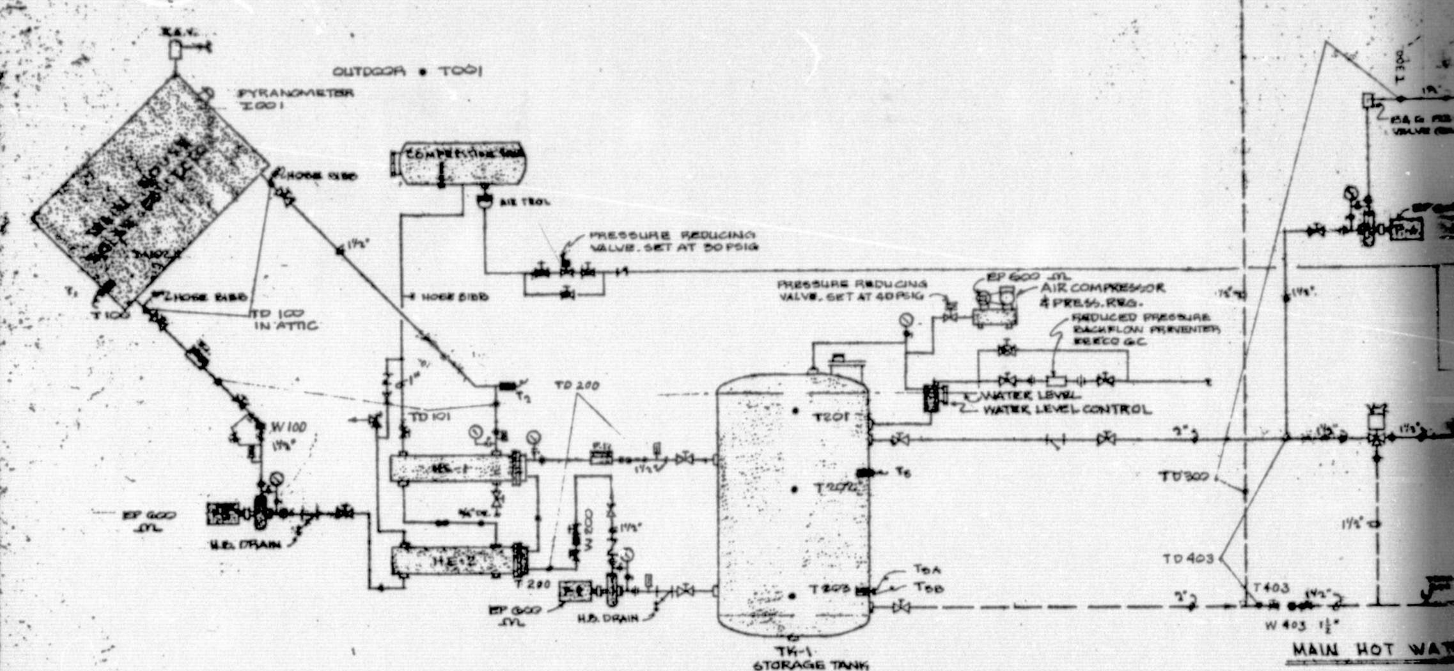
REVISED 6/6/74

COPPER DEV.

SHEET NO.
M-3

B-1

APPENDIX C



SYSTEM CONTROLS
EP 600 SL

PUMP SCHEDULE								
No.	MFG.	SERIES	SIZE	GPM	HD.	H.P.	RPM	IMPELLER
P-1	B & G	1522	1½AAB	25	26'	½	1750	8 1/4
P-2	B & G	1522	1¼AAB	25	8'	¼	1750	4 1/4
P-3	B & G	1522	1¼AAB	22	47'	1	3500	3 5/8
P-4	B & G	1522	1¼AAB	25	12'	¼	1750	
P-5	B & G	1522	1¼AAB	12	28'	¼	1750	
P-6	B & G	1522	1¼AAB	26	47'	1	3500	4 3/4
P-7	POOL FILTER					1		
P-8	DECK DRAIN					¾		
P-9	GRUNDFOS	UP25-42SF				1/20		
P-10	B & G	BOOSTER	PD-1"AA	22	15'	¼	1750	

HEAT EXCHANGER SCHEDULE										
No.	MFG.	CAT. NO.	SHELL SIDE				TUBE SIDE			
			GPM	ΔP	EWT	LWT	GPM	ΔP	EWT	LWT
HE-1	B & G	WU 67-42	25	5.5'	140°		25	4.7'	189°	
HE-2	B & G	WU 67-42	25	5.5			25	4.7'		
HE-3	B & G	WU 67-42	25	5.0'	190°	140°	12	4.1'	110°	130°

PROPYLENE GLYCOL SHELL SIDE
PROPYLENE GLYCOL SHELL SIDE

WATER HEATER SCHEDULE								
No.	MFG.	CAT. NO.	GPM	ΔP	EWT	LWT	KW	REMARKS
WH-1	LAARS		22	4	127/190	177/210		NATURAL GAS FIRED RATED AT 250 MBH INPUT
WH-2	RHEEM				60	140	4.5	

VALVE SCHEDULE							
No.	MFG.	SIZE	ΔP	VALVE CAT. NO.	MOTOR CAT. NO.	C_v	GPM
V-2	HONEYWELL	1½	1.6'	V5013	M934/Q618	30	25
V-3	GENERAL	1	2'	V731 FDB 5ST2	H10A321B3E1	13	12
V-4	GENERAL	1	2'	V731 FDB 5ST2	H10A321B3E1	13	12
V-5	GENERAL	1	2'	"	"	13	12
V-6	GENERAL	1	2'	"	"	13	12
V-7	GENERAL	1	2'	"	"	13	12
V-8	GENERAL	1	2'	"	"	13	12
V-9	GENERAL	1	2'	"	"	13	12
V-10	GENERAL	1	2'	"	"	13	12
V-11	HONEYWELL	1½	1.6'	V5013	M944/Q618	30	25
V-12	GENERAL	1½	1.6'	V731 HDB 5ST2	H10A321B3E1	30	25
V-13	GENERAL	1½	1.6	"	"	30	25
V-15	HONEYWELL	1¼	5.6'	V5016	M944/Q618	16	20

LEGEND

- GATE VALVE
- GLOBE VALVE
- BALANCING COCK
- CHECK VALVE
- STRAINER
- ELEC. MOT. VALVE (V)
- FLOW INDICATOR (F.I.)
- RELIEF VALVE
- UNION
- TEMP. SENSOR (T)
- GAUGE COCK
- THERM. & WELL
- FLOW METER TAPS

F.S. WATER FLOW SWITCH
AFS AIR FLOW SWITCH
(T) TEMPERATURE SENSOR
PRV PRESS. REDUCING VALVE

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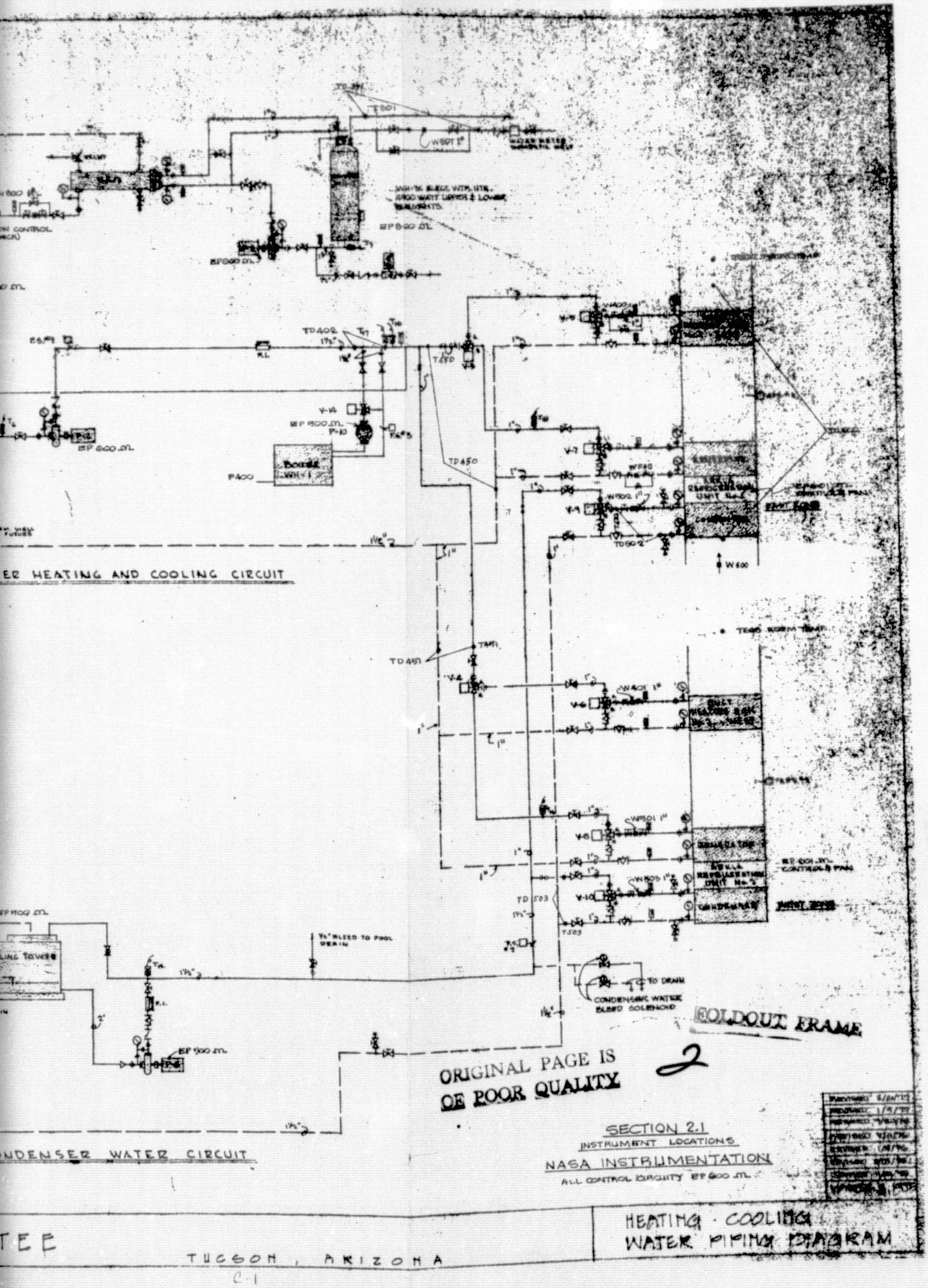
A RESIDENCE FOR: GEORGE M. HARTLEY, TRUS...



ER HEATING AND COOLING CIRCUIT
ONDENSER WATER CIRCUIT
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SECTION 2.1
INSTRUMENT LOCATIONS
NASA INSTRUMENTATION
HEATING · COOLING
WATER PIPING DIAGRAM
TEE
TUCSON, ARIZONA
C-1

APPENDIX D

1

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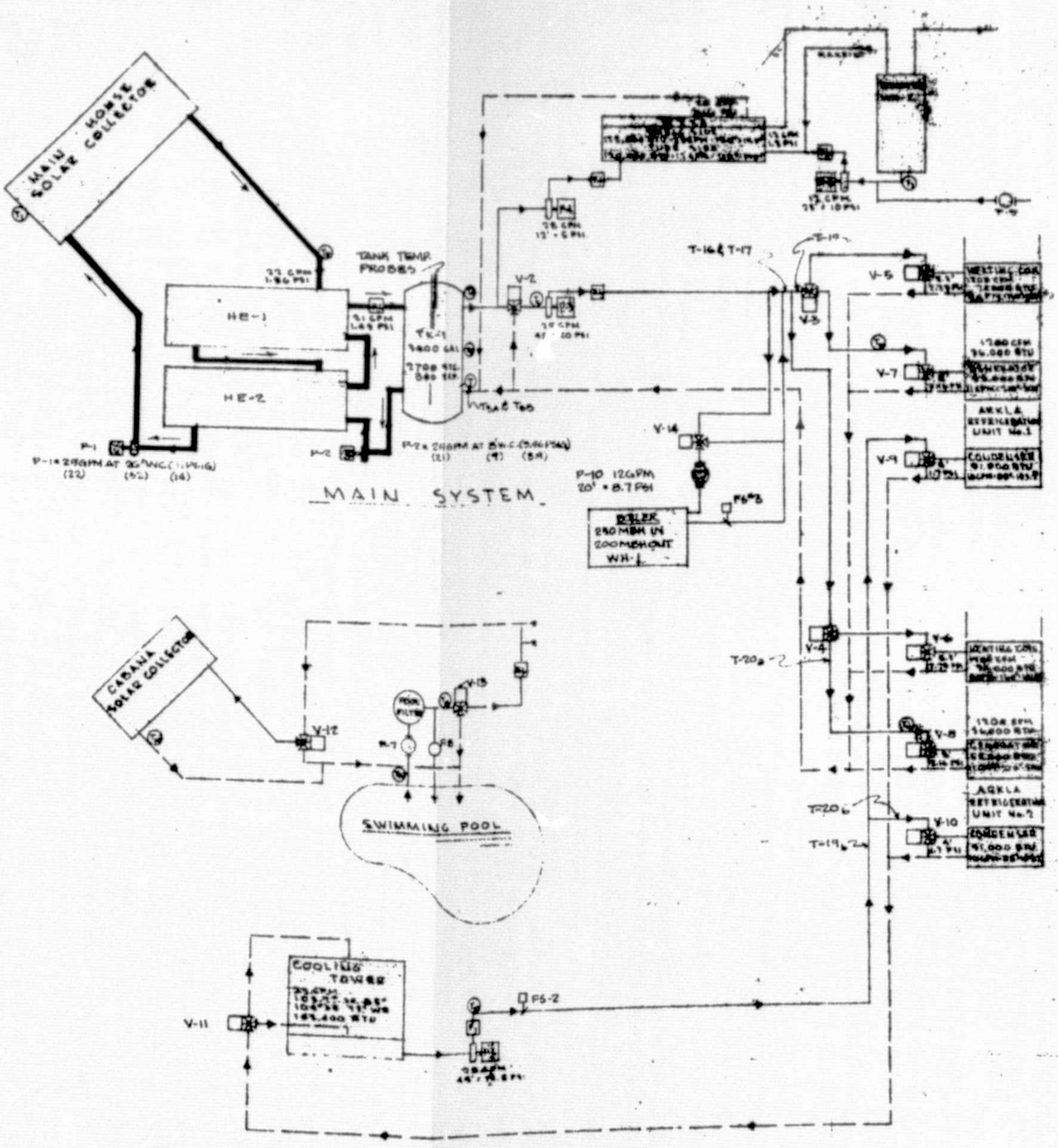

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HEAT TRANSFER FLUID FLOW
ENERGY COLLECTION

TUCSON ARIZONA

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1

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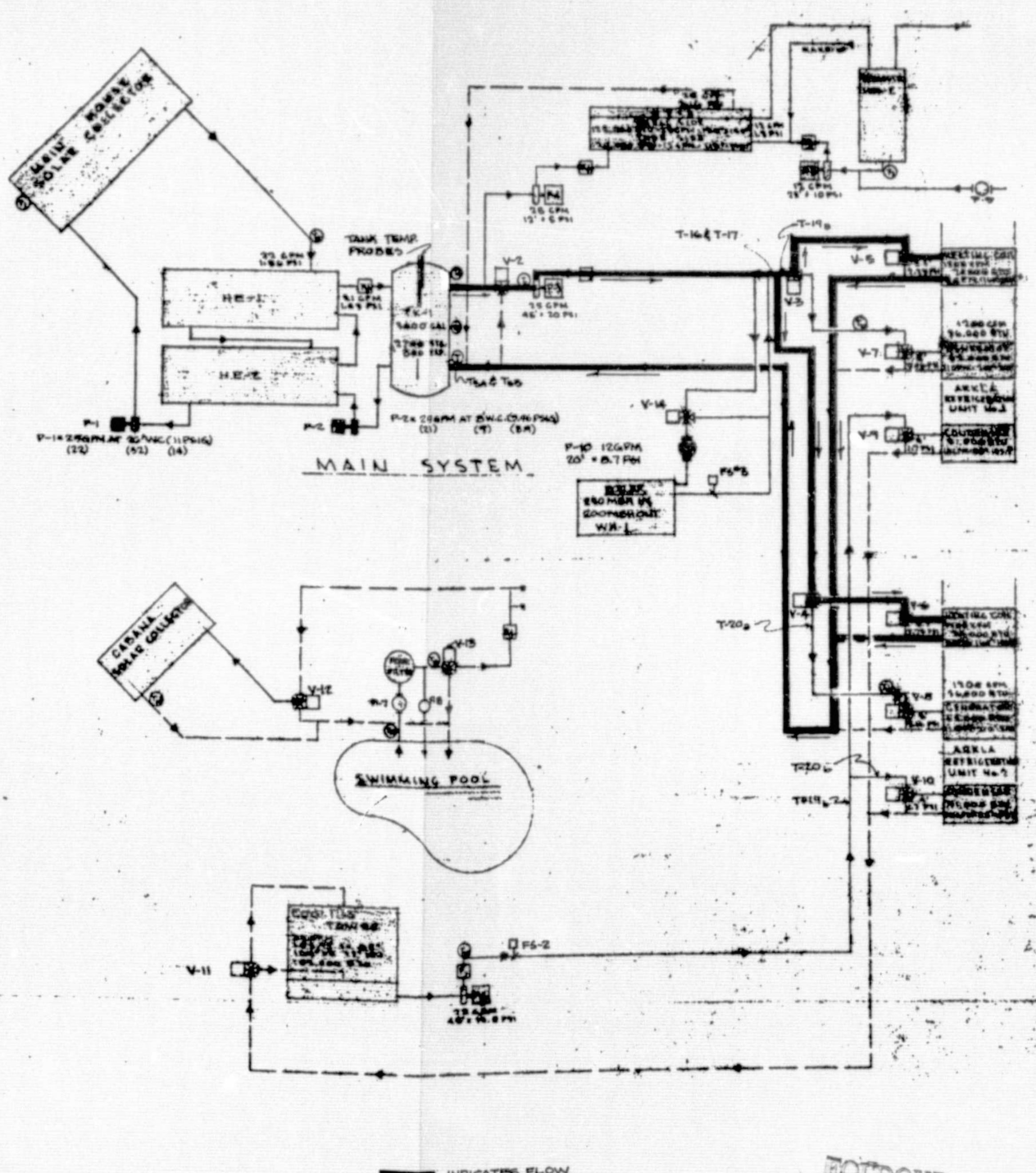

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HEAT TRANSFER FLUID FLOW
SPACE HEATING FROM STORAGE

TUCSON, ARIZONA

D-2

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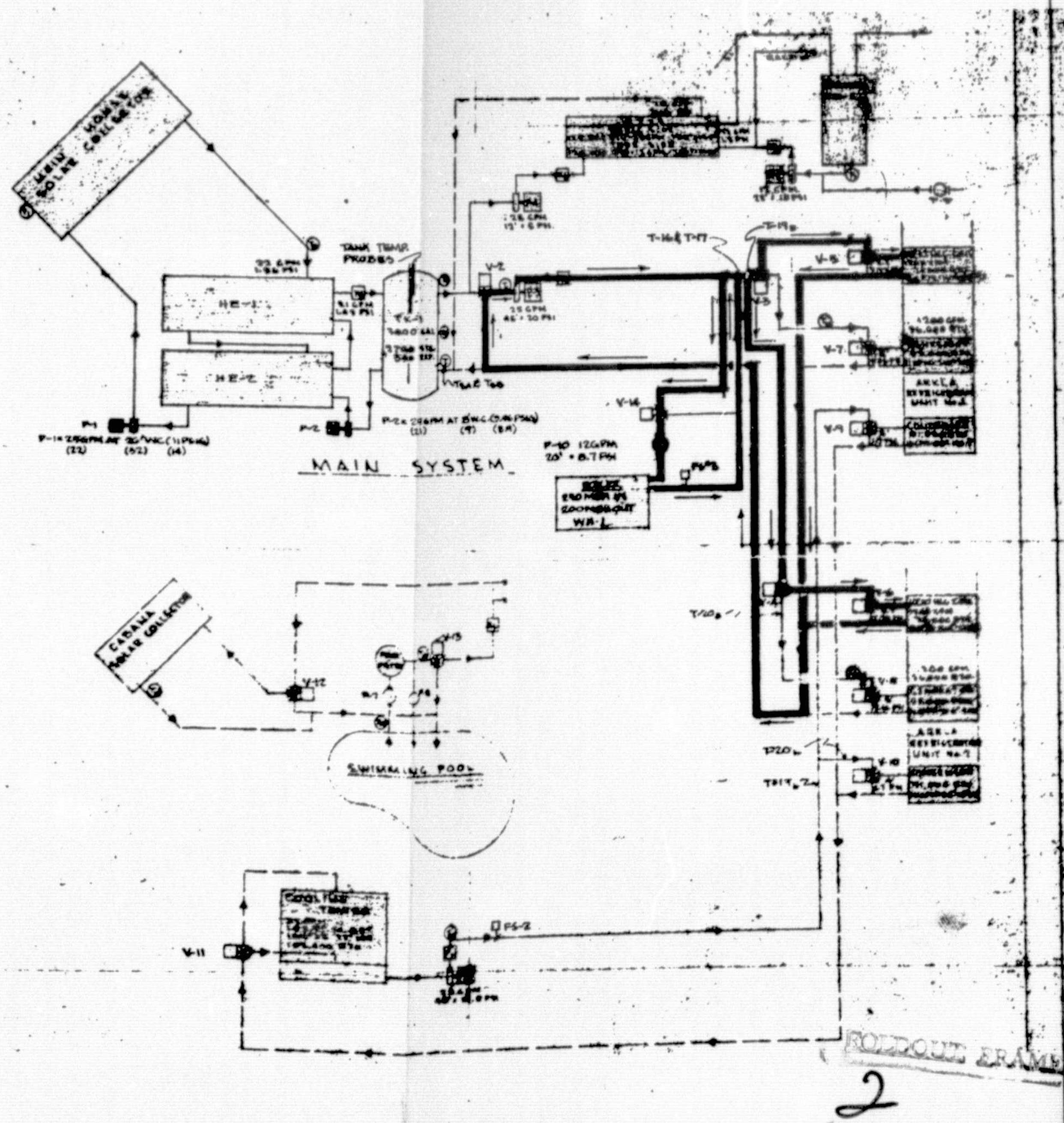

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LAR HOUSE

HEAT TRANSFER FLUID FLOW
SPACE HEATING FROM AUXILIARY

TUCSON, ARIZONA

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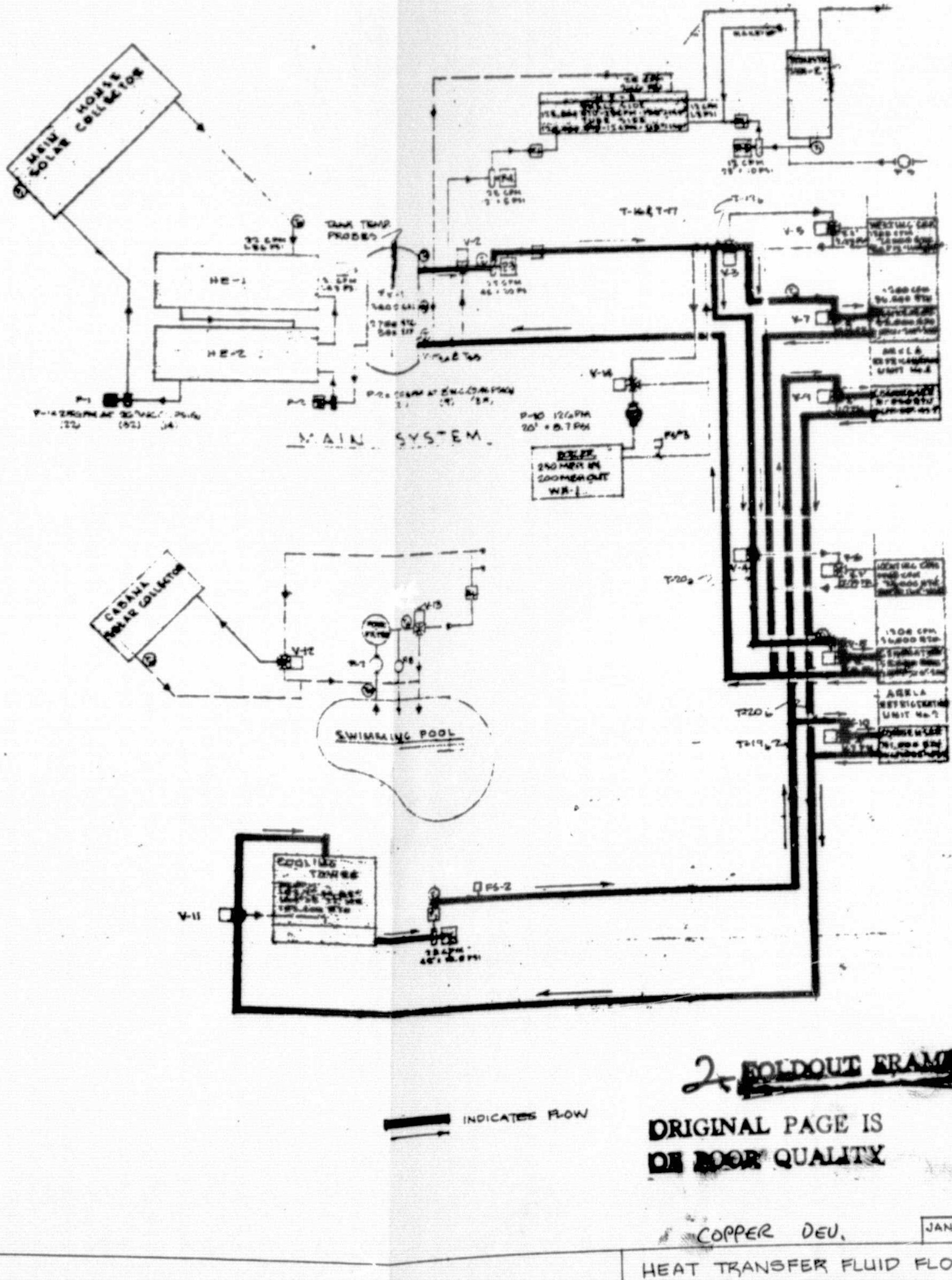
DECADE 80 SOLAR HOUSE



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OLAR HOUSE

HEAT TRANSFER FLUID FLOW
COOLING FROM STORAGE

TUCSON, ARIZONA

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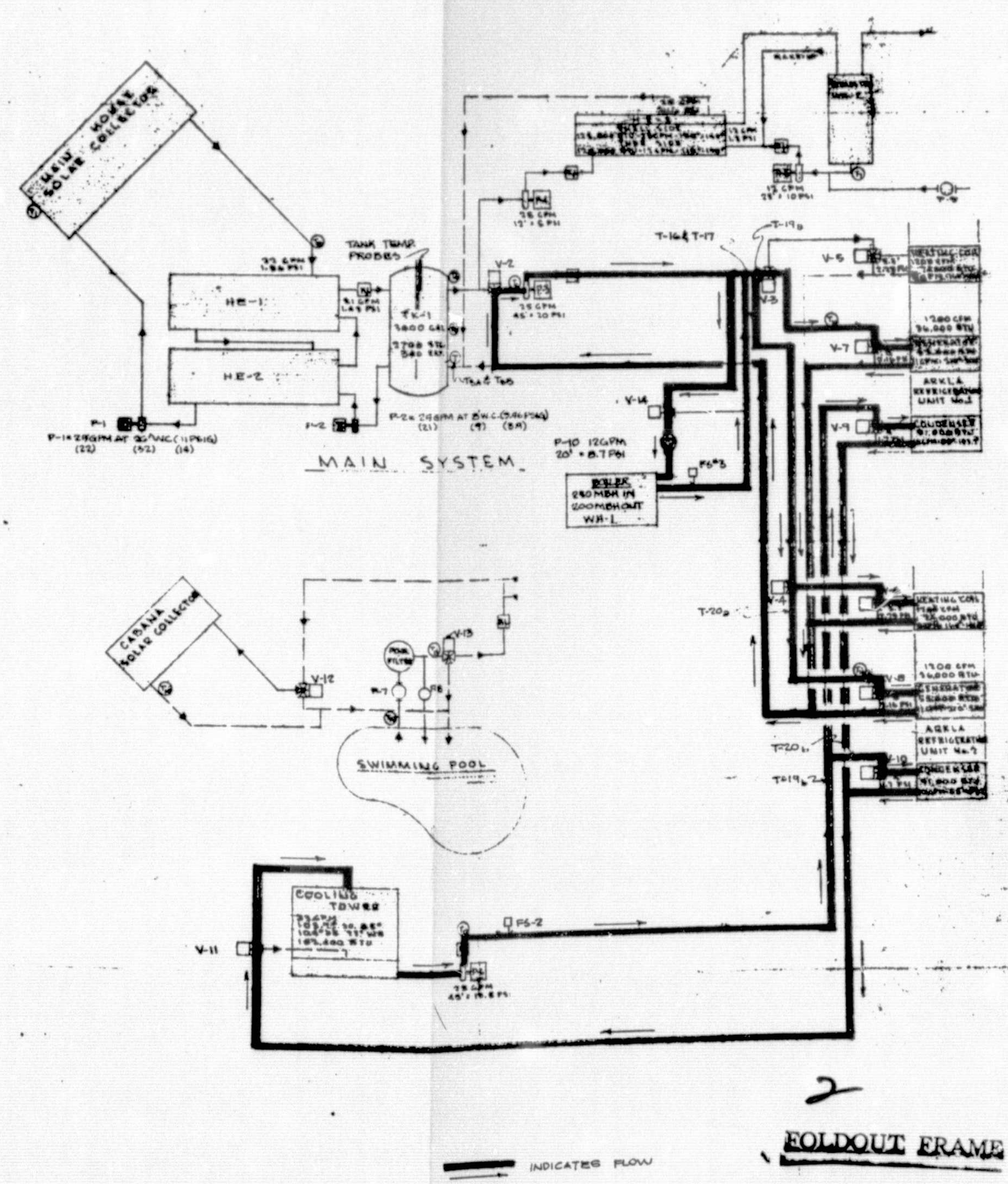
DECADE 80 SOLAR HOUSE



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OLAR HOUSE

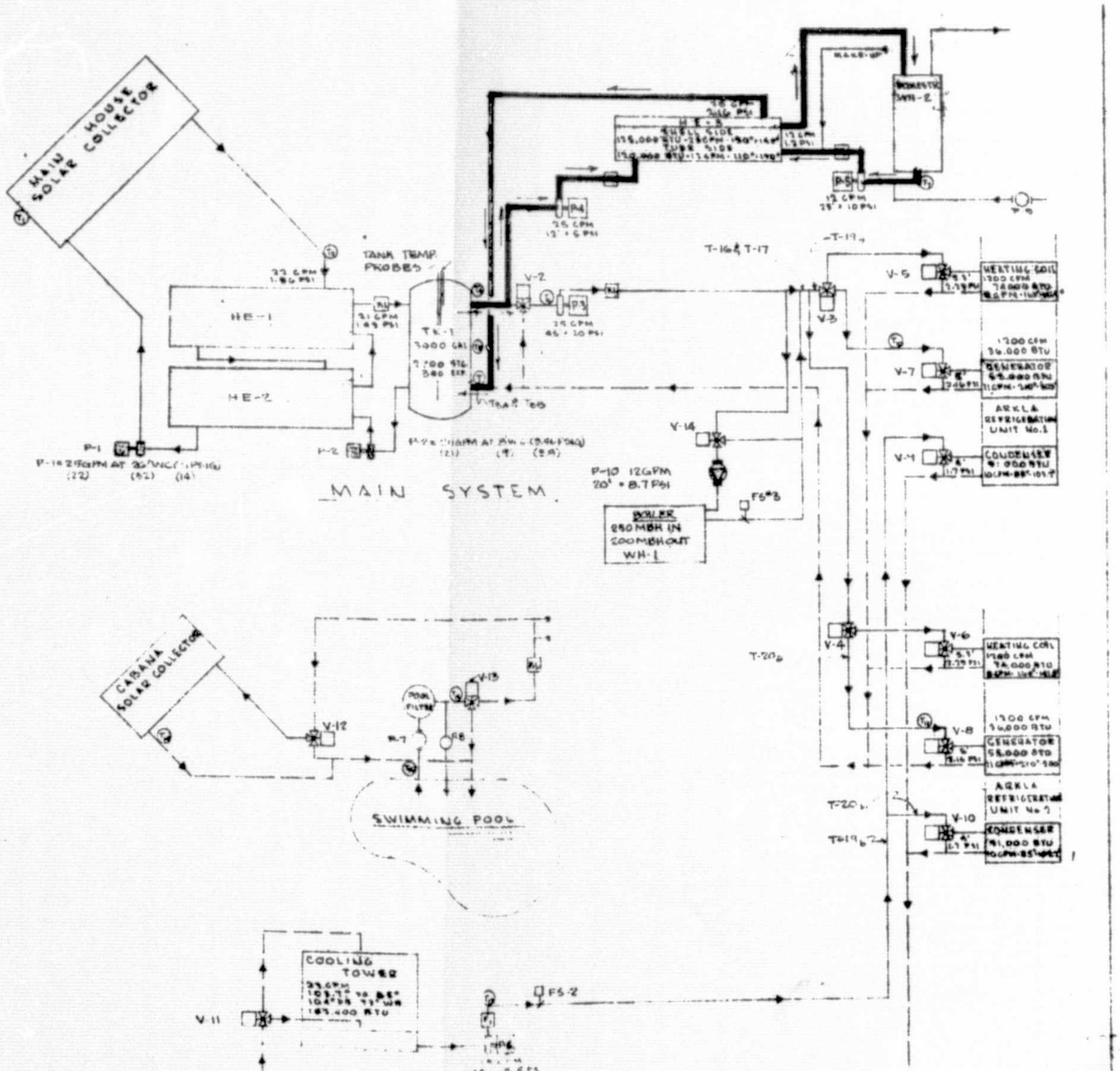
TUCSON, ARIZONA

D.5

HEAT TRANSFER FLUID FLOW
COOLING FROM AUXILIARY

BOUQUET FRAME

DECADE '80 SOLAR HOUSE



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INDICATES

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SOLAR HOUSE

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