

most temperature level of the gas turbine's heat re-
 tect. It can be much more readily adapted to the
 needs of dry cooling. In fact, about ten times less
 air (correspondingly heated to ten times the temper-
 ature) is permissible with a steam plant) suffice to
 dispose of the gas turbine's heat. Thus, the advent
 of the closed-cycle gas turbine, practically adaptable
 only to the HTGR's high gas temperature, is of par-
 ticular importance to the solution of heat-rejection
 problems and thereby provides a much wider free-
 dom of site choice.

Even in the absence of a dry cooling requirement,
 the attractions of the direct-cycle nuclear gas turbine
 in terms of plant simplification and capital cost sav-
 ings are impressive and add greatly to the prospect
 of the capital cost reduction so essential to achieve-
 ment of really economic nuclear power.

A second, perhaps less dramatic, but certainly
 more significant, distinction of the compactness
 typical of closed-cycle machinery is provided by Fig.
 2, which compares the size of such a system with
 that of a representative open-cycle system as pre-
 sently used for power peaking duty. In this case, the
 striking point is the enormous increase in power for
 roughly similar size brought about mainly by the
 elimination of the closed-cycle's exhaust.

Fig. 3 conveys something of this potential by il-
 lustrating graphically the extreme compactness of the
 closed-cycle gas turbine, which allows its complete
 incorporation into space in the reactor vessel that
 were needed to house solely the boiler of a steam
 nuclear power system. The degree of the reduction
 in machinery size achievable is further emphasized
 by Fig. 3, which depicts the rotor of the 425,000-hp
 turbo-compressor component embodied in Fig. 3 and
 an automobile engine drawn to the same scale.

When it is realized that, additionally, the whole
 primary circuit circulation system, the water treat-
 ment plant, the feed pumps, the feed heaters, and
 the entire turbine hall are all eliminated, it becomes
 apparent that we are not talking about minor partic-
 ulars in cost, but rather about the prospect of a
 real revolution in the power industry.

Conclusions

In essence, the intent of the foregoing discussion is
 to suggest that the optimal performance attraction
 of the HTGR type of reactor power plant are sub-
 stantially realized by the many practical open-
 cycle and maintenance advantages that just gas
 turbine provides. Consideration of the future poten-
 tial of the gas turbine additionally affords perhaps
 the greatest promise of really substantial plant cost
 reduction thus far observed. The combination of an
 HTGR and the fuel resource concentration in this
 project and the fuel resource concentration in this
 project are associated with the introduction
 of the peaking alone can be fully realized only by ap-
 propriate deployment of both types of systems,
 which are indeed complementary to a total power
 program and not virtually exclusive rivals.

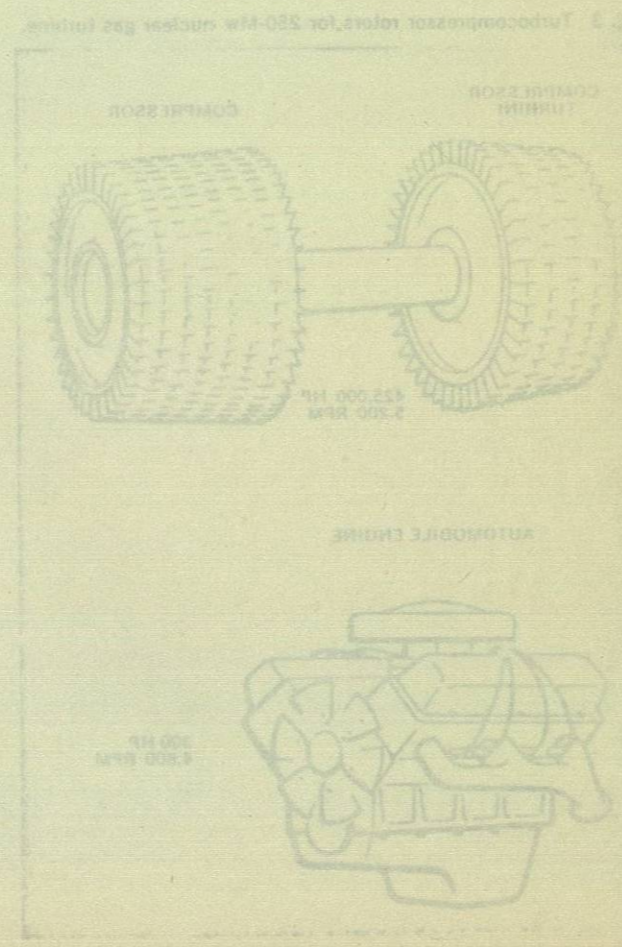
The joint role of FTR's and HTGR's may thus
 offer the most promising way of meeting the impen-
 ding energy crisis.

For example, would amount to less than 12
 percent of the generating costs associated with a
 modest capital cost of \$400/kw. A modest
 fuel cost increase can thus easily wipe out a large
 cost advantage. Furthermore, even a small out-
 come has the same effect, for by far the greater
 part of operating cost is independent of whether or
 not a plant is working.

Such a plant is working.
 It not really sells a nuclear power plant, then (par-
 ticularly one of the new generation), is the cost of
 building it and the likelihood that it can be kept
 running as indicated by demonstrably simple mainte-
 nance, as well as confidence in reliability. These
 factors, together with factors affecting freedom of siting
 and what really count. It is in these areas
 that the prospects of the fast breeder are less clear.
 Detailed reports exist for further study.

The reactor itself are largely matters of practical
 engineering rather than physics, and are concerned
 only with the capital cost and other characteris-
 tics of presently constructed types of plant, but
 importantly, with the impact of future techno-
 logical and technical developments. Prominent
 among the latter are the increasing pressure of envi-
 ronmental factors and the possibilities offered by
 eventual adoption of the closed-cycle gas turbine to
 needs of nuclear power.

The connection between these two factors is
 clearly that, because of the inherently much higher



energy, technology and solar architecture

Solar architecture can ease the energy
 shortage over the next two decades. It
 can reduce by 70 per cent the residential
 power needs in most of the Southwest
 through buildings whose materials, struc-
 tural elements, landscaping, and opera-
 tion are designed to take maximum ad-
 vantage of night-sky cooling and direct
 use of solar energy for space and water
 heating. Such a structure, "Sky Therm,"
 is now being evaluated by the govern-
 ment.

H. R. HAY

Sky Therm Processes and Engineering, Los Angeles, Calif.

The first commercial impact for solar energy will
 be for space heating in the Southwest, where most of
 the heavily populated areas have abundant sunshine
 and mild climate. In Southern California, perhaps
 90 percent of residential use of power for thermal
 comfort can be eliminated; the other 10 percent is
 needed during protracted rainy or overcast days. In
 1968, winter heating consumed 63 percent of domes-
 tic power demand and water heating required 15
 percent—another area for solar energy direct use.
 About 62 percent of summer household electricity
 use was for air conditioning and again about 15 per-
 cent was for water heating. Thus natural energy
 forces have the potential for reducing home power
 use by 70 percent.

The air-conditioning load coincides hourly and
 seasonally with the peak power demand on the dis-
 tribution system. Thus, there is strong justification

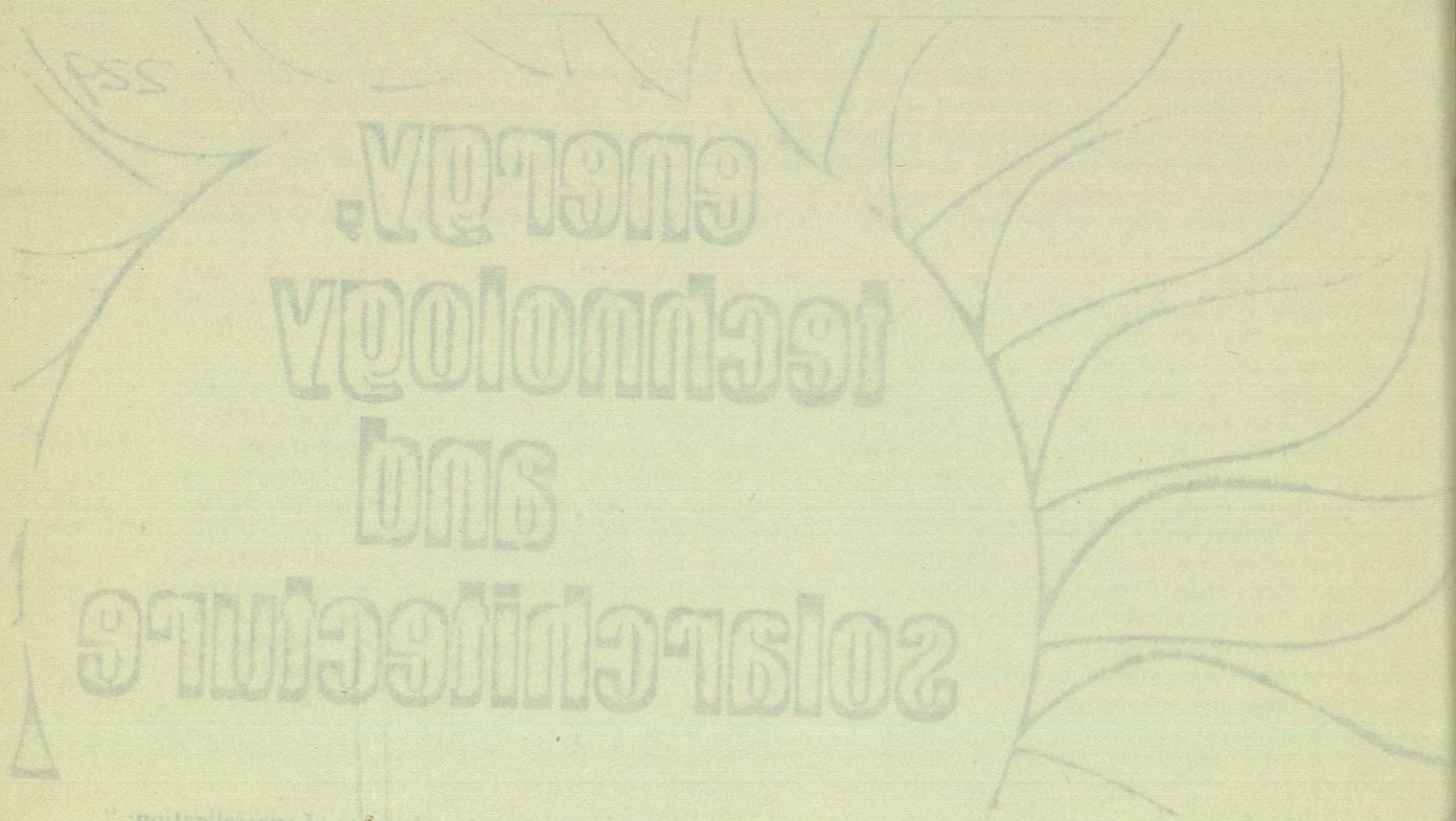
for going to the trite ultimate of specialization: "...
 to know all there is to know about nothing." This
 particular nothing is outer space. Man made better
 use of it thousands of years ago than we do after
 physically penetrating it. To save power, we must
 return to the direct use of the night sky as a heat
 sink. There are advantages in coordinating this ef-
 fort with the direct use of solar energy.

Mutually Advantageous

Facing a power shortage and brownouts, the Los
 Angeles Water and Power Department has stopped
 promotion of "Gold Medallion" all-electric homes.
 To prevent the crippling of industry and conse-
 quent unemployment, end use priorities for power
 may soon deny occupants of "electric homes" the
 thermal comfort which produces about 15.5 percent
 of the system demand. Southern California may be
 forced to use high sulfur oil that will increase smog
 problems; the city is on record as regretting its part
 in the air pollution formed by thermal power plants
 hundreds of miles away in the deserts. It is, there-
 fore, advantageous for both utilities and industry to
 promote diurnal energy heating and cooling.

In addition to assuring comfort in periods of power
 brownout, natural air conditioning may also relieve
 the new house owner of unnecessary expenses. In
 Los Angeles, heating and cooling a 2000- to 2400-
 sq-ft house, plus water heating, costs \$18.50 in a
 \$24.00 monthly electric bill. Disregarding any rate
 change, 70 percent reduction by use of diurnal ener-
 gy flux would result in a \$17-saving. Applied to re-
 duce a \$25,000, 30-year mortgage on a house, this
 saving would permit paying off the mortgage seven
 years earlier with over \$10,000 less interest cal-
 culated at only 7.0 percent, (a \$12,700 saving at 8.5
 percent interest rate).

Wherever heating and cooling are used in the
 Southwest, natural energy flux utilization can reduce



for going to the limit of specialization. To know all there is to know about nothing. This particular nothing is outer space. Man made better use of it thousands of years ago than we do after physically penetrating it. To save power, we must return to the direct use of the night sky as a heat sink. There are advantages in coordinating this effort with the direct use of solar energy.

Mutually Advantageous

Facing a power shortage and breakdown, the Los Angeles Water and Power Department has stopped promotion of "Gold Medal" all-electric homes. To prevent the crowding of industry and consumer manufacturing, and use priorities for power may soon deny occupants of "electric homes" the thermal comfort which produces about 15.5 percent of the system demand. Southern California may be forced to use high sulfur oil that will increase smog problems; the city is on record as rejecting its part in the air pollution caused by thermal power plants hundreds of miles away in the desert. Here, there are alternatives for both utilities and industries to provide diurnal energy for heating and cooling.

In addition to securing comfort in periods of power blackout, natural air conditioning may also reduce the new home owner's energy expenses. In Los Angeles heating and cooling a 2000 sq ft house plus water heating costs \$18.50 to \$24.00 monthly electric bill. Decreasing any rate change, 70 percent reduction by use of diurnal energy flow would result in a \$17 saving. Applied to a \$25,000, 30-year mortgage on a house, this saving would permit payment of the mortgage seven years earlier with over \$10,000 less interest calculated at only 7.0 percent. (\$12,700 saving at 8.5 percent interest rate).

Whenever heating and cooling are used in the Southwest, natural energy utilization can reduce the air-conditioning load countless hours and use by 70 percent.

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The first commercial impact for solar energy will be for space heating in the Southwest, where most of the heavily populated areas have abundant sunshine and mild climate. In southern California perhaps 90 percent of residential use of power for thermal comfort can be eliminated, the other 10 percent is needed during protected rainy or overcast days. In 1968, winter heating consumed 83 percent of domestic power demand and water heating required 10 percent—another area for solar energy direct use. About 65 percent of summer household electricity use was for air conditioning and again about 15 percent was for water heating. Thus natural energy sources have the potential for reducing home power use by 70 percent.

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Solar architecture can ease the energy shortage over the next two decades. It can reduce by 70 percent the residential power needs in most of the Southwest through buildings whose materials, structural elements, landscaping, and operation are designed to take maximum advantage of night-sky cooling and direct use of solar energy for space and water heating. Such a structure, "Sky Therm," is now being evaluated by the government.

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tained in the mildest climate merely by building more heat capacity into the house; full use of diurnal forces would not be required except in the severe climates. For most residential purposes, horizontal, low efficiency, low-cost rooftop thermal collectors and dissipators are adequate. The sloped collectors developed in northern states with lower radiation intensity could be smaller and less prohibitive in cost if used in southern areas, but their circulation of air or water as a heat-transfer medium would require more power and their cooling efficiency would be lower than horizontal rooftop devices.

The solar interest boom-and-bust cycle of the past 20 years need not repeat itself if research becomes freed from wrong locales, emphasizes economy, minimizes dependency upon supplementary power, and integrates apparatus with building design. This will require interdisciplinary efforts and broader understanding of solarchitecture. Initial concentration of solar energy development in the Southwest, where commercial success is more likely, would cause privately financed research to extend the markets into other areas as rapidly as technology and economics coincide. The first evaluation of a diurnal energy air conditioning system funded by the U. S. Department of Housing and Urban Development will pertain to a "sky therm" house to be built in California.

Principles of Solarchitecture

Within local limitation, solarchitecture is better practiced as an art in developing countries than it is in the advanced regions of the world. By reviewing the basic principles, modernizing the technology, and analyzing the impact which solarchitecture can make on the power and pollution crises, we may recognize not only great potentials but we may also find reasons for reconsidering substantial portions of our way of life.

Solarchitecture, in the recent past, has not been so closely related to space heating with solar energy as it has to reduction of heat load through site selection, orientation, overhangs and brise soleils, fenestration treatments, and landscaping. This emphasis was directed toward lowering the operating cost of powered air conditioning. With seasonal peak demand for power now resulting from air conditioners, a national effort is being made to increase the amount of insulation in the walls and attics of new houses. Since this is intended to reduce solar radiation effects, solarchitecture is as directly involved as if the insulation were used to retain heat derived from solar collectors.

The future use of photovoltaic cells (mounted on the walls and roofs of buildings) to supply the electricity for those purposes for which the more efficient direct-use solar energy appliances are not adaptable will become an important aspect of solarchitecture. It is a very broad, interdisciplinary subject and it is fundamental to the development of economic use of natural energy forces.

Geographic Climatology

Geographic climatology is a developing science basic to the use of diurnal energy flux. Climate data provided by weather stations do not approach the

qualitative or quantitative needs of solarchitecture. Climates vary recognizably within a few miles; shade patterns of hills and buildings create large differences in micro-climate within hundreds of feet. Detailed data on temperature, dew point, precipitation and cloud cover, and solar radiation are prerequisites for selection of house design and materials and for consideration of heating and cooling. We can no longer afford the convenience of ignoring the climate and installing overpowering thermal rectifying appliances where these are not essential. In terms not requiring technical acuity, plot maps of zoned property should reveal climate-related energy requirements for obtaining thermal comfort.

In practical terms, solarchitecture is entirely compatible with the objectives of conservation groups both in energy and in land usage. Neither solar heating nor night-sky cooling is enhanced by recessing a house under large old trees on a hillside. Collection of solar energy is not so feasible on north hill slopes where the vegetation grows more slowly. Direct night-sky cooling is independent of solar exposure, but efforts toward conversion of solar energy to produce cooling have the same orientation limitations as those of solar heaters. It would be well for solar advocates to fully respect the environmental concerns of our time; direct use of solar energy does; indirect use for the production of transmissible power does not. Abandoned fields without trees become choice sites for new construction in accordance with solarchitectural principles. Such fields allow freedom of orientation and for tree planting which avoids undesirable shading effects.

Structural Features

The high heat capacity of earth, stone, and brick is now little used to modulate diurnal energy effects in industrial countries. Costs of manufacture, transport, and erection of these materials for walls having required thickness for adequate heat storage are excessive—as is also the cost for concrete. Earth materials acquire new status through solarchitecture. Sand-filled cavity walls can add heat capacity and obviate the need for hauling sand away from some construction sites. More significantly, the ground can be better used as a heat sink.

Plastic moisture barriers permit use of slab-on-ground construction and also of walls that are built partially below ground level—especially where the annual mean ground temperature is within the comfort zone. Use of perimeter insulation has demonstrated that a slab-on-ground floor may be the most thermally stable element of a room; wall-to-wall carpeting is then insulation wrongly placed.

Heat storage is being studied by other investigators not only to better utilize solar energy but also to shift a portion of peak power demand to hours of lower load. Conventional electric heating and cooling devices operated during off-peak hours have their excess thermal effects stored in high-heat-capacity materials which are a source of thermal comfort during peak hours when the devices are not expected to be operable. Chemical salts and rocks have been used as heat storage materials, but the high heat capacity of low-cost water is made increasingly appealing.