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The ASEAN Energy Study Mission

May 25-June 13, 1980

DEPARTMENT OF ENERGY Assistant Secretary for International Affairs Office of Energy Consuming Nations
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Introduction

This report to the Agency for International Development (AID) summarizes the May 25-June 13, 1980, study mission of U.S. energy facilities and institutions by a team of energy experts from the Association of Southeastern Asian Nations (ASEAN). Sponsored by AID in conjunction with the Departments of State and Energy, the ASEAN team consisted of two experts from each of the five member countries (Indonesia, Malaysia, Philippines, Singapore and Thailand) plus ASEAN's Director for Science and Technology. They were accompanied by Tom Cutler and Guntis Terauds of the Department of Energy (DOE), and Roger Yancey of Argonne National Laboratories. The purpose of the fact finding mission was to familiarize ASEAN officials with current U.S. programs in alternative energy and to begin a dialogue on possible areas for cooperative energy programs. It is the purpose of this report, therefore, to describe the facilities and technologies seen by the ASEAN team and identify areas of potential energy cooperation between the United States and ASEAN.

The joint communique of the August 1978 ASEAN-U.S. Economic Consultations in Washington, D.C., first identified energy as a major area for U.S.-ASEAN cooperation. This agreement followed Vice President Mondale's pledge of U.S. support for ASEAN's efforts to develop alternative energy sources during his May 1978 trip to Asia. This position was reiterated by the Secretary of Energy at the ASEAN-U.S. Economic Consultations and later by the Secretary of State during his meeting with ASEAN Foreign Ministers in mid-1979. Shortly thereafter, the United States formally proposed to initiate cooperation in the energy area with ASEAN by sponsoring a 3-week technical study visit in the United States.

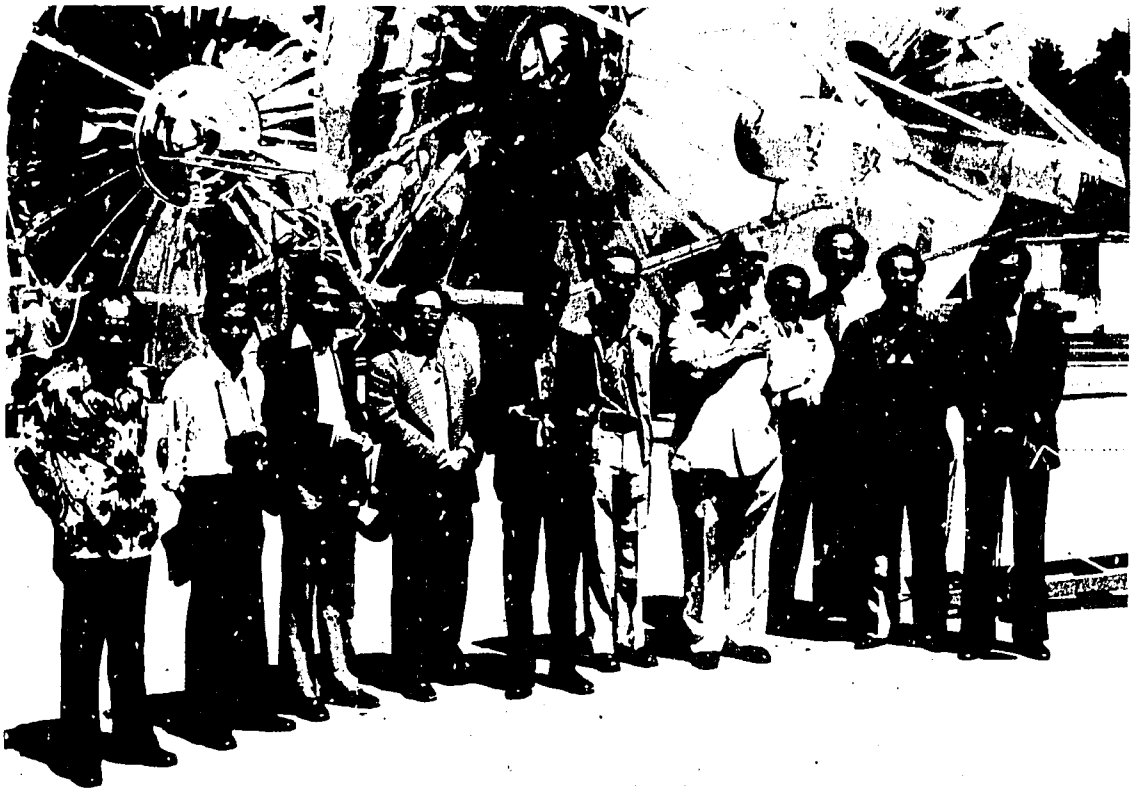
The ASEAN team visited a wide range of alternative energy facilities, including the world's largest facilities in the following areas:

— geothermal;
— solar/photovoltaic;
— solar thermal; and
— coal slurry.

Wind, coal combustion and conversion technologies were also highlighted, including a tour of coal liquefaction and gasification pilot plants. The trip did not concentrate on biomass technologies, since that had been the focus of a recent BioEnergy Tour sponsored by AID which included representatives from the ASEAN countries.

The study mission concluded with discussions at the Department of State on long-term energy cooperation between the United States and ASEAN. The primary objective of this cooperation is to reduce dependence on fossil fuels by promoting the use of alternative energy sources and improving the efficiency of energy use.

List of Participants



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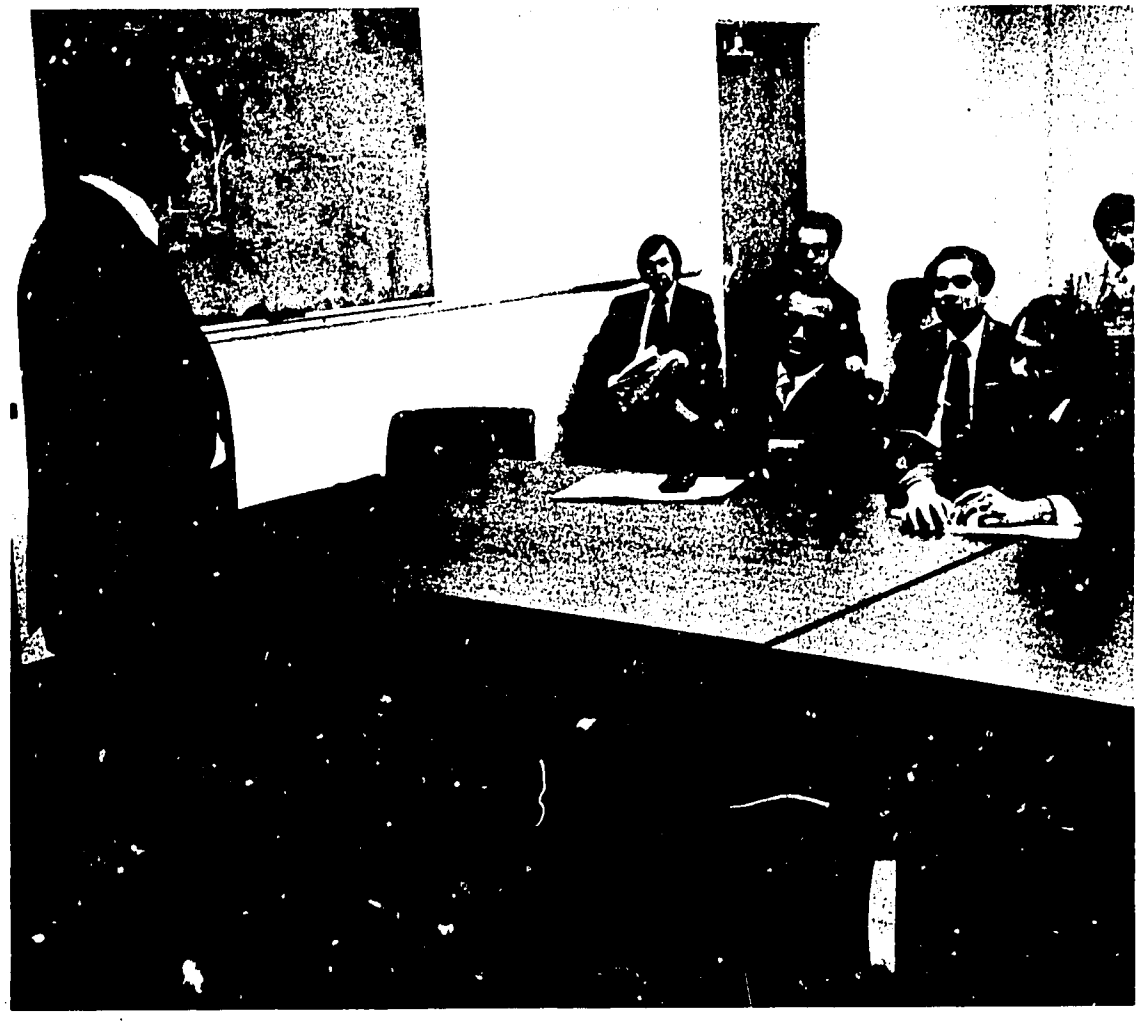
Lawrence Berkeley Laboratory

The ASEAN team's first stop was the Lawrence Berkeley Laboratory at the University of California, near San Francisco, where it received a series of energy briefings. The purpose of this session was to provide the ASEAN team with a broad view of renewable energy and demand management as an introduction to its tour of U.S. energy facilities. The program began with a short welcome and an explanation of the itinerary by Robert Ichord, Energy Specialist in the Asia Bureau of AID. Then Elton Cairns, Director of Berkeley's Energy and Environment Division, introduced members of the Berkeley staff and outlined the morning's agenda, which included presentations on energy assessments, the growth in urban energy demand, commercial building energy conservation, energy demand management, and renewable energy.

Energy conservation was seen by all participants to be an increasingly important component of national energy policies. Potentially uncontrollable growth in energy demand was of greater concern to a large portion of the group than potential energy supply limitations. One presentation pointed out that most projections of energy demand are literally extrapolations of historical data and certain allegedly "fixed" relationships, e.g. the ratio of GNP to energy use. However, these rela-



Dr. Robert Ichord of AID welcoming the ASEAN team at Lawrence Berkeley Laboratories.

tionships can change over time as economies develop and mature. The linkage between population growth, specifically urban population growth, and energy demand was also described as having major relevance to projections of future energy requirements. Analyses were presented forecasting that per capita energy consumption in the urban areas of industrial societies will level off while LDC urban energy consumption per capita will increase tremendously. Combined with expected large increases in Asia's urban population through the year 2000, increasingly high energy growth rates are almost inevitable. The speaker on demand management warned that although some developing countries have already adopted energy conservation policies, there is a risk that the rush to modernize may result in some unnecessary energy demand. Therefore, nations should take steps now to insure increased efficiencies of energy use.

On the supply side, other Berkeley speakers addressed the question of how much government emphasis should be placed upon the promotion of alternative energy sources such as solar, wind, geothermal, and biomass. Time constraints prevented lengthy discussion on this important topic since the ASEAN team had to depart for their next stop, a firsthand look at an operating geothermal facility. During the next three weeks the ASEAN team visited 17 alternative energy and coal conversion facilities so there were many opportunities later on to discuss prospects for alternative energy within their region amongst themselves as well as with American experts.

Geysers Geothermal Field

The ASEAN team arrived at Union Oil's Geothermal Headquarters in Santa Rosa that afternoon where they were met by Harry Bain and driven out to the Geysers, about 90 miles north of San Francisco. It is the world's largest geothermal facility with a gross generating capacity of 932 MW, saving the equivalent of 12.2 million barrels of oil a year. When current expansion plans are completed in the 1990's, the Geysers may produce enough natural steam to generate 2000 MW.

Since the 1840's the Geysers area has been known for its surface geothermal activity. The name "Geysers" is misleading, however, since the area contains fumaroles which are small vents in the earth's surface which emit natural steam and are not true geysers. The first attempt to harness this steam was made in 1922 but it was not until 1955 that steam was discovered in commercial quantities, for the purposes of electricity generation. Initially developed by the Magma Power Company, no generating plants were connected to the steam until 1960 when Pacific Gas and Electric (PG&E) built a 12,000 KW unit. Despite initial technical problems and high costs, the project continued and Union Oil Company became operator of the site in 1967. By 1973 the Geysers was the world's largest geothermal facility and selling base load electricity to PG&E.

Geothermal-generated electricity has proven to be very competitive with other sources for PG&E. The steam is delivered to PG&E at a cost of 1.87 cents per KWH and the final bus bar cost of the electricity is only 3.7 cents per KWH. This compares with other average electricity supply costs incurred by PG&E on the rough order of magnitude of 2.5 cents per KWH from nuclear, 4.4 cents per KWH from coal, and 9.1 cents per KWH from oil.

One of the factors contributing to the Geysers' economic competitiveness with other sources of electricity is that the

Harry Bain of Union Oil leads the ASEAN team through the Geysers geothermal field. Natural steam in background rises through wells over a mile deep to the earth's surface at an average temperature of 355°F and at an average pressure of 100 pounds per square inch.

Geysers is a dry steam field with low levels of dissolved gases and trace elements present. After these impurities are spun off in a centrifugal separator the steam can be sent directly to the turbines via insulated pipes without any further processing. By comparison, steam or hot water fields such as those found in the Philippines are more costly to operate. Union Oil, for example, is managing this type of geothermal project on the Philippine island of Luzon where it has drilled more than 60 wells. It is expected that 440,000 KW will be generated by the end of 1980 making it the second largest geothermal energy producing country in the world.

The ASEAN team expressed interest in the fact that the Geysers has 175 producing wells which took an average of 61 days to drill at a cost of $1.2 million each (1979$). The average well depth is 7800 feet through which, on an average, 355°F steam rises at a pressure of 100 pounds per square inch (psi). Problems of corrosion were discussed as were environmental controls and steam turbine performance.

Details regarding equipment suppliers and subcontractors were provided at the group's request.

Although the Philippines' geothermal program is the most advanced of the ASEAN countries, Indonesia has large geothermal resources and Thailand is currently investigating its geothermal potential. At one point during the tour it was suggested that the inclusion of geothermal energy in U.S.-ASEAN energy projects would be most appropriate under a "lead country" format for cooperative programs.

Mt. Laguna Air Force Station

Located 60 miles east of San Diego, the Mt. Laguna Air Force Station's photovoltaic facility is a classic example of how, at isolated locations, solar energy can be cost-competitive with other energy sources. The 60 KW solar cell power system generates up to 11 percent of the station's average load requirement. By augmenting the diesel system used to generate electricity for the base, the solar facility saves 13 barrels per day of diesel fuel plus the cost of transporting it to the top of the 7,000 foot high Mt. Laguna.

The Mt. Laguna facility was the world's largest photovoltaic installation when it was completed in June 1979 but shortly after the ASEAN mission, in late July 1980, a larger 100 KW facility at Natural Bridges National Monument in Utah began operation. Because it is located at a remote radar base, the Mt. Laguna facility is managed by the U.S. Army's Defense Photovoltaic Program Office and by the USAF Aerospace Defense Command, under a cooperative program between the Department of Defense and the Department of Energy known as Military Application of Photovoltaic Systems. The principal objective of this program is to stimulate latent markets for solar systems thereby accelerating industry growth and supporting reduced unit costs.

Following a welcome and briefing from USAF Lt. Col. Richard Claytor, the base commander, and his staff, the ASEAN group toured the solar facility. Most of their time was spent inspecting its 2/3-acre collector field consisting of 2,366 solar cell modules. The modules contain 40 individual solar cells each, are grouped in panels and mounted on frames at an angle of 25° from the horizontal for maximum year-round collection. The team also toured the utility shed where computer printouts of the facility's operation sent to Sandia Lab for analysis were distributed to the members.

Operation of the 60 KW system is completely automatic, including its state-of-the-art power conditioner which converts direct current from the photovoltaic solar array to alternating current at the precise voltage, phase, and frequency to match the power from the diesel generator unit. After the sun rises in the morning and the solar power level increases to about 5 percent of capacity, the system automatically connects itself to the electrical grid. When power from the array decreases, either because of sustained heavy cloud cover or darkness, the system disconnects itself until power levels become sufficient to activate the start-up cycle. The system does not include a battery storage unit but several days later at the Schuchuli solar Indian village the ASEAN team inspected an operational battery storage system.

At Mt. Laguna's photovoltaic facility the ASEAN team walked through the collector field where it was described how the solar cells can continue producing electricity without their protective shields.

Although Mt. Laguna represents a large scale application of photovoltaic technology, the decentralized, modular nature of photovoltaics makes it well-suited for providing the small amounts of electric power required for

water pumping, grain grinding, and refrigeration in ASEAN's rural areas. Unfortunately photovoltaic-power can be expensive. Not counting the $300,000 expended on research and development, the construction and installation cost of this facility was $1.3 million, but recent cost decreases in the manufacture of silicon wafers have brought the cost of replacement under $1 million. When the facility was built the cost per peak watt of installed capacity was estimated to be $30 but this cost has now been reduced to less than $10. For example, the cost of building the recently completed Natural Bridges solar facility was only $6.40 per watt of installed capacity as compared to its original design cost of $22 per watt of installed capacity.

Still these costs were seen to be too high for immediate commercial application in the ASEAN region even though components such as metal and wood stands could be built in rural ASEAN areas, Continued advances in reducing costs, however, might permit their economical use in certain areas within a few years. The group asked many questions about the durability of the system—indeed, Mt. Laguna was selected as a test site because of its exposure to a wide range of natural elements—and noted that California's dry air precluded testing the system's ability to operate under humid conditions as exist in Asia. Nevertheless, the ASEAN team was very impressed with the system's easy operation and maintenance, low operating cost, durability, benign environmental impact, and performance.

Mohave Generating Station

The Mohave Generating Station, approximately 100 miles south of Las Vegas in southern Nevada, has a total capacity of 1,580 MW from two coal-fired steam turbine-generator units. Managed by the Southern California Edison Company, the plant's unique feature is the manner in which its coal slurry fuel is transported, stored for utilization, and dewatered for burning. The ASEAN team received a technical briefing from Don Alworth of California Edison before touring the facility.

A coal slurry pipeline, largest in the world, transports coal 275 miles at a rate of 660 tons per hour from Peabody Coal Company's Black Mesa Mine to the Mohave Generating Station in just three days. The coal is crushed at the mine to 2-inch particle sizes and delivered to the Black Mesa Pipeline Company which dry crushes the coal further to 1/4-inch particles. Water is introduced to create a 50 percent water/50 percent coal slurry and pumped through the 18-inch line to Mohave.

At Mohave the coal slurry is held in four 8 million gallon storage tanks where giant mechanical agitators move through the water so that the coal solids are maintained in suspension. The slurry is pumped from these tanks through a heat exchanger which raises its temperature to 140°F into twenty Dynacone centrifuges per unit where it is dewatered. Approximately 75 percent of the water is removed and the remaining coal cake is ground and dried in pulverizers after which the coal is burned in the furnace. Approximately 350-370 tons per hour of coal fuel are consumed by each boiler at full load operation. This corresponds to slurry flow rates of approximately 2300 gallons per minute (GPM) to 2500 GPM, respectively.

Six cooling towers and one electrostatic precipitator serve each steam generator. The precipitators remove 98.6 percent of the

plant's particulate emissions. Research efforts began in 1971 to perfect "wet scrubbers".(sulphur dioxide control devices) which absorb the gas in a water slurry of crushed lime or limestone. Testing was completed in 1976 and the technology developed from these tests is now being used by other coal-fired generating stations where high sulphur coal is burned.

Besides being environmentally efficient, the Mohave plant is also quite economical. Its 1977 production costs averaged 44 cents per million Btu, compared to average costs to Southern California Edison of 253 cents per million Btu for oil and 185 cents per million Btu for gas.

The ASEAN team was particularly interested in the technical problems encountered by the plant which have been mostly in the operation's unique dewatering phase and the techniques used to solve these problems. The addition of four storage ponds was also described in detail by Mohave personnel. The significance of this stop on the ASEAN energy tour, therefore, lies in the demonstration of U.S. coal transportation, processing, and environmental control technology. It was of most interest to the representatives from Indonesia, which is developing its coal reserves for power plant use, and Singapore, which has considered building coal-fired plants if its strict environmental standards can be met.

During their inspection of the Mohave power plant, the ASEAN team had a close look at unique equipment used to dewater the coal slurry in preparation for combustion in the boilers.

Sandia National Laboratory

On the morning of May 30 the ASEAN team drove to Sandia National Laboratories outside Albuquerque, New Mexico. Until a few years ago Sandia was essentially a nuclear laboratory but now it is responsible for major programs in non-nuclear areas such as geothermal, wind, and solar energy; coal liquefaction, in situ gasification and combustion technologies; and enhanced oil and gas recovery and oil shale production. Most of its solar efforts are devoted to making cost and performance comparisons among competing designs.

Upon their arrival, Robert Stromberg, Supervisor of the Solar Technical Liaison Division, briefed the group on the history of Sandia Labs, its current renewable energy programs, and the solar and wind hardware the group would see throughout the day. After the briefings, Stromberg led the group on a walking tour of Sandia's mid-temperature solar systems test facility and then, just before lunch, the photovoltaic test facility.

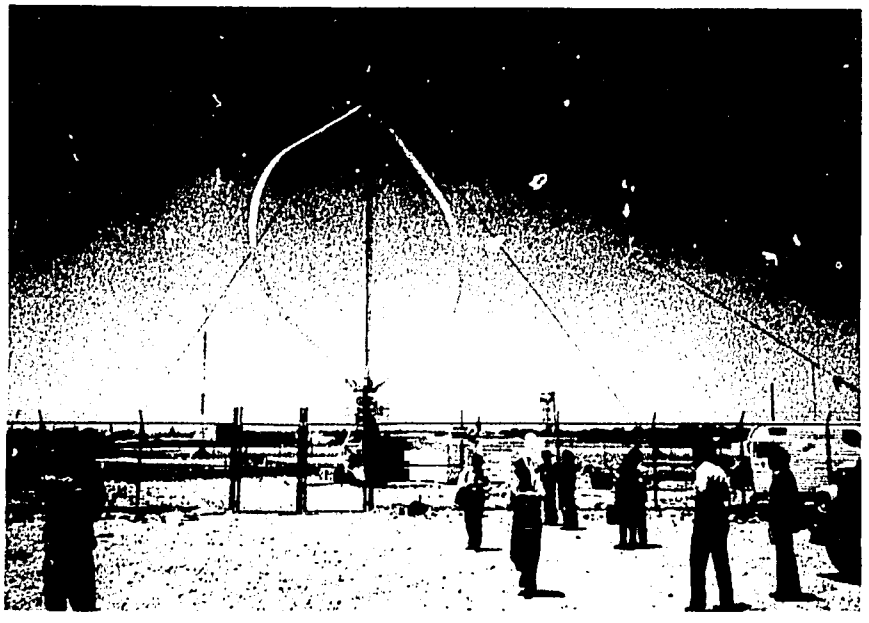
It was obvious to the ASEAN group that the solar work performed at Sandia was in the research and development stages, and not the application stage as had been seen at Mt. Laguna. Stromberg described the tests being conducted on each piece of equipment and the new design being used to improve the performance of giant concentrating, parabolic dishes capable of producing very high temperatures. He pointed out that Sandia publishes technical reports on its exploration of central receiver, photovoltaic, wind, and linear focus thermal technologies.

As the group walked to the photovoltaic testing site nearby, they paused to tour a passive solar building that was being used as a workshop and storage shed.

After lunch, the ASEAN group visited the vertical-axis wind turbine test facility, and happened to arrive just before an afternoon breeze tripped the Darrieus wind machine and put it into operation. This 17 meter, 50 KW Darrieus vertical-axis wind turbine system has two primary advantages over a horizontal-axis machine according to the Sandia guides. The generator and gearbox are located closer to the ground, reducing the structural requirements of the tower and providing better access for maintenance. Inasmuch as vertical-axis machines need not turn to face the wind, yaw control is eliminated. Additionally, because vertical-axis turbines encounter a natural stalling in high winds, there may be a reduced need to protect the machines against gusting.

Disadvantages of the vertical-axis design include an aerodynamic efficiency of about 10 percent less than horizontal-axis machines, limited ability of the rotor to self-start (thereby requiring an electric starter), and generally lower rotation speeds, which require a high drive train torque capacity. Considering all these factors, a Darrieus machine will produce about 50 percent of the annual energy of a propeller-type horizontal-axis machine of a comparable power rating. Because of design considerations, maximum unit sizes are ex-

This two-bladed Darrieus wind machine at Sandia stands 17 meters tall and can generate 50 KW of electricity.



pected to be smaller for vertical-axis machines, but when all factors are considered they are generally seen to be more economical than horizontal-axis machines, particularly in medium sizes. For example, commercially available vertical-axis machines rated at 500 KW cost around $500 per KW of installed capacity, which is considerably less than that for horizontal-axis machines.

To wind up the day, the Central Receiver Test Facility was opened to the group for a walking tour and briefing. The central power test facility is the largest facility providing experimental support in the areas of receiver evaluation, heliostat evaluation, and control system simulation. It consists of 222 heliostats which direct solar energy in a controlled fashion on experiments located in a 200-foot tower. Projects include placing boilers in, or on top of, the tower where temperatures of 1500°F have been reached. Although it is not the purpose of the solar tower to find out what temperature it can reach, Stromberg estimated that it could heat boilers up to 2600°F. This type of large-scale, high temperature solar energy was of interest to the entire ASEAN team, particularly for its potential industrial applications.

Coolidge Solar Irrigation Pump

On Saturday morning, May 31, the ASEAN team flew to Phoenix and then drove to Coolidge, Arizona, to tour a solar powered irrigation facility, the world's largest solar thermal power plant. Located on a private farm, the 150 KW solar power plant experiment is funded by DOE, the Arizona Solar Energy Commission, and the University of Arizona. Technical supervision is provided by Sandia Labs and the University of Arizona, whose Dennis Larson greeted the group upon their arrival.

Larson explained that the magnitude of irrigation energy requirements, potential natural gas shortages, and greatly increased energy costs following the 1974 oil crisis motivated Arizona farmers to explore the feasibility of solar powered irrigation pumps. In 1977, a 25 KW photovoltaic irrigation pump was built in Nebraska and two parabolic trough-type solar thermal systems with Rankine cycle turbine engines rated at 50 KW and 25 KW, respectively, were built in Gila Bend, Arizona, and Willard, New Mexico. Thermal energy storage facilities for nighttime operation were included in the Willard system and then at Coolidge, which was completed in the fall of 1979.

The 150-KW capacity of the Coolidge plant was selected as the optimal rating to provide water from three deep wells for the irrigation of 160 acres of cropland. Each of the three pumps requires about 50 KW to pump some 1,400 gallons per minute from the 380-foot deep wells. Utilizing a 23,000 square foot field of Acurex single-axis-tracking, parabolic, trough-type collectors in a series of north-south oriented rows, the system heats a heat transfer oil (Caloria HT43) which runs through a collector receiver tube coated with a black chrome surface. This receiver tube is surrounded by a Pyrex tube. The sun's rays reflecting off the distributed collectors are focused onto the tube heating the fluid to 550°F. The 6x10 foot, line focus, concentrating collectors have aluminum reflective surfaces and concentration ratios of 36 to 1.

The group visited the control building, collector area, and generating plant. They were told that the system's overall energy collection and conversion efficiency is expected to average 7 percent annually, but its interconnection with the local public utility allows for 24-hour operation of the pump. However, it has the capacity to store 30,000 gallons of hot

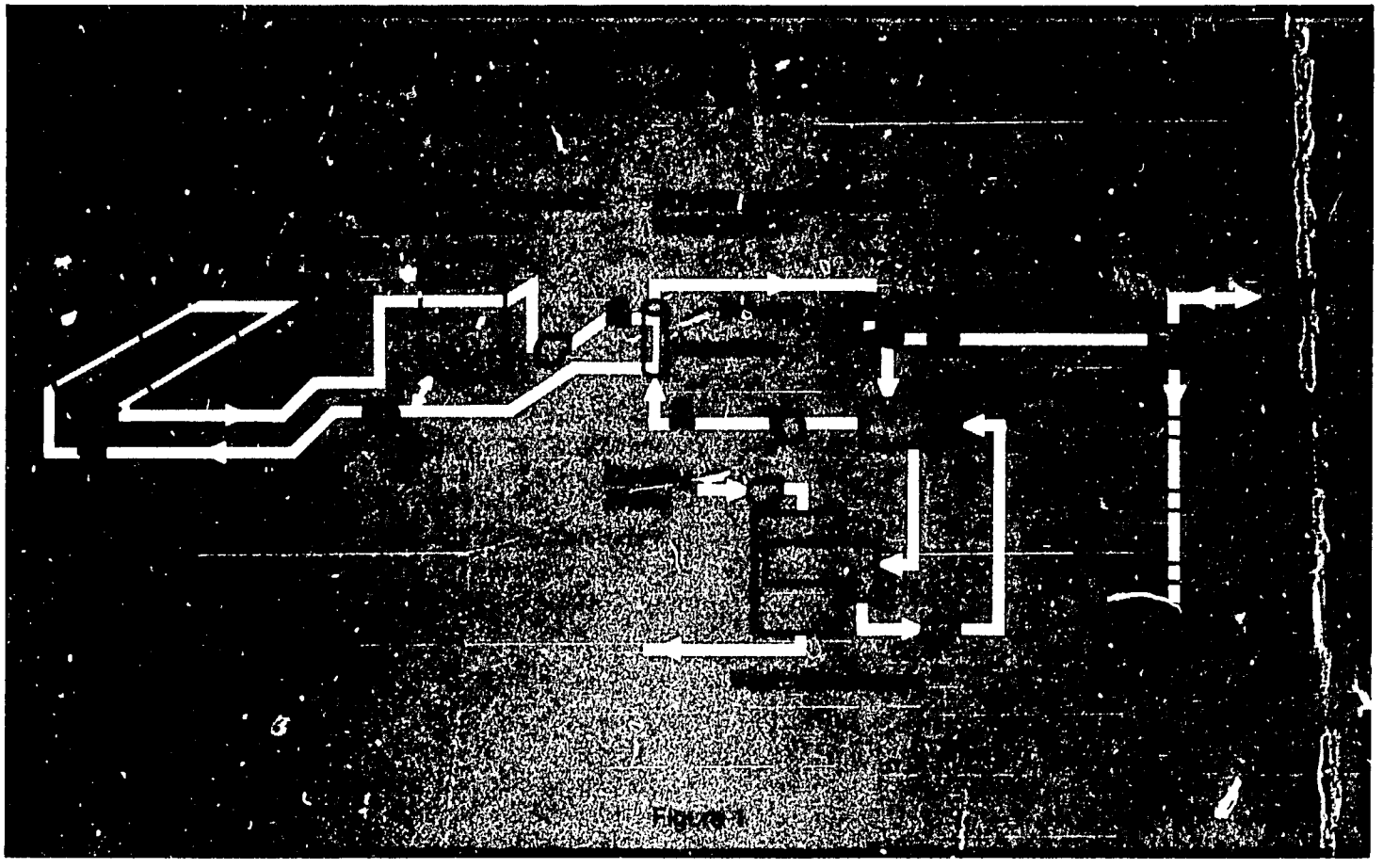
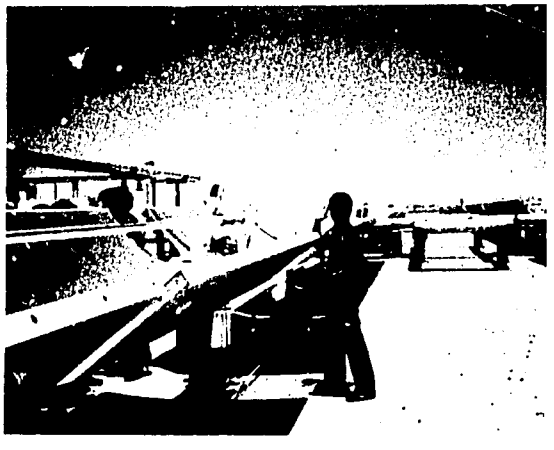


Figure 1

oil and planned collector expansion will permit 20 hours of "stand alone" operation on sunny days.

Because it is not a "stand alone" facility, a considerable effort at Coolidge is directed toward optimizing its interconnection with the local utility. By recording plant output and farm use, conservation and load shifting measures are being developed to improve the matching of power supply and demand between the solar plant and utility, especially during peak hours. Other experiments are being conducted to evaluate the solar collectors, thermal storage, and turbine generator operation.

The parabolic trough, concentrating solar thermal collectors at Coolidge.



The ASEAN team felt the application of solar energy to irrigation was compatible with their countries' requirements but noted that cost remained a prohibitive factor. Concentrating collectors can yield temperatures double those of less expensive flat-plate collectors and are therefore more appropriate when high pumping rates are required, such as at Coolidge. Unfortunately, cost is a drawback at $3,000-$10,000 per KW of installed capacity. All technical questions on the system's operating characteristics were answered by Larson, who expressed optimism at reducing solar energy costs.

Phoenix Solar Energy Jubilee

On Sunday, June 1, several members of the ASEAN study mission visited exhibits at the Solar Jubilee in downtown Phoenix. Held in conjunction with the 25th annual meeting of the American Section of the International Solar Energy Society, the Solar Jubilee offered displays from manufacturers, dealers, researchers, builders, government agencies, universities, and a host of others involved in the development and commercialization of solar energy. Displays ranged from solar to biomass to wind and from solar water heaters to power towers. Presenting state-of-the-art solar hardware to the general public, the Jubilee was designed in part to encourage greater acceptance of solar energy in the southwestern United States.

Because of their tight schedule the ASEAN energy experts were not able to attend the week-long conference which began the next day.

Schuchuli Solar Village

Schuchuli is a small remote village of the Papago Indian Tribe located about 120 miles south of Phoenix, Arizona, and 17 miles from the nearest available power grid. The ASEAN team was briefed by William Bifano, Manager of NASA's Photovoltaic Development and Support Project Office, in Phoenix before the 3-hour drive to Schuchuli. He explained that Schuchuli is an example of "cluster" solar applications whereby a centrally located power system provides electricity to several discrete loads. This is characteristic of village and medical service applications where several types of electrical service are required. By comparison, the solar thermal irrigation pump in Coolidge, Arizona, seen two days before, is a single application type.

At one time the cost of connecting Schuchuli to the nearest electrical grid was deemed prohibitive and the village's largest energy source was power supplied by a windmill to pump water from the village's well. But wind intermittency resulted in unreliable water supplies and there was still no electricity for the tribe to have electric lighting or refrigeration facilities. Gasoline and diesel powered generators were tried next but proved to be too expensive and difficult to maintain for the village's 100 inhabitants. Then on December 16, 1978, a 3.5 KW photovoltaic installation began operation under a Department of Energy funded project managed by NASA as part of DOE's National Photovoltaic Conversion Program. NASA's Solar and Electrochemistry Division furnished the power system, associated electrical equipment, and supervised installation by the Papago Construction Company. The village's electrical distribution system was designed and installed by the Papago Tribal Utility Authority.

As the world's first village powered entirely by photovoltaics, Schuchuli is similar to thousands of other small rural villages throughout the world in terms of its population size, low income, remoteness from urban population centers, extended-family social structure, and relatively small electricity requirements. Before the solar electric system began oper-

The operation of the photovoltaic solar system at Schuchuli is monitored by the village chief, shown here greeting the ASEAN team. Data on the solar system's operation is recorded by the chief in an adjacent building where the storage batteries are kept and analyzed by NASA.

ating the village relied on wood, propane, and petroleum products (kerosene, diesel, and gasoline) for primary energy.

The 3.5 KW solar facility is operated at 120 volts, DC, to reduce distribution losses and to maximize system efficiency. Three rows of eight solar panels located in a 70-foot by 100-foot fenced area sit atop locally constructed support structures designed to withstand 100 mph winds. Each panel is 4 feet by 8 feet and contains eight modules each of which has 42 solar cells.

The power storage system consists of fifty-three 2380 ampere-hours capacity, lead calcium type batteries which are stored in a separate building next to the solar collector array. This building also houses the load management system powered by four pilot cells incorporated into the design to protect the batteries from excessive discharge and to maintain operation of the more critical loads at the expense of less critical loads. For example, at 50 percent depth of discharge, the washing and sewing machines are disconnected, at 60 percent the lights are disconnected, at 70 percent the water pump is disconnected, and finally, at 80 percent depth of discharge, the refrigerators are disconnected. These loads are reconnected to the system sequentially as the batteries are recharged.

As a first of its kind photovoltaic power system, the Schuchuli system is totally instrumented to provide engineering data. Although much of this data is recorded automatically, the village chief reads the panel meters and is trained to recognize "anomalous" operation.

Bifano told the group that the cost for the 3.5 KW photovoltaic system at Schuchuli was $108,483 (1978$), excluding experiment-related costs. Assuming a 20-year life (10 years for batteries), and 10 percent discount factor, the levelized annual capital cost of the system is $12,700. For the predicted value of annual energy consumption, i.e., 6255 KWH per year, the resultant energy price of the solar electricity is $2.03 per KWH. By comparison the corresponding price for diesel generated electricity is $1.73 per KWH for

$2.00 per gallon fuel. For utility line extension, electricity prices range from $1.55 to $1.91 per KWH, assuming a 20-year life, 10 percent discount factor, and 5 percent escalation per year in fuel and electricity costs (over normal inflation).

Due to continued cost reductions brought about by increased production volumes and improved technology, photovoltaic-generated electricity is expected to decrease in price to less than $1 per KWH by 1981. At this price, photovoltaics would be competitive with both diesel generators and powerline extensions where annual energy consumption is under 15,000 KWH.

The Schuchuli village chief led the ASEAN experts through the village so they could see the end uses of this solar energy system, including family refrigerators, lights in the homes and community buildings, a communal washing machine and sewing machine, and a 1100 gallon per hour capacity water pump. It was apparent that the tribe had no problems accepting the introduction of solar energy into their life. The absence of maintenance problems associated with the solar energy system and its acceptance by the tribe seemed to indicate that Schuchuli was a promising example of solar energy applied to a rural village.

Solar Energy Research Institute

The Solar Energy Research Institute (SERI) was created out of the Solar Energy Research, Development and Demonstration Act of 1974 to take the lead in supporting the National Solar Energy Program and to assist in the establishment of the industrial base necessary for the widespread, early utilization of solar energy. In March 1977 the Energy Research and Development Administration (now part of DOE) evaluated many proposals for SERI and announced that SERI would be managed and operated at Golden, Colorado, by the Mid-West Research Institute, an independent, non-profit organization. SERI formally began operations on July 5, 1977, and saw its budget double from $12.7 million in fiscal year 1978 to about $25 million in fiscal year 1979.

SERI's responsibilities through 1985 have evolved to include:

- conducting solar research, development, and related activities;
- supporting DOE in the management of domestic and international programs in solar research, development, and demonstration;
- assisting the Federal Government in the formulation of national solar energy policies, plans, and strategies;
- contributing to the establishment of a solar energy industrial base that will foster the widespread use of solar technologies; and
- operating as the lead center for research in the National Photovoltaic Program (the Jet Propulsion Laboratory in Pasadena, California, is the lead center for applications).

To achieve these goals SERI has embarked on a wide range of research, training and information dissemination programs in photovoltaics, biomass, wind, active solar heating and cooling, passive solar technology, industrial process heat, solar thermal technology, ocean systems, and solar energy storage. In addition, SERI has established a Solar Energy Information Data Bank, Solar Education Data Base, a state Solar Incentives Study program, and a bi-monthly Solar Law Reporter. Cooperative solar programs with South Korea, Mali, Spain, France, Italy, Israel, Australia, Japan, and Brazil are managed by

SERI as well as the the $100 million U.S.-Saudi Arabian SOLERAS program.

One of the most interesting projects at SERI is the development of a handbook of agriculture applications of solar energy. Aimed at the developing countries, this handbook analyzes state-of-the-art alternative energy sources in terms of their suitability for agricultural end uses such as pumping and drying. Another project at SERI entails the field testing of a new methodology for evaluating the solar potential of rural villages. Considerable interest was expressed by the ASEAN team in these and other SERI programs.

The discussions at SERI were organized as a dialogue, with the schedule dominated by question and answer sessions. Energy experts specializing in biochemical sources, photovoltaics, systems analysis, solar thermal, wind systems, ocean thermal energy conversion (OTEC), materials research, environment and social impacts, information systems, and SERI's international programs were present for the lively discussion. This session gave the ASEAN team an opportunity to reflect upon the energy hardware they had seen thus far and raise more theoretical issues regarding renewable energy. When the dialogue ended it was discovered that there was not enough time to tour SERI's test facilities because the group was scheduled to visit the Rocky Flats Wind Facility.

Rocky Flats Wind Systems Test Center

The Rocky Flats Wind Systems Test Center in Golden, Colorado, develops, tests, and conducts research on small wind machines (under 100 KW) and serves as the largest national test center for DOE's Federal Wind Energy Program. The program's principal objective is to accelerate the commercialization of wind systems. Performance reports on tests conducted at Rocky Flats on commercial wind machines are published in order to provide potential buyers with consumer information and to disseminate technical data that can be used by those developing wind energy systems. When the ASEAN group arrived at Rocky Flats it was met by Corville Nohava of DOE and Rockwell International personnel responsible for operating the facility. Before starting a tour of the site they described the equipment used to evaluate the machines and measure their technical characteristics.

Although there is a variety of commercially available wind machines, many of which have been tested at Rocky Flats, the cost of windpower is still too high compared to conventional energy sources for its use to be widespread. However, in those areas where power costs are high, wind power can be a logical alternative. The fact that mechanical output wind machines of local design and manufacture have been used for years in developing countries indicates that wind is an accepted form of non-conventional energy. Similarly, electrical wind machines of the type seen at Rocky Flats could serve the power requirements of remote or windy villages in the ASEAN region.

An average wind speed of at least 5 meters per second (10-12 mph) is normally required to run wind systems with any degree of economy. A doubling of wind speed results in 8 times more power available for a wind machine. For example, a location with an an-

nual average wind speed of 12.5 mph offers up to twice the energy available compared to a site with a 10 mph aveage. Rocky Flats was selected as a testing site because of winds sometimes exceeding 100 mph which come down out of a mountain canyon and across the flats. During sustained periods of insufficient wind, machines have been tested upon moving railroad flatcars.

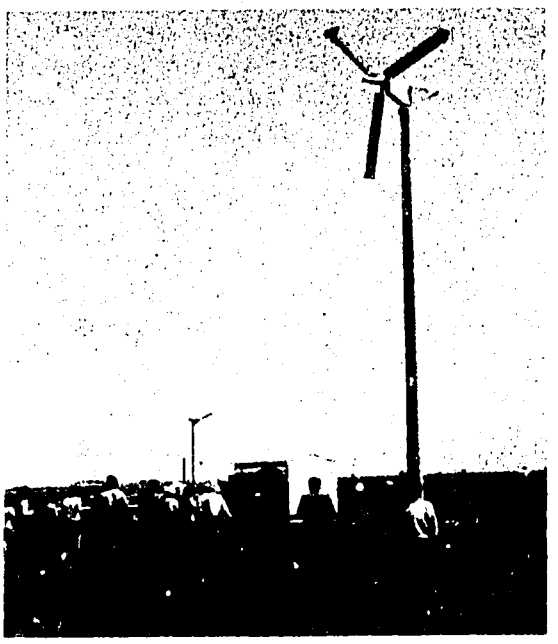
The ASEAN experts pointed out the need for wind maps of their countries, particularly along coastlines, before they can fully assess their potential for wind energy. Problems of wind intermittency, including timing of local winds compared to when energy from a wind machine is required, might then be dealt with in a more sophisticated manner.

Rocky Flats tests both high and low technology wind machines. Although wind technology is almost fully developed, high technology improvements in wind energy costs and reliability are still being sought as are improvements in "home-built," low technology systems which can be constructed with local materials and labor. About 10 wind machines were inspected. These test sites included a support pad (foundation), tower, and a utility shed, where data and power junction boxes are located.

Among the machines seen operating was the two-bladed "Enertech 1500" prototype rated at 1.5 KW. The commercial version of this horizontal-axis, downwind machine has three blades and cost about $3,000 at the time of the tour. (This price excludes tower and installation charges which vary according to tower requirements at the site.) Also inspected was the commercially available PDI Wind Jennie which is a 4 KW upwind, horizontal-axis machine selling for approximately $4,500. One of the larger machines viewed was the 20 KW Mercom, a six-bladed, horizontal-axis downwind machine priced at $22,500, excluding the tower and installation.

Two technical developments evident at Rocky Flats and shown to the group were (1) the use of a downwind rotor instead of an upwind rotor for horizontal-axis wind machines and (2) new vertical-axis wind machines. These developments are described below.

Upwind machines have dominated the world market for 40 years but recently downwind rotors have come into greater use because they can be less complex systems (no tail is required) and therefore reduce costs. For example, all but one of the horizontal-axis prototypes being developed by the U.S. Government are of the downwind design in order to determine whether their performance and reliability can match that of upwind machines. However, the 2.5 MW MOD-2 machine developed by Boeing Engineering and Construction which utilizes a tail-less upwind rotor may foster new breakthroughs.



This upwind, horizontal-axis wind machine and its utility shed containing data and power junction boxes was one of about ten wind machines viewed by the ASEAN team during their visit to the Rocky Flats Wind Systems Test Center.

The vertical-axis machines described to the group were of the type originally designed by George Darrieus in the 1920's, and later developed at Sandia Laboratories. The potential advantages of the vertical axis design over horizontal-axis systems are that no rotor orientation system is required (rotor area is always fully exposed to the wind), no slip rings are required to transmit energy to the base of the tower, and the aluminum blades do not require pitch control.

As explained by members of Rockwell's staff, inherent in the third advantage are two minor

disadvantages to this system. Because the blade remains stationary throughout each revolution, the angle at which the wind strikes the airfoil is not always optimum. This results in a reduction in performance as compared with ideal horizontal-axis systems. In addition, because one or both of the blades are not in an optimum position at any given point in the rotor path, the Darrieus needs assistance to start up—provided either by an auxiliary motor or an auxiliary rotor which can self-start in the wind.

A vertical-axis design simpler than the Darrieus, the straight-bladed pitchless vertical-axis wind turbine, has not been fully tested. There is a commercial version available, however, known as the Pinson 1.2 KW machine which costs $9,300. Its structural simplicity and ease of manufacture may prove particularly useful for developing countries.

The Rockwell staff said that currently available vertical-axis machines cost from $9,000 to $15,000 for 2-4 KW units compared to a $3,000-$8,000 range for horizontal-axis machines of similar output. However, commercially available vertical-axis machines in the larger sizes are much more cost-competitive than the horizontal designs. The Malaysian representatives expressed interest in the vertical-axis machines, particularly because they generally require less maintenance than horizontal-axis machines.

Institute for Gas Technology

The Institute for Gas Technology (IGT) in Chicago was founded in 1941 as an independent, international, non-profit energy research and education organization. Affiliated with the Illinois Institute of Technology, IGT is supported by over 200 member companies and 45 international associate organizations. Its Technical Information Center contains the largest collection of gas technology information in the world and publishes five periodicals on gas technology and other energy topics. In addition, IGT operates large-scale process research and pilot plant facilities which the ASEAN group visited on a 15 acre site near its main headquarters.

The Gas Developments Corporation (GDC), whose president, Mr. Aman Khan, met with the ASEAN group, operates as IGT's commercial subsidiary. GDC has operated training projects in Algeria, the United Arab Emirates, Abu Dhabi and elsewhere, and is working with the Malaysian National Oil Company, PETRONAS, in developing a plan for utilizing offshore gas reserves. Product development, licensing, commercialization, and other consultant services are offered by GDC. In its role as marketing and licensing agent for patented technologies developed by IGT, GDC has commercial programs for the U-Gas and Hygas coal gasification processes, the Solar-Mec heating and cooling system, and the Hytort oil shale process.

Considerable interest was shown by the ASEAN team in IGT's educational programs after it was learned that a group of Malaysian engineering students were about to graduate from one of IGT's gas technology programs. Since 1971 when training programs were established for Algeria's growing natural gas industry, IGT and GDC have run training and technology transfer programs on a wide range of topics including operations for LNG plant technicians, industrial conservation, biogasification technology (peat), synthetic fuels from oil shale, gas distribution system engineering, and energy from biomass and wastes. The morning's technical briefings on IGT's Solar-Mec heating and cooling system, gas conversion processes, and bio-gas research efforts

might be summarized by the statement by one of the spokesmen that "the sun is free but gas is cheaper."

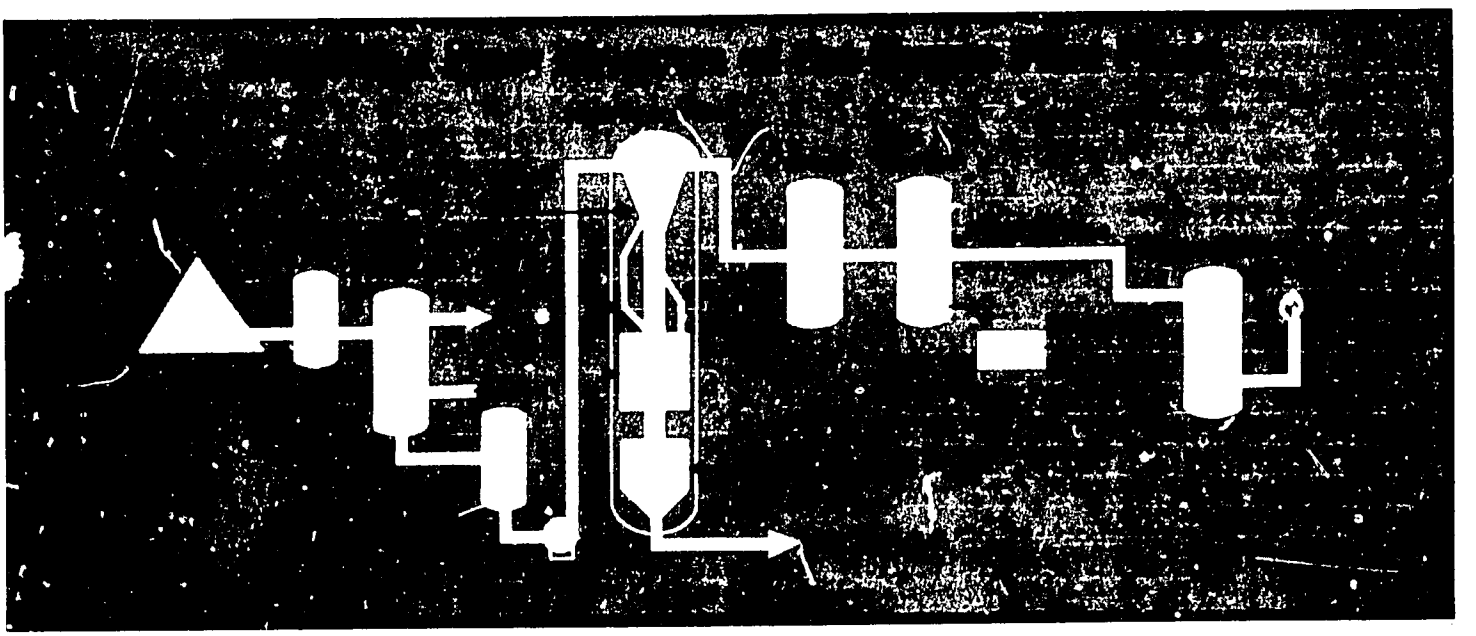
Field testing began in 1975 for the Solar-Mec system which is a solar-augmented system for heating, cooling, and humidity control of surprisingly simple design. It has no compressors or high-speed machinery yet can provide complete environmental control for a house or small building. Singapore's interest in solar air conditioning systems became apparent during the question and answer period on Solar-Mec. The ASEAN team was also briefed on IGT's biomass program, sponsored jointly by DOE and a utility, whose gasification tests have shown that several types of peat compare favorably with coal as a fuel for producing methane.

After their briefings and lunch, the ASEAN team proceeded to IGT's Energy Development Center and pilot plant facilities for a tour and additional briefings on its U-Gas, Hygas, and Hytort processes.

IGT officials gave a very detailed explanation of the U-Gas process as the ASEAN team toured the pilot plant. Capable of utilizing any U.S. coal as its feedstock without pretreatment, the patented U-Gas process produces a medium Btu fuel gas, 250-350 Btu per standard cubic foot, when oxygen, steam, and coal are injected into the reaction system. When air is substituted for oxygen, a lower Btu gas (100-150 Btu) is produced.

The gasifier itself is a single-stage fluidized-bed reactor. Coal is crushed to less than 1/4 inch size, then introduced to the gasifier via lockhoppers. Within the fluidized bed, coal reacts with steam at a pressure of 50 to 350 psi. Temperature of the bed depends on the type of coal feedstock, and is chosen to maintain non-slagging conditions at all times. The selection of operating pressure is determined by the ultimate use of the product gas. At the specified conditions, coal is gasified rapidly, producing a mixture of hydrogen, carbon monoxide, carbon dioxide, and a smaller fraction of methane. The mixture is about half nitrogen, if air is used. Nearly all sulphur present in the coal is converted to hydrogen sulfide, which can be easily removed from the product gas by commercially available processes.

The gas produced could replace natural gas, such as imported LNG, or No. 2 fuel oil. Gas costs for the medium BTU gas in 1978$ were estimated by the IGT staff at $3.50 to $4.00 per million Btu for a larger plant size. Synthetic gas costs for the proposed U-Gas demonstration plant in Memphis, Tennessee, are expected to be competitive with oil and natural gas, but specific figures were not available.



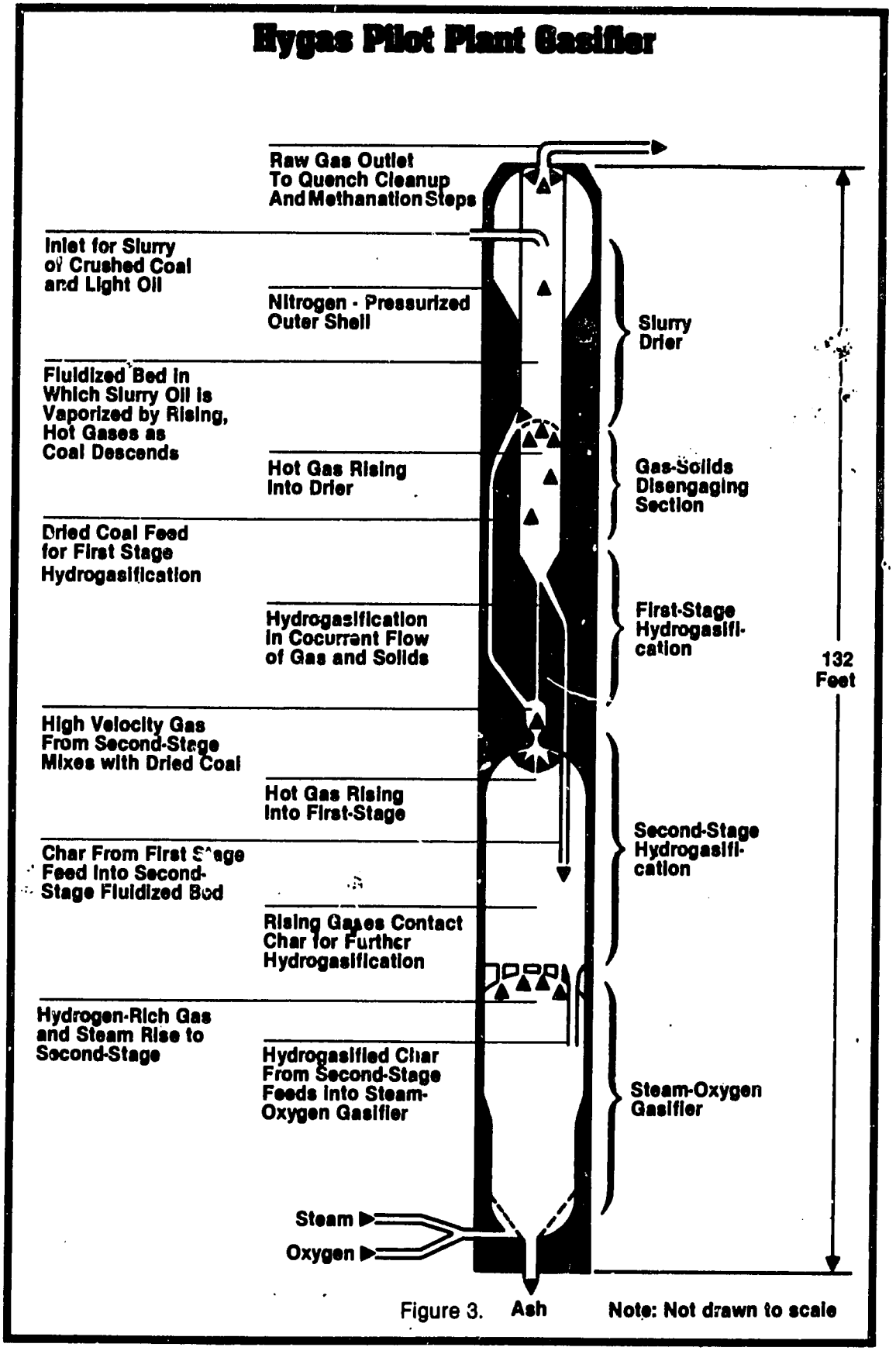

Hygas Pilot Plant Gasifier
Raw Gas Outlet To Quench Cleanup And Methanation Steps
Inlet for Slurry of Crushed Coal and Light Oil
Nitrogen - Pressurized Outer Shell
Slurry Drier
Fluidized Bed in Which Slurry Oil is Vaporized by Rising, Hot Gases as Coal Descends
Hot Gas Rising Into Drier
Gas-Solids Disengaging Section
Dried Coal Feed for First Stage Hydrogasification
Hydrogasification in Cocurrent Flow of Gas and Solids
First-Stage Hydrogasification
132 Feet
High Velocity Gas From Second-Stage Mixes with Dried Coal
Hot Gas Rising Into First-Stage
Second-Stage Hydrogasification
Char From First Stage Feed Into Second-Stage Fluidized Bed
Rising Gases Contact Char for Further Hydrogasification
Hydrogen-Rich Gas and Steam Rise to Second-Stage
Hydrogasified Char From Second-Stage Feeds Into Steam-Oxygen Gasifier
Steam-Oxygen Gasifier
Steam
Oxygen
Ash
Note: Not drawn to scale

Figure 3.

Although early development of the U-Gas process was funded by IGT, recent work has been supported by DOE. The proposed Memphis plant is expected to produce 175 mcf of gas daily from 2800 tons of coal and is jointly funded by DOE and the city of Memphis.

Next, the ASEAN team inspected the Hygas pilot plant which is also capable of converting all U.S. coals to synthetic natural gas, essentially methane. Basic research on the Hygas process began in 1944 and in 1967 IGT was awarded a contract to design, construct, and operate the pilot plant by the Department of the Interior's Office of Coal Research (now part of DOE) in conjunction with the American Gas Association (whose support was taken over by the Gas Research Institute in 1978). The pilot plant was designed to produce 1.5 mcf of gas from 80 tons of coal to serve as a basis for designs of a commercial Hygas plant. Cost estimates provided by IGT showed it to be less expensive than several other gasification processes for all types of U.S. coals.

Hygas is a second generation process that first reacts a heated coal slurry with gases (methane, carbon oxides, hydrogen, and steam) and then hydrogen at temperatures up to 1850°F and pressures up to 1000 psi to produce methane directly in the reactor. This step of the process is called hydrogasification. Residual hydrogen and carbon monoxide, also formed in the reactor, are converted catalytically to make the rest of the methane. The gas product has its sulphur compounds removed to less than one part per million and is then ready for direct pipeline use

Although the Hytort oil shale development facility was shut down for maintenance, the group also had an opportunity to tour it at the end of the day. This unit can process one ton of shale per hour and can produce either oil or pipeline-quality gas. Economic analyses based on experimental hydro-retorting results have indicated that a Hytort syncrude plant processing 92,610 tons of Eastern shale (Devonian or Mississippian) per stream day could produce oil at a selling price of $18-$19 per barrel. Although a pilot facility has not been built to test the process on a larger scale, IGT has proposed to DOE that a 2000-ton per day pilot plant be constructed from which the process could be scaled up directly to a commercial-size operation.

Representatives from Thailand were particularly interested in this part of the tour, citing their country's oil shale deposits, and made inquiries regarding the testing of Thai oil shale by the IGT process.

Argonne National Laboratory

At Argonne National Laboratory in Chicago the ASEAN team received briefings on Argonne's conservation and solar programs and toured laboratories working on ocean thermal energy conversion (OTEC) and fluidized bed combustion. Most of Argonne's work is in the nuclear area but it has recently been devoting more of its resources to non-conventional sources of energy. Argonne is operated under a contract by DOE, the University of Chicago, and the Argonne Universities Association, a consortium of 30 universities.

The ASEAN team was very interested in the tour of test facilities for the fluidized-bed coal combustion process. This process, which burns crushed coal in the presence of crushed limestone, can cut stock-gas pollutants by more than 90 percent and would have useful applications in countries such as Singapore, for example, where environmental

protection is a high priority. Fluidized bed combustion captures undesirable sulphur dioxide and nitrogen oxide emissions during combustion, thereby eliminating the need for flue-gas desulphurization equipment. Because it is relatively insensitive to variations in fuel quality and has better heat transfer in the turbulent combustion zone of the fluidized bed, this technology also has the advantage of lower boiler capital costs than conventional boilers.

Argonne's OTEC test facility also attracted interest since there are waters in the ASEAN region where OTEC might be feasible. Further development is necessary first, however, before the difference in ocean temperature gradients can be exploited to generate electricity via the OTEC method.

It was particularly fitting that the team visit Argonne since its Program Management Support Office played an important support role in coordinating the study mission.

Ashland Oil's H-Coal Facility

The ASEAN team spent a full day at Ashland Oil Company's energy facilities in Catlettsburg, Kentucky. Ashland is one of the largest U.S. petroleum refiners and has a very active R&D program which has become increasingly involved in the synthetic fuel industry. For example, the wholly-owned subsidiary, Ashland Synthetic Fuels, Inc., operates the H-Coal, coal liquefaction facility. Coal operations are conducted through various subsidiaries and affiliates whose combined annual coal sales (5.3 million tons in 1979) would place Ashland among the top five coal producers in the United States.

The day began with a slide presentation on the patented H-Coal process, which was initially developed by Hydrocarbon Research Inc., and a tour of the pilot plant.

Ashland is one of several companies participating with DOE and the State of Kentucky to study the technical and economic feasibility of the H-Coal process which converts coal to liquid hydrocarbons. Situated next to Ashland's largest refinery, the pilot plant is designed to process up to 600 tons of coal per day and produce 1,800 barrels of liquid products. The pilot plant is sized to test commercial process equipment, but is far too small for an economically viable commercial production unit. Commercial plants are already in the planning stage, however, since the price of the synthetic oil is expected to be competitive with world oil prices. Preliminary economic evaluations indicate a capital requirement of $2 billion for a commercial plant to produce 50,000 barrels of oil a day.

The process involves mixing pulverized coal with a recycled oil mixture and reacting the slurry with hydrogen under high temperature (850°F) and high pressure (3,000 psi). Hydrogeneration occurs in the presence of a catalyst and produces a wide variety of hydrocarbon products including fuels and chemicals. Plant gases, stripped of sulphur, are burned in the internal fuel system. The H-Coal process can use bituminous, sub-bituminous or brown coals as well as lignite and produces clean, low sulphur petroleum substitutes regardless of the sulphur content of the coal used. About three barrels of coal-derived liquids are obtained per ton of coal and by adjusting the severity of the process, this end product can be either a synthetic crude or power plant fuel (see figure 4).

The pilot plant facility cost $166 million including $43 million for design and research and $123 million for construction. Operational costs are estimated at $130 million over a 2-year period. By coincidence, the ASEAN

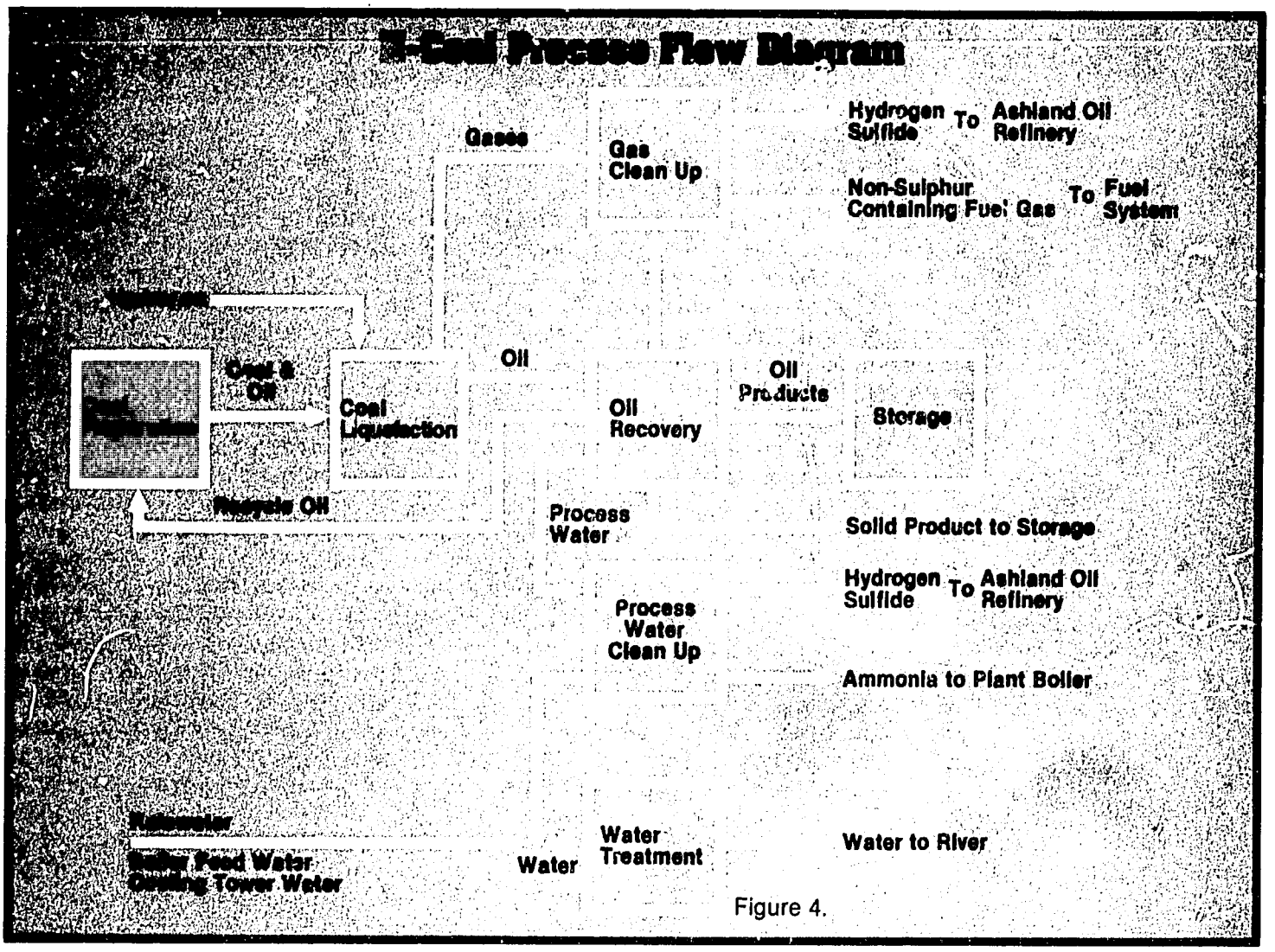


Figure 4.

team was visiting the plant the day the first continuous test run of the plant was taking place and so there was press coverage of both the H-Coal opening and the ASEAN tour.

After their tour the group returned to Ashland's offices for a technical briefing on its patented Reduced Crude Conversion (RCC) refining process. Conventional refining processes separate crude oil into various components including gasoline, home heating oil, and residual fuel. The RCC process, according to Ashland's representatives, converts most of the residual fuel—the bottom of the barrel—to lighter products such as gasoline. Most U.S. refineries produce about 50 percent gasoline from a barrel of crude and the RCC process increases this yield by 25 percent. Utilizing high temperature catalytic conversion techniques, the RCC process allows Ashland to either upgrade heavy oil to gasoline (which accounts for about 40 percent of U.S. petroleum consumption) or produce the same yield of gasoline with 20 percent less crude.

Following the briefing, the ASEAN team inspected the RCC demonstration plant before proceeding to Ashland's Research Development facilities. A short presentation was given and then the team toured the facility with Ashland scientists on a one-to-one basis so that there could be specific technical discussions in the areas of interest to the ASEAN team members.

New Alchemy Institute

On Saturday, June 7, the ASEAN team and Dr. Norman Brown, Energy Advisor to AID's Asia Bureau, drove from Boston to Woods Hole, Massachusetts, where they visited the New Alchemy Institute. The objective of the Institute's research and educational programs is to design and test human support systems—food, energy, and shelter—that are environmentally benign and economically efficient. Another important aspect of this approach to energy problems is the emphasis upon small scale applications and minimizing reliance upon fossil fuels. The Institute's concentration on appropriate technologies is reflected by its rural farm setting. Upon their arrival the group was greeted by an afternoon rain so most of their time was spent inside one of the Institute's bioshelters instead of being outside with the wind machines and other energy hardware.

Inside the bioshelters were several freestanding fiberglass cylinders filled with water and fish. It was explained that the sunlight penetrates the translucent fiberglass to warm the water and spur algae growth. Some of this algae is eaten by herbivorous fish whose wastes are metabolized by the oxygenation of the water through photosynthesis. The algae also absorb heat such that one 650-gallon cylinder will absorb and then release the heat equivalent of 30 gallons of oil over the 150 day heating season. One of the best discussions came after the group was told that since outdoor solar ponds remain warm year round, the Institute is designing a passive solar house that employs these ponds as thermal storage units.

A Thai member of the team who was conducting research on solar ponds was very interested in the experience the Institute had with the various materials used to build solar ponds, particularly the fiberglass panel roof of the bioshelter. Other officials were impressed with the "natural simplicity" of New Alchemy's solutions to energy problems.

MIT Energy Laboratory

Dr. Marvin Miller of MIT's Energy Laboratory welcomed the ASEAN team when they arrived at the MIT campus in Cambridge, Massachusetts. He explained that MIT organized the energy laboratory in 1972 to carry out a wide variety of research projects on energy technology and related economic and policy issues. An interdisciplinary group of MIT faculty members, professional staff, visiting scientists and engineers, and graduate and undergraduate students perform work under a budget which, in 1979, exceeded $10 million. About three-fourths of these funds are from government sources and the rest from corporations and private foundations.

The sessions at MIT were on very specific topics with the exception of the overview of the Lab's wide range of activities by Professor David White, Director of the Energy Laboratory. His presentation provided useful insights into the organizational, budgetary, and management principles of running a large energy research organization. Of particular note was MIT's interdisciplinary approach to energy problems and its emphasis upon close

interaction of experts from different fields of energy research.

The technical briefings covered MIT's research on biomass, pyrolysis, and health effects of fossil fuel utilization, combustion research, and the health effects of inorganic combustion aerosols and sulphur dioxide. These briefings reflected MIT's recognition that economies will be based upon fossil fuels, particularly non-oil fuels, for a long time before non-fossil fuels become a major source of energy. One of MIT's goals is to bring about more intelligent utilization of the fossil fuel resource base through its research and the dissemination of its findings.

A brief walking tour of MIT's facilities, including the environmental research laboratories, combustion facilities, and test area for fluidized bed combustion, concluded the MIT portion of the day. A small part of the team met with Carroll Wilson, Project Director for the World Coal Study, instead of taking the laboratory tour.

Refuse Energy Systems Company

On their way to General Electric's (GE) facilities in Lynn, Massachusetts, the ASEAN group visited the Refuse Energy Systems Company (RESCO) which provides GE with steam at an average rate of 185,000 pounds per hour. Built in October 1975 the RESCO plant burns 1,500 tons per day of garbage from nearby municipalities (who pay RESCO $15.40 per ton for this service) in a refuse incinerator which heats steam to 825°F at 600 psi. This steam is piped to GE's facilities next door and used to generate electricity for manufacturing processes, plant heating, and equipment testing.

RESCO accepts municipal, commercial, and light industrial refuse but not chemical or liquid wastes. Over a period of one year the plant will recover 25,000 tons of ferrous metals and 40,000 tons of aggregate materials used by the construction industry. The plant not only reduces the cost of community trash disposal but has also received awards for its environmental excellence. According to RESCO officials, the plant, which is similar to one operating in Singapore, encountered some problems in the first 3 years such as corrosion on the heat exchangers and slagging on the walls. Now it is operating at a profit. One participant recalled the importance Lawrence Berkeley officials attached to urban energy consumption trends and remarked that large cities could use more RESCO-type facilities.

General Electric

The ASEAN team then went next door to visit the Medium Steam Turbine Department at GE's Lynn River Works facility. After a welcome by John Weigel, Manager for International Power Generation Sales and Projects, a series of very technical briefings and discussions transpired. The first presentation centered on new developments in combustion technology for power generation, notably combined cycle, integrated gasification combined cycle, and cogeneration technologies. In the combined cycle power plant, hot waste gases from a gas turbine generator are used to create steam and power a steam turbine generator. In GE's single shaft STAG plants, the generator is driven at one end by the gas turbine and the other end of the shaft is directly connected to the steam turbine. Coal-fired combined cycle power plants would also utilize a gasifier of the pressurized fluidized bed type to produce gas from coal (see figure 5). Other multi-shaft systems using multiple gas turbines with heat recovery steam generators to drive a larger single steam turbine generator are now commercially available.

Coal Fired Combined Cycle Power Plant

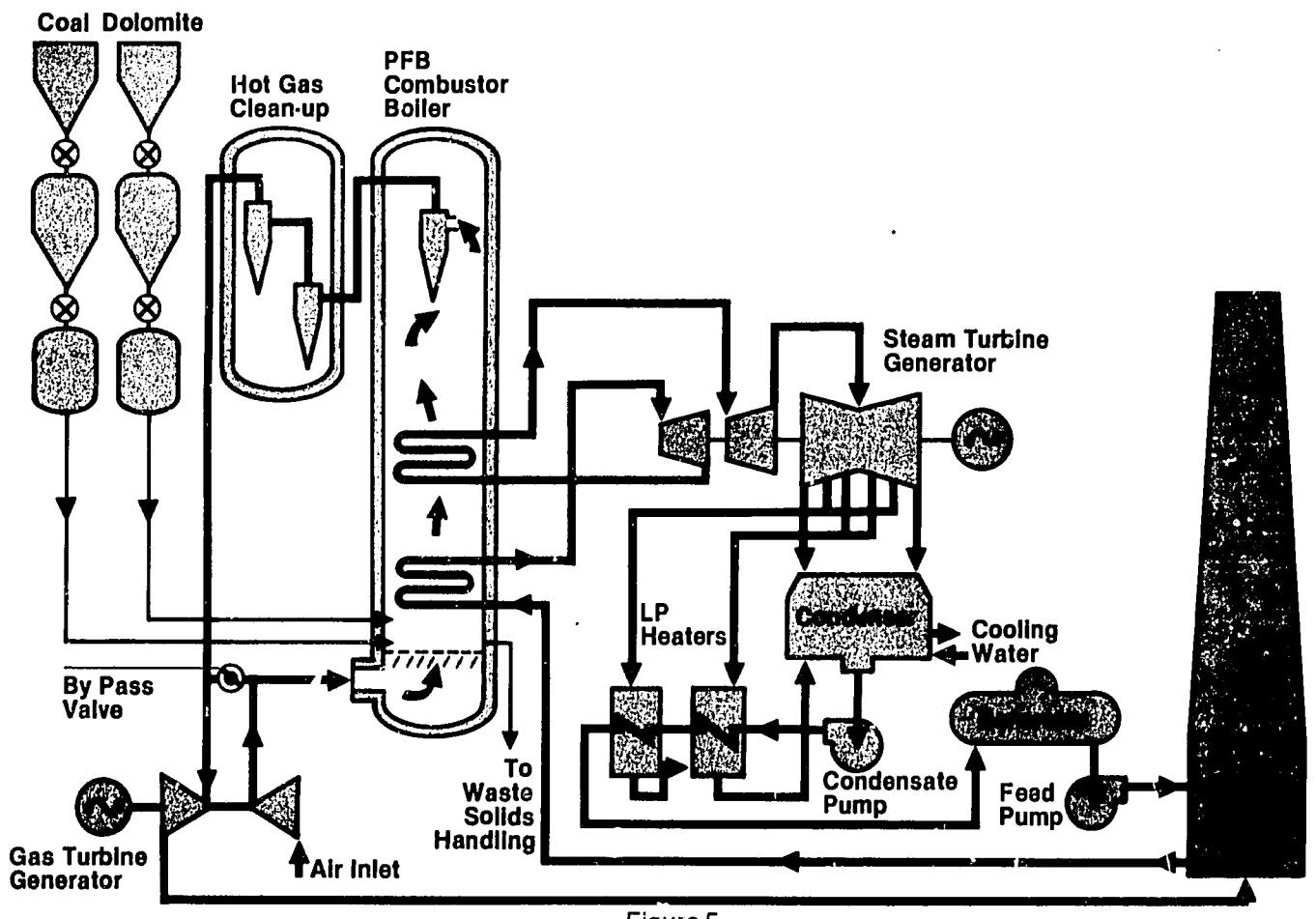


Figure 5.

Combined-cycle power systems have been commercially available for some time, particularly in the case of GE's STAG modular design system, and have proven to be reliable and efficient. Materials were handed out to the group on currently available systems as well as on future developments. For example, the group was told that although pressurized fluidized bed combined cycle units in 80-100 MW modules are ready for the demonstration phase, GE expects future developments to improve its 34-64 percent net plant efficiency to 40-42 percent in the 1985 to 1993 time period with demonstration-sized 300 to 600 MW plants and then in the 1990's to 44-46 percent for commercial plants. Emissions performance will improve from the 97 percent sulphur retention during this time while the real cost of the plants per KW of installed capacity will decline from $700-$750 per KW to $600-$640 per KW in 1978$. Electricity costs are estimated at 45-50 mills per KWH for the currently available system while future commercially sized plants are estimated to be able to sell electricity at 35-40 mills per KWH.

The rest of the presentations were on the following subjects:

- geothermal steam turbine-generator applications and turbine materials;
- steam turbine construction;
- advanced power generator and storage programs at GE (including molten carbonate fuel cell power plants); and
- other GE energy programs such as fuel cells, magnetohydrodynamics (MHD), OTEC, solar photovoltaic and thermal electric, wind power, and the liquid metal fast breeder.

In many instances, technological advances in the metallurgy required for these processes were cited as key objectives in GE's research.

Department of Energy

The ASEAN team's first day in Washington, DC., was spent at DOE Headquarters where they were welcomed by John Treat, Deputy Assistant Secretary for International Energy Resources. Brief presentations were given on:

- renewable energy resources (by the National Academy of Sciences);
- industrial conservation (DOE);
- solar power economics (Institute for Energy Analysis);
- alcohol and other biomass fuels (Resources for the Future);
- energy resource data banks (U.S. Geological Survey);
- atmospheric fluidized bed combustion (Nuclear Utilities Services, Inc.);
- coal conversion technology (DOE);
- country energy assessments (DOE);
- utilization of small hydro resources (DOE); and
- geothermal energy (DOE).

Discussions were structured so that most of the time was spent on questions and answers, and spontaneous discussion. Each speaker distributed written materials and their presentations were received with considerable interest by the ASEAN team. The presentation on DOE's Industrial Energy Conservation Program by its Director, Doug Harvey, sparked what may have been the day's most productive session, partially because the ASEAN team's itinerary had emphasized energy production technologies and partially because DOE's program is so extensive.

Several ASEAN officials felt the presentation on energy assessments by Robert Jackson of DOE's Office of International Affairs was especially useful since they knew very little about DOE's activities in this area. This program assists nations in evaluating their energy needs, uses, and resources. The program is designed to suggest alternative energy strategies that are consistent with the host government's economic development goals. Managed by DOE, cooperative assessments have been carried out in Egypt, Peru, Argentina, Portugal, and Korea but none so far in an ASEAN country.

ASEAN-U.S. Business Council

The next day the ASEAN team went to the offices of the U.S. Chamber of Commerce where they were met by William E. Tucker, Vice-Chairman of the U.S. Section of the ASEAN-U.S. Business Council and President of the Caltex Petroleum Corporation, as well as other U.S. members of the ASEAN-U.S. Business Council. An ASEAN representative gave a brief summary of the team's tour followed by a presentation by Mr. Tucker on energy in the 1980's. He pointed out that over-dependence on oil has already resulted in serious economic dislocations and, if the world does not reduce this excessive dependence, it will soon face increasingly intractable economic stagflation in the developed countries and slower economic growth with inflation in the developing nations. Current technical capabilities make a transition to alternative sources of energy possible, but formidable sociological and institutional obstacles must be overcome if this is to be achieved successfully. A major theme of this session was that continued government-business cooperation can make a substantial contribution to efforts by the U.S. and ASEAN to solve energy problems at both the national and regional level.

Department of State

One of the ASEAN team's most important stops was at the Department of State where they were welcomed by Anthony C. Albrecht, Deputy Assistant Secretary for East Asian and Pacific Affairs. The DOE representative, Tom Cutler, and several of the ASEAN energy experts summarized their impressions of the facilities visited and the technologies studied after which a general discussion ensued. Some of the objectives for a long-term cooperative energy program suggested by AID officials were:

— expanding knowledge on present and future energy requirements and options;

— increasing the exchange of technical energy information;

— enhancing educational and institutional capabilities in alternative energy technologies and energy demand analysis and management; and

— improving the planning, implementation, and evaluation of alternative energy demonstration projects.

The U.S. participants offered the following as prime areas for interaction:

— ASEAN energy demand sector analyses (e.g., cooperative studies of energy use in transportation, agriculture, and industry);

— energy conservation programs in selected industries (e.g., cement manufacture, pulp, and paper);

— ASEAN-U.S. energy information clearing house (lead-country approach by technology); and

— annual catalogue of renewable and non-conventional energy projects, prepared by the United States and ASEAN.

While seeking a suitable framework for a long-term cooperative energy program, the U.S. participants also presented several possibilities for short-term activities:

— technical seminars (e.g., coal assessments techniques, new developments in biomass conversion);

— technical study missions;

— ASEAN energy scholarship program (e.g., at the Asian Institute for Technology (AIT) and other institutions in the region); and

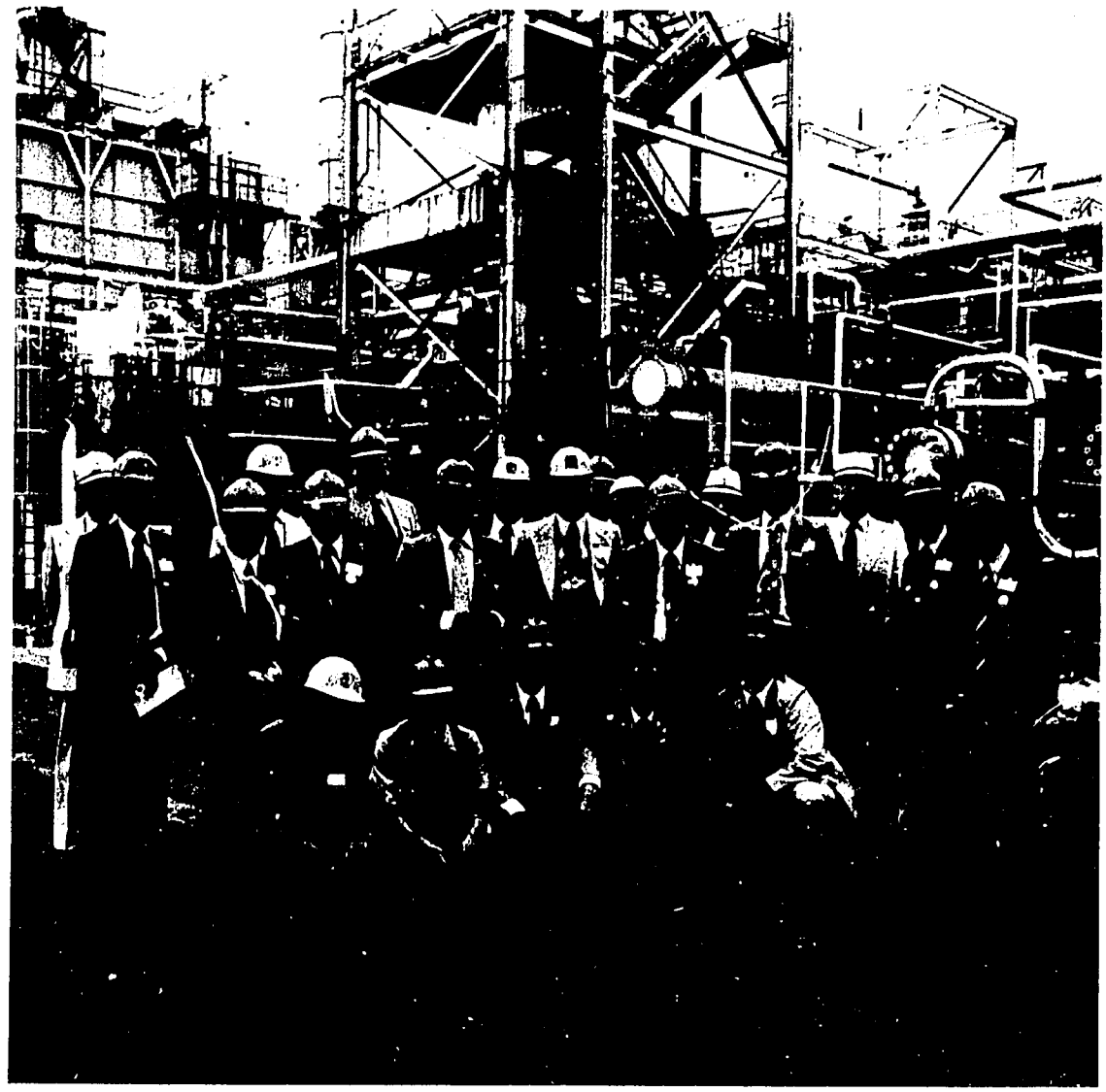
— regional workshops on social, technical, economic, and management aspects of alternative energy technology demonstration projects (particularly in terms of substitution of conventional energy technologies).

The meeting ended with the possibility that the existing ASEAN scholarship program at AIT might be supplemented for the purpose of initial U.S.-ASEAN energy cooperation.

Later, in July 1980, the United State formally proposed an initial project, to begin as soon as practicable, consisting of the following three elements:

1. **Technical Assistance:** U.S. sponsors one energy technology expert at AIT for a period of 2 years. This expert would teach energy courses and be available for consulting and field research in ASEAN countries. Possible areas would be in liquid fuels from biomass, and conservation.
2. **Professional Development:** ASEAN Energy Technology Seminar. Four-week seminar for four participants from each ASEAN country. Possible modules would be:
   — coal gasification and liquefaction;
   — biomass;
   — photovoltaics;
   — conservation technology; and
   — coal resource assessment techniques.

While touring the H-coal facility the ASEAN team paused for a group picture with Ashland officials in front of the liquefaction reactor vessel.



3. **Information Exchange:** Support for AIT's Renewable Energy Resource Information Center (RERIC). Provision of support for RERIC in the form of personnel, publications, mailing expenses, travel, computer time and microforms, acquisitions, equipment, and subscriptions for ASEAN countries.

In conclusion, the visit of ASEAN energy experts was a significant step toward the further development of alternative energy programs between the United States and the member countries of ASEAN. Many of these proposals for energy cooperation emanated directly from the study mission during which areas of potential cooperation were identified. The United States hopes to enhance future relations by adding a new energy dimension to U.S.-ASEAN cooperation as was stated by Secretary of State Edmund Muskie at the June 1980 U.S.-ASEAN meeting in Kuala Lumpur, "We hope to increase our energy cooperation with ASEAN. We hope that the recent tour of the United States by ASEAN energy experts will generate new projects for cooperation, particularly in the area of nonconventional energy sources." This hope was realized in September when the U.S. and ASEAN agreed to begin the initial energy projects at AIT as described above and to continue their efforts to develop a longer term cooperative program in alternative energy.

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