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CHINA, ENERGY, AND INTERNATIONAL ASSISTANCE:

THE DONOR AS RECIPIENT

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The Ironies of History:

I find the very fact of a workshop on China's energy, conducted for the U.S. Agency for International Development in an effort to provide guidance for American relations with the People's Republic of China in the area of international assistance, a remarkable phenomenon. Let us just remember for a moment where we were a short decade ago in U.S.-China relations. In 1970, the questions at a workshop on China and international aid would have been completely different. Much thought and discussion would have been devoted to the issue of the applicability of the "Chinese model" to problems of development in the Third World. Participants would have wondered if China's "path of development," revolutionary in tone and authoritarian in substance, could have much appeal in the grasslands of Africa or the mountains of Latin America. In general, the conclusions would have been (and were at the time) that China's path of revolution, self-reliance, and mass mobilization would have difficulty taking root elsewhere in the Third World, that China's international aid program was a mixed success smoothing relations with friendly Third World nations but doing little to develop new friendships, and that particularly in the wake of the Great Proletarian Cultural Revolution there was little prospect that Peking would successfully export Mao's revolution to other corners of the globe. None of these issues, just one decade later, would appear to have any relevance at all, either to China's political future or to problems of international assistance. Indeed, the China of 1980 is a strange progeny born of Mao's peasant revolution and Stalin's industrial revolution, a prodigal son who speaks of social and economic modernization and promises democratic reforms, justice before the law, and some measure of freedom.

If the truth be known, none of the early American pilgrims to China's shores had any idea of the pace at which the new relationship would unfold. I remember vividly the evening of July 16, 1971. I was sitting with a group of my colleagues in a hotel in Peking having dinner. Our group was the first delegation of American scholars to have visited the PRC in more than twenty years.[1] The waiter came in with a big dish of Sichuan shrimp (very hot) and calmly announced that Henry Kissinger had just made a secret visit to Peking while we were out touring the countryside and that Nixon would be visiting China to discuss normalization of relations within a few months. The utter astonishment with which we received that dish of Sichuan shrimp lasted for a decade and has afflicted visitors from both sides. You could read the same look of wonder on Deng Xiao-ping's face as he peered out from under a massive white Stetson during his visit to the United States in February 1979. The image of Texas Deng flashed across countless front pages in newspapers around the world.

In 1970 the ships of most countries gave China a wide berth as they plied the waters between Yokohama and the Strait of Malacca. In 1980, seismic exploration vessels owned by American oil companies are shooting lines in joint exploration zones along the Chinese continental shelf. In 1970 it was barely legal for an American citizen to visit the PRC. In 1980 the Defense Department is openly considering technical assistance to Peking's military modernization program. In 1970 hundreds of millions of dollars of frozen Chinese and American assets lay gathering dust in forgotten bank accounts. In 1980 the U.S. Export-Import Bank is busy extending $2 billion in direct credit to American companies that want to do business with China. These contrasts are essential to our understanding

of the sudden transformation of relations between the United States and China and to our deliberations regarding the role of technical assistance to China from the United States and from China to various countries of the Third World. We must begin with an understanding that the astonishing pace of development in political and economic relations between the United States and China is neither a historical accident, nor a series of discrete and unconnected events. Rather, the pace and intensity in the new Sino-American relationship is a direct reflection of broader changes in the international environment. In 1980, the international community is experiencing three major crises and must respond with programs directed toward orderly transitions in energy policy, economic policy, and security policy. The new relationship with China just happens to sit at the intersection of the energy crisis, the global economic crisis, and a new basic shift in the strategic balance.

The energy development of the PRC, its international energy relations with other countries, and its potential role in energy-related international assistance programs are all conditioned by the pressure cooker of Sino-American relations and by the broader international context of the energy crisis, the economic crisis, and the shifting strategic balance. I would like to put forward several propositions regarding China's potential role in international energy assistance programs and then go on to review the history of international aid programs that have affected or been affected by China's energy development.

Proposition 1: The donor is the recipient. China is one of the very few countries in the world that is in a position to both give and receive technical assistance in energy development. Indeed, over the next decade or two, China's effectiveness in

giving energy aid may be conditional in part on Beijing's ability to absorb advanced foreign energy technology.

Proposition 2: International assistance for China's energy development is good for the American economy and for the international economy. Encouraging a rapid pace of energy development in China would have minimal harmful side effects on American industry and a beneficial impact on U.S.-China trade, and on international trade more generally.

Proposition 3: International assistance for China's energy development is in the security interests of the United States and the industrial democracies.

Proposition 4: Any form of international assistance to China should be conditional on progress in U.S.-China relations, including both economic and political conditions.

Let us return to a discussion of each of these four basic propositions in the sections below. It is important to make these points at the outset in order to draw attention to the direct link between China's efforts to acquire foreign energy technology and Beijing's own energy aid programs in other countries. This link between receiving and giving energy aid has been present since the inception of the Chinese energy development program some thirty years ago. American aid policy toward China should be founded on the understanding that the PRC is both a donor and recipient of international assistance, and that this double role in international assistance programs is likely to persist over the next several decades.

China and Energy Aid -- A Short History:

Foreign visitors to China often note that Chinese energy production equipment and energy technology bear an unmistakable resemblance to Soviet prototypes. The resemblance, particularly of older equipment, is no accident. Soviet technical assistance to Chinese energy industries began soon after the establishment of the People's Republic. In February 1950, the two countries signed the Sino-Soviet Treaty of Friendship, Alliance, and Mutual Assistance during Mao's visit to Moscow.[2] The Soviet Union provided heavy assistance for the development of China's fledgling petroleum industry during the 1950's. Whereas Western oil company geologists had dismissed China's petroleum resource potential as negligible, Soviet geologists launched a massive search for oilfields, identifying the principal Chinese sedimentary basins, conducting aerial magnetometer and gravimetric surveys, and training thousands of Chinese geologists in special institutes. It is rumored that a Soviet team in 1956 discovered what later became the Taching oilfield complex on the Sungliao Plain, although the Chinese have always denied the rumor. It is known that Soviet technicians participated in the expansion of Yumen oilfield, the development of the oilfield at Karamai in Xinjiang Province, and the construction of China's first major oil refinery at Lanjou.
It is still not known what proportion of this assistance to the Chinese oil industry was provided gratis as aid, and what proportion was reimbursed through trade or direct payments. Here again the Chinese and Soviet versions differ considerably.

Concurrent with its early program of technical assistance to the Chinese petroleum industry, Moscow also exported critical refined petroleum products to China throughout the 1950's, providing about 50 percent of

Chinese petroleum product needs and peaking at exports of three million metric tons of gasoline, kerosine, diesel fuel, and lubricants in 1959 and 1960. Early Chinese refineries had no catalytic cracking facilities and produced only very small quantities of the distillates from the relatively heavy Chinese crudes available from domestic fields. This made China directly dependent on the Soviets for critically needed fuels, despite the fact that coal constituted the main fuel so that China never imported more than 3 percent of total commercial energy consumption, even at the height of dependency on the Soviet Union. The PRC produced enough bituminous coal to export about 200,000 metric tons per year to the Soviet Union in partial payment for imported petroleum products.

The Chinese also received considerable technical assistance during the 1950's from the Soviet Union and Eastern Europe (particularly Poland) in the development of the coal industry. Many Chinese mines today bear the imprint of Soviet design, along with a mixture of equipment imported from Western Europe and produced in domestic machinery plants.

Russian participation in the development of the Chinese electric power industry was not an entirely happy experience. The Soviets got off on the wrong foot by marching off with Japanese generating sets left at Manchurian hydropower dams during the evacuation in 1945. After the Chinese revolution ended in 1949 with victory over the Kuomintang, the Russians offered to help in the construction of both thermal and hydropower stations. But Soviet designs were not always adaptable to Chinese conditions. One of the giant hydropower projects designed by Soviet engineers, the San Men Gorge project on the Yellow River (Huang He) near Xian, silted up almost immediately and had to be redesigned and reconstructed at enormous cost.

Moscow also helped China develop its nuclear energy program, much to the regret of later generations of Soviet leaders. Under an agreement signed in 1955, China received technical assistance in locating and mining uranium deposits. The Soviets also helped in the design and construction of the Lanzhou gaseous diffusion plant, which subsequently became the hub of China's nuclear weapons program. No nuclear power reactors were ever developed in China under Soviet tutelage, but the Russians did provide a 10 megawatt experimental reactor for the production of radioactive isotopes and the training of Chinese scientists. There is little question that Soviet technical assistance greatly accelerated the development of a Chinese nuclear arsenal. Moscow's refusal to provide a prototype atomic bomb, as stipulated (the Chinese claim) in the agreement of 1955, was one of the factors that led to the political rift between the two countries in the late 1950's.

If Soviet technical assistance to Chinese energy industries was sometimes a mixed blessing, the abrupt departure of Soviet technicians in 1960 was an unmitigated disaster for China's energy development. The Russians not only took their blueprints and expertise home with them, but also canceled or delayed the delivery of key items of equipment for a wide range of Chinese construction projects. The export of refined petroleum products was not cancelled immediately, but tapered off over a three-year period to insignificant levels. The combined effect of Mao's mobilization strategy during the Great Leap Forward (1958-1960) and the withdrawal of Soviet assistance was to plunge the Chinese economy into a deep depression that lasted for three years (1960-1963) and was followed by a partial recovery (1964-1965) before the Cultural Revolution (1966-1969) once again sacrificed the economy to Mao's search for a radical road to

some undefined revolutionary utopia. Among Chinese energy industries, the coal industry and the electric power industry were hardest hit by the loss of Soviet aid. Coal production dropped at least 100 million tons per year between 1960 and 1961 and did not recover to previous levels until 1970. Total electric power output remained constant at about 30 billion kilowatt-hours per year between 1959 and 1962 before resuming annual growth. Large hydropower projects, such as the giant Liujiaxia power dam, were delayed for a full decade before construction could be completed while the Chinese replaced critical Soviet components with equipment of domestic design and manufacture.

The petroleum and nuclear industries fared better in the wake of the Soviet aid withdrawal than the coal and electric power industries. The oil industry was saved by the discovery and development of Daqing oilfield. Russian geologists had completed survey work at Daqing and were just about to initiate test drilling when they were ordered to leave in February 1960. The Chinese government, recognizing its vulnerability in the face of dependency on Soviet refined petroleum, placed development of Daqing and the oil industry at the very top of their priorities from 1960 through 1965. 100,000 Chinese workers were rushed to the Sungliao Plain to "smash open the earth with (their) fists and dump our backwardness in petroleum into the Pacific."[3] Crude oil output doubled from 1960 to 1965 as Daqing came on line. This did not prevent a serious shortage of refined petroleum products in the early 1960's, when many trucks and buses were converted to methane or natural gas carried in great canvas bags on the roofs of the vehicles.

The nuclear weapons industry was also carefully protected after the withdrawal of Soviet aid. China exploded its first fission device

on October 16, 1964 and the development of fusion weapons followed close behind. There is some speculation that Czechoslovakia may have provided China with uranium refining (not enrichment) assistance prior to the detonation of the first Chinese nuclear weapon.[4] Beijing carefully shielded its tiny community of nuclear scientists from the ravages of the Cultural Revolution, and from subsequent political disruptions.

The entire course of energy development in China was directly conditioned by the Chinese experience with Soviet technical assistance. From 1960 until 1970 Beijing was completely isolated from both the Soviet bloc and the West. A small amount of energy plants and equipment -- refinery components and generating equipment in particular -- was imported from Italy and other West European countries in the early 1960's. Even the Soviet Union continued to sell China a few electric power generators each year, trade which continues today. But border tensions with the Soviet Union and the war in Vietnam effectively isolated the PRC over a period of ten years. At the height of the Cultural Revolution, Beijing isolated itself from the rest of the world as well, as only a single Chinese ambassador (to Egypt) remained at his post.

The extreme isolation and xenophobia of the 1960's in China led the Chinese leadership toward the most extreme interpretation of the concept of "self-reliance," in both energy and industrial development. The concept underlying self-reliance, that China should control its own political and economic destiny, had been a central theme in Chinese development since the "self-strengthening movement" of the mid-nineteenth century. Economic self-determination remains a powerful force in Chinese planning today, and should not be underestimated by foreigners seeking to do business with China:

> "The use of foreign funds for importing technology and equipment must be combined with domestic scientific research and manufacture. Comrade Zhou Enlai pointed out long ago: With regard to imported technology and equipment, we must study them, use them, improve them, and create new ones. Equipment should be introduced simultaneously with technology. From now on, we should not only import necessary technology and equipment, but, what's more important, make great efforts to train and build up our own scientific research force and our capacity to manufacture our own equipment." [5]

The spirit of economic self-determination is far from dead in the China of 1980, and I would anticipate that it will remain a central feature of Chinese energy planning, either under the rubric of self-reliance or under some other label, in the decades ahead.

During the 1950's and 1960's, the People's Republic of China also became a giver of economic and military aid, at first in tandem with Soviet assistance programs and later in direct competition with Soviet aid. Sino-Soviet competition during the 1960's doubtless greatly accelerated the pace of Chinese aid in the Third World, in Eastern Europe, and in Vietnam and North Korea.

Chinese economic aid to Third World countries tended to focus on a few dramatic programs, such as the Tanzam Railway project. But there were in addition a number of smaller Chinese projects, including some energy projects, particularly the construction of electric power plants. During the 1970's, the PRC assisted in the construction of the Bouenza hydropower station and transmission lines in the Congo, worked on power station construction in Equatorial Guinea and Ethiopia, and assisted Tanzania with geological exploration and development of a coal mine at Tukuyu.[6] There are periodic rumors that Lybia and Pakistan have requested Chinese assistance with the construction of nuclear facilities, although I have never seen any concrete evidence that Beijing has been forthcoming with technical assistance of any sort in the nuclear field, other than in the training of nuclear scientists. This sort of assistance remains

a risk, however, as long as the PRC refuses to participate in international nuclear control agreements and insists on its policy of unilateral constraint in the spread of nuclear technology.

Geographic proximity is a very important determining factor in Beijing's international energy policies. Energy relations with market economy countries in Asia have been conducted on the basis of trade agreements, rather than aid projects, but often the export of energy commodities (crude petroleum, refined petroleum products, and coal) to Southeast Asian nations has been at concessionary prices. China exported coal to East Pakistan from 1957 until 1975, trade that was interrupted when Bangladesh achieved independence.[7] Significant quantities of refined petroleum products (primarily diesel fuel) have been exported to Hong Kong since the mid-1950's and to Thailand since 1974. The PRC has exported crude petroleum to the Philippines since 1974 and to Thailand since 1976. Beijing is currently committed to continue this trade at about one million metric tons (8 million barrels) per year each to the Philippines and Thailand through the mid-1980's.[8] In the case of each of these trade agreements, China offers price concessions for the first few years with the understanding that the price will reach normal market levels as the trade matures. Both the Philippines and Thailand have had trouble refining the heavy and waxy Chinese crudes and must mix it with lighter crudes before processing in local refineries. This practice puts a low ceiling on the quantity of Chinese crude that either country could accept from the PRC, unless China's offshore crudes prove to be easier to handle.

Beijing has not to date participated in any large-scale technical assistance programs or energy construction projects in the market economy countries of Southeast Asia. Political and economic relations with the

ASEAN countries are currently quite warm, despite some residual fear in Thailand, Malaysia, and Indonesia that China might once again accelerate its support for communist guerilla groups that continue to resist central government authority. Beijing has exchanged technical delegations with several ASEAN countries, an activity that is often a prelude to technical assistance programs. I believe that the PRC could potentially be of great assistance in ASEAN energy development, a subject to which I return below.

Sino-Soviet rivalry was nowhere more apparent than in China's energy relations with North Korea and Vietnam. Concessionary export of energy commodities to China's communist neighbors was an important element of this energy relationship. Oil exports to North Korea began in 1964 under the terms of a 1963 agreement, and oil exports to Vietnam were initiated in 1965.[9] The exact volume and composition of this trade are still unknown, but based on fragmentary intelligence reports available to the public, I believe that oil exports to North Korea and Vietnam were primarily in the form of refined products and ran at between 0.5 and 1.0 million metric tons per year to North Korea and between 0.2 and 0.5 million tons per year to Vietnam. In both cases a pipeline was constructed across the Chinese border and in both cases much of the oil was at least partially refined on the Chinese side of the border. In both cases, the oil was offered at far below market prices. Oil exports from China tended to fill in a gap between what the Soviet Union was willing to sell each of the two countries and the greater amount that each wanted to obtain.

China's oil exports to North Korea continue today. But exports to Vietnam were cut off in early 1978 because of the acrimonious dispute between Hanoi and Beijing that developed following the communist victory in Vietnam. The Chinese dispute with Vietnam had many elements, including

a Vietnamese tilt toward Moscow in security relations, harsh Vietnamese treatment of Chinese merchants in southern Vietnam, a troublesome border dispute, and finally the Vietnamese invasion of Cambodia. The Sino-Vietnamese dispute reached the level of open conflict in the Spring of 1979 as Beijing waged its "punitive" expedition and sent massive forces into the northern provinces of Vietnam.

One element of the Sino-Vietnamese dispute that bears some attention here is the question of aid relations. China has provided considerable military and economic assistance to both North Korea and North Vietnam since the 1950's. That aid included Chinese assistance with a number of energy production facilities in both countries. Aside from the construction of the "Friendship Oil Pipeline" across the border, China and North Korea cooperated in the construction and operation of hydropower plants along the Yalu River, which runs along their common border. The PRC may also have assisted in the construction of oil refineries in North Korea, and was said to have offered crude oil to the Koreans at half the price paid for Soviet oil. China provided massive economic and military assistance to Vietnam during the Vietnam War and Beijing has since put the total figure for aid and low interest loans to Vietnam at some $10 billion. In addition to annual oil exports, China assisted in the construction of the 100 megawatt Ninh Binh coal-fired thermal power plant and in several other energy construction projects in Vietnam. Following Hanoi's victory in the war, and with rising tension between the two sides, Beijing reduced the level of annual economic assistance and began shifting items formerly given as aid into the trade column. This reduction of aid then became an element in the dispute, publicly aired in polemics from both sides.[10] Aid relations were severed completely with Vietnam in July 1978.

China's energy relations with Eastern Europe are particularly interesting in the context of energy aid. Political factors dominate energy relations with the East European countries to an extent that exceeds most other regions. China has been both the recipient and giver of technical assistance in energy construction projects in its relations with Eastern Europe. And once again there is a close relationship between programs designed for technical assistance purposes and direct trade in both energy commodities and energy plants and equipment.

Until about 1965, the PRC was strictly on the receiving end of the energy relationship with Eastern Europe. East European countries supplemented Soviet technical assistance programs to the PRC during the 1950's. Poland helped with the development of the Chinese coal industry. Czechoslovakia, East Germany, and Hungary assisted in the construction of electric power plants in China. Romanian equipment was used extensively in China's new oilfields and refineries, and Beijing continues to import drilling rigs and other oilfield equipment from Romania to this day. Since China was cut off from Western trade by the American embargo, virtually all foreign energy technology and equipment was imported from the Soviet Union and Eastern Europe. This reinforced the imprint of the Soviet model on the early development of all Chinese energy industries. As political relations with the Soviet Union deteriorated during the 1960's, China made efforts to keep some access to East European energy technology and increased imports of energy plants and equipment, particularly from Romania. But the Cultural Revolution seriously disrupted relations with East European capitals, and Beijing concentrated increasingly on its relationship with Albania, the only remaining Chinese ally in the region. By 1965, the PRC had reversed the direction of technical assistance,

providing Albania with technical assistance and equipment for several large energy projects (thereby diverting the manpower and components from China's own energy development programs). Beijing assisted in the construction of the Mao Zedong hydropower station at Van i Dejes in 1965, the Fieri oil refinery in 1969, and the Fierza hydropower station in 1971. But during the 1970's, relations with Albania followed the path of relations with Vietnam, and all Chinese assistance projects in Albania were terminated in 1978.

More recently, Beijing has strengthened its energy relations with Romania and added Yugoslavia to its list of political friends in Eastern Europe. China now exports a minor amount of "political" crude oil to both Romania and Yugoslavia along with modest quantities of specialized refined products. Romania continues to provide both technology and equipment to the Chinese oil industry and participated in the construction of the Peking General Petrochemical Works, one of China's largest refineries. The closeness between China and both Romania and Yugoslavia can be measured in direct proportion to the political distance between those two countries and Moscow. If Poland maintains its independence past the current crisis, one would expect to see a similar relationship evolve over time between Warsaw and Peking.

China and Technology Acquisition -- Recent Developments

As stated at the outset, the period since the breakthrough in Sino-American relations in 1971 has been one of astonishing change in internal structure and external relations. An important element of that change has been the radical shift in methods of technology acquisition. Beginning in 1972, immediately after the first Nixon visit and concurrent

with the achievement of diplomatic relations with Japan, Beijing shifted its energy technology acquisition programs toward Japan and the West. The Chinese government began signing import contracts for a growing volume of trade in modern energy plants and equipment, hoping to acquire the technology as part of the deal. Between 1972 and 1978, China imported about $4 billion in energy production plants and equipment. These new orders were balanced almost precisely by foreign exchange earned through the export of crude petroleum to Japan. A wide range of modern equipment and complete plants were purchased, including components and production facilities for the coal industry, the electric power industry, petroleum exploration and development, refineries and petrochemical plants, offshore oil platforms and seismic survey equipment, and a huge array of support equipment for pipelines, ports, shipping, and other facilities. Japan and Western Europe split about 85 percent of this trade evenly, leaving American companies with 10-15 percent of the orders by value. The program was greatly accelerated between 1976 and 1978, following the death and replacement of Mao and Chou, their replacement by the "modernizers" under Hua Guofeng and Deng Xiaoping, and the wholesale purge of the "gang of four" leadership identified with Mao and the Cultural Revolution. During 1978, as the relationship with the United States began to have security overtones and moved toward diplomatic and trade normalization, the stream of orders for foreign energy plants and equipment suddenly overflowed into a torrent of negotiations and contracts for multi-billion dollar development projects in the coal, steel, electric power, and petroleum industries.

The important characteristic of the period between 1972 and 1978 from the perspective of technology acquisition is that Beijing consciously

abandoned the extreme interpretation of technological self-reliance ballyhooed during the Cultural Revolution, shifted the basic prototypes for its energy industries to Western models, and downplayed direct aid and technology transfer as the principal means of technology acquisition. The energy plants and equipment ordered from Japan, Western Europe, and the United States were thought to carry advanced technology with them, as if the crates landing on Chinese docks contained technological and scientific arcana as well as steel components. To be perfectly fair, the Chinese government also sent numerous Chinese teams abroad for training during this period, opened exchange relationships with universities in the United States and elsewhere, and revitalized their own intellectual community which had been smashed by twenty years of abuse and the excesses of the Cultural Revolution. But it was also clear that before 1978 the Chinese government and most of the energy planning minstries believed that the primary route for technology acquistion was the direct purchase of advanced plants and equipment from abroad.

The early bubble of euphoria for direct purchase of energy plants and equipment burst in the early months of 1979. Citing a sweeping "readjustment" in its modernization program, Beijing cancelled or delayed billions of dollars in preliminary contracts signed just months before. A number of factors helped to prick the bubble. Prominent among these were: the realization that China had finite foreign exchange reserves even if foreign credit were to expand radically (which it did); fear that domestic consumption, tight foreign markets, and limited resources would clamp a low ceiling on earnings from the export of crude oil to Japan (which happened); realization that domestic management, planning, and the entire structure of the economy would have to be reconstructed

in order to properly and efficiently absorb the new technology (a process of reorganization which is underway now); and perhaps most importantly, the awareness that advanced technology could not be imported in crates of equipment, but could be acquired more directly (and cheaply) by buying the technology first and then building or importing the equipment to go with it. During 1979 and 1980, Chinese planners shifted sharply in favor of direct technology purchase as the principal strategy for technology acquisition:

> "In the case of complete sets of large equipment imported in the early 1970s, it is estimated that every U.S. dollar spent on imported equipment needed, on an average, an investment of about four yuan (RMB) in ancillary equipment at home. If foreign funds are used on a scale exceeding the ability to provide investment for ancillary equipment, it will hold up the progress of construction and cause serious waste....
>
> ...Most of the complete sets of large equipment we imported in 1978 consume much energy and this has exacerbated the shortage of fuel and power. We must never do this again in the future...
>
> ...In the past we suffered from importing relatively more equipment but too little technology." [11]

The shift toward direct technology purchases is having a staggering impact on China's relationship with the outside world, perhaps as important in many respects as the political and diplomatic openings of the 1972-1978 period. Direct technology acquisition through commerce is an important step toward integration of the massive Chinese economy with the world economy and with the economies of the industrial democracies. In order to implement this step, the Chinese leadership is creating a basic infrastructure of domestic law and organization to interface with the market economy countries. The promulgation of the joint venture law, the Chinese acceptance of international patent conventions, banking arrangements that facilitate the flow of long term credit and cash purchases, the creation of special economic zones, membership in the World Bank and other multilateral financial institutions, and the structure of contracts for joint offshore exploration of China's continental shelf are all

measures designed to facilitate the flow of advanced foreign technology directly into the mainstream of Chinese industry, agriculture, and commerce. It is equally clear that in taking these steps, radical by any measure for a communist country, China is trying to preserve the basic structure of its domestic socialist economy and is attempting to shield that economy from the vagaries of the economic crisis in the international economy. The extent to which Beijing is successful in achieving the twin goals of direct access to advanced technology and protection of the domestic economy remains to be seen over the coming years of this decade.

I want to emphasize, underscore, and repeat that the United States in particular stands to benefit directly and commercially from the shift toward direct technology purchase. It is clear from a close examination of data on energy plant and equipment purchases by the Chinese over the past decade that Beijing prefers the United States as a source of "cutting edge" energy technology and prefers Japanese and European sources for large scale plant and equipment purchases that tend to incorporate now-standard design features. That is, when the Chinese feel a need for standard plant components and "line" technology, they go to European suppliers because of lower prices and concessionary financing. But when they are looking for the most advanced technology, such as seismic equipment, control and communication gear, computers and data processing equipment, and aircraft, there is a strong bias in favor of American suppliers. This is a rule of thumb, not a cosmic law. But it does mean that the shift in favor of direct technology purchases and away from wholesale plant and equipment purchases should run in our favor. I believe that recent trade data would bear out this generalization. Bilateral 1980 U.S.-China trade is expected to be more than 20 percent greater than

for the previous year and should exceed Soviet-American trade by a considerable margin. According to the Department of Commerce, the two largest deals this year between China and American companies are both for the direct purchase of advanced American energy technology (Westinghouse steam turbine technology and Hughes Tool Drill Bit technology).[12] In the case of the Hughes deal, the company would continue to provide a substantial supply of drill bits and parts and would then phase this supply out as Chinese production facilities come on line. In the petroleum industry, direct technology purchase may be accompanied by service contracts, such as seismic surveys or well logging, rather than by supplementary equipment purchases

This development should make obvious the link between China's technology acquisition programs and American commerce (Proposition 2, page 4). The U.S.-China Trade Agreement signed July 7, 1979 and approved by Congress on January 24, 1980 lays out an orderly framework for the direct purchase of American technology needed by Chinese energy industries and for other trade. Patent agreements, tax agreements, Exim Bank credits, and protection for American companies doing business with China through the Overseas Private Investment Corporation (OPIC) are other important elements of a framework for U.S.-China trade in advanced energy technology, and all of these elements are being arranged by the Department of Commerce and other U.S. agencies. There is very little risk that trade in advanced energy technology would damage American industry in the future. Unlike the Chinese textile industry, the electronics industry, or other industries where the United States has mixed feelings about unrestricted trade, there is little prospect that rapid development of China's basic energy industries would foster unfair competition or would flood American markets with foreign products.

This does not mean that American companies should rush into China deals with little or no preparation and no protection for the technology that they offer. Each transaction should be checked in advance to see if it is properly covered by patent agreements, risk insurance, etc. If anything, technology is more vulnerable to appropriation without compensation than plants and equipment. Some types of technology, for example chemical formulas, are not protected by current agreements. To be fair, Peking is making efforts to accommodate the needs of American companies and shows no sign of jumping bail on any of its technology contracts. Beijing used to insist on direct cash purchases of technology in which a 10-20 percent lump sum royalty would be followed by two or three further payments at defined stages during delivery of the technology.[13] But the Chinese are increasing the flexibility of such arrangements and are willing to accept long-term running royalty licenses for certain types of technology. Chinese technicians are taking training at the U.S. Patent Office and increasing their sophistication in the handling of sensitive patents. For its part, the U.S. government should be sharply aware of the problem of retransfer of sensitive (e.g. nuclear) or "dual use" defense technologies to third countries. We would be most unhappy, for example, to find plutonium reprocessing technology (hypothetically) purchased by China from France as part of a nuclear power deal, arriving in Pakistan.

Direct International Assistance (Aid) -- What Role for China?

Beijing's ambitious new programs for technology acquisition through direct purchase of advanced foreign technology leave most questions regarding international technical assistance (aid) unanswered. Is China in a position to offer international assistance, particularly in technically complex energy technologies, to other countries? Beyond strictly commercial arrangements, should the United States provide China with direct economic aid of any sort? What role should China play in multilateral aid programs? What is the link between China's ability to give aid and China's absorption of foreign technology? What conditions should be attached to the sale or giving of advanced Western technology to the PRC? These problems are of concern both to multilateral institutions such as the World Bank or the United Nations Development Program (UNDP) and to agencies in the United States government, the Department of Energy and the Agency for International Development, concerned with programs that might provide assistance to China's modernization program.

There is little question that Beijing has greatly reduced the scope of bilateral Chinese aid to Third World countries since 1978. The number of new projects declines each year, as does the money value of the assistance rendered. Furthermore, China seems to be shifting its own aid programs in the direction of financial assistance through long-term low-interest loans and credits and is channeling much of what remains of the Chinese aid program through international organizations such as the UNDP, the Food and Agriculture Organization, the World Health Organization, and so on. I think that the Chinese government correctly perceives that using established multilateral channels for its own aid programs gets more political mileage by the establishment of a much broader network of

professional contacts and at far lower cost than massive programs like the Tanzam Railway project. New bilateral assistance is being rendered in the form of direct credits from the Bank of China.[14] During 1979 the Bank of China extended some $460 million in credits, including $145 million to a Philippine shipping company, $150 million to the African Development Bank, and $165 million to various companies in Hong Kong. On the other side of the coin, by February 1, 1980, the PRC had received some $26.2 billion in foreign credits including $16.4 billion in Exim Bank credits and government guaranteed loans and another $9.8 billion from commercial banks. Japan is the largest single source of these credits, with a total of $11.6 billion. Although once again credits should be counted as commercial transactions in the strict sense of the word, and not international assistance, the dual Chinese role in both giving and receiving development credits illustrates the link between Beijing's role as a donor and recipient of international development funds. This dual role should expand as China participates actively in the World Bank.

China's dual role as a donor and recipient of international assistance is also visible in Beijing's relationship with the UNDP. By 1978 China had donated $7.3 million to the United Nations Development Program. But in that year the PRC began to request aid from UNDP programs as well. The first request involved a three-year program of assistance in language training and audio-visual equipment for the foreign language schools in Peking.[15] This year the UNDP is helping China establish a computer Information Processing and Training Center in Peking that could become the core unit in a nationwide network of computer facilities for scientific and technological research. By the end of 1980, the UNDP

has $14 million in projects approved or underway, $10 million in pending projects, and perhaps as much as $150 million in programs envisioned for China.[16] In addition, China is discussing or receiving technical assistance through UNESCO, WHO, and the FAO. The United Nations Fund for Population Assistance has one of the largest aid projects in China, a $47.3 million program of assistance for census and family planning programs.

As you well know, American programs of technical assistance to the PRC are concentrated heavily in the energy sector of the economy. U.S. aid to China's coal and electric power industries was first proposed during Secretary of Energy Schlesinger's November 1978 visit to China, just prior to the establishment of diplomatic relations. Vice President Mondale signed a protocol on August 28, 1979 pledging U.S. assistance in hydropower development and water resource management. This protocol for the first time permits a wide range of U.S. agencies to participate in China-related projects. In August 1979, China was redefined as a "friendly country" by the State Department and AID. This redefinition was extended on July 9, 1980 when the PRC was formally moved out of Country Group Y (Warsaw Pact) and into Country Group P by the Department of Commerce. As I understand it, the PRC is still ineligible for concessionary grants and low-interest loans from AID under Section 620 of the Foreign Assistance Act of 1961 which prohibits these forms of direct aid for communist countries. An exemption would apparently require a special act of Congress. But Beijing is eligible already for assistance that is reimbursed on a services rendered basis, and this is the foundation for the Department of Energy programs. Costs that must be reimbursed by the Chinese include the purchase of information, research and development activities, project design activities, and technical training for Chinese specialists in the United States.

Under the terms of the U.S.-China Protocol on Hydroelectric Power and Related Water Resource Management (August 1979), the Department of Energy is responsible for coordination of energy-related projects in the PRC. The Department of Energy is supposed to oversee the farming out of contracts to private U.S. firms for trade in goods and services that would be generated by the agreement. But there is some concern, particularly among American engineering and consulting firms, that the Department of Energy, the Tennessee Valley Authority, and the Army Corps of Engineers may provide the bulk of the technical work themselves at concessionary costs to the Chinese, thereby shutting out the private sector from potentially lucrative contracts.[17] Beijing is particularly interested in getting help in the design of the Three Gorges hydroelectric project on the Yangtze River, a project which if implemented would be the largest hydropower dam in the world with a generating capacity of some 25 gigawatts and annual output of 110 billion kwh. Construction of the dam would require 15 years and would cost $6.2 billion (1980 dollars). The Department of Energy sent a delegation to the site in March of this year, and raised serious reservations about the project, indicating that it might entail many unforeseen technical hazards and could be replaced by 5 or 6 smaller projects with the same generating capacity and at less cost.[18] Despite these reservations, however, private U.S. firms are lining up to get a piece of the action. This raises serious questions about the interface between technical aid programs and private ventures in China, but I doubt that such problems are without precedent in U.S. aid programs generally.

I believe that an element of U.S. assistance policy toward China should be to encourage continuation and expansion of China's dual role

as a donor and recipient of international development assistance. There is probably no way to tie our own technical assistance to the PRC to specific Chinese aid projects in the Third World. But we should make it generally understood in Beijing that American technical assistance with the development of energy industries and other sectors of the Chinese economies should be balanced by Chinese programs in other countries. We might even attempt some joint aid experiments that would involve coordination of technical assistance to certain Third World countries from the United States and the PRC. Such an arrangement might seem bizarre at first glance, given the ideological and cultural distance between China and the United States in their respective approaches to development problems. But in fact it might turn out to be the case that China and the United States have highly complementary assets to offer in the development setting. China is particularly strong, for example, in small-scale energy technology suitable for rural application (see Smil's paper). The United States leads the world in computerized systems analysis of energy problems and in large-scale technology suitable for the urban and industrial sectors.

Some analysts question China's ability to provide technical assistance to other countries in conventional commercial energy industries -- coal, electric power, and petroleum. Citing the lagging condition of China's own commerical energy technology, and the relative wastefulness of energy utilization in the PRC, skeptics suggest that perhaps rural energy development is the only area in which China has much to offer the rest of the Third World. While agreeing that China has particular strength in energy development programs directed toward traditional agricultural and rural problems, I do not accept the argument that the PRC is unable to provide significant assistance in conventional energy development as well.

What, then, does China have to offer the Third World in the development of conventional energy industries? The answer to this question hinges on an understanding that most Third World countries do not require massive infusions of advanced "cutting edge" energy technologies, such as offshore drilling technology, nuclear power plants, or magnetohydrodynamic power generators, at least not yet. The five ASEAN countries, for example, face a serious readjustment in their energy economies over the next decade, but cutting edge energy technologies are not necessarily the answer to their energy development problems. The world is rapidly approaching, or has already entered, an extended plateau phase in the international oil market. That is, the physical volume of crude petroleum available on the world market is very likely to remain constant over the next decade and may decline somewhat.[19] This means that no additional oil is likely to be available for import by the ASEAN countries, at any price. And the price paid for future imports is certain to rise. All five of the ASEAN countries are characterized by very high growth rates (5-10 percent per year) in the modern sectors of their economies -- the cities, industry, and transportation. All of these sectors require additional oil, either imported or domestically produced, in order to continue the rapid pace of expansion achieved over the past decade. Furthermore, economic development generally throughout the region, including the rural sector where most people still live and work, is driven by the engine of high growth rates in the modern sectors.

Two of the countries in the ASEAN group are modest oil exporters (Indonesia and Malaysia). However, the pressure of rising domestic consumption places a ceiling on oil export revenues needed for the rest of the economy and may eventually eliminate oil exports entirely. Some of the oil exported by Malaysia and Indonesia goes to the other three members of

ASEAN (Thailand, Singapore, and the Philippines), all of whom are heavily dependent on oil imports for their commercial energy supply. The plateau phase of the world oil market is already putting serious downward pressure on growth rates in the modern sectors of all of the ASEAN countries, imperiling their entire economic development programs at a critical phase. If there is an absolute limit on the amount of oil available to the region and if that limit has already been reached, then the ASEAN countries must develop indigenous energy industries in order to supply future increments of additional commercial energy to fuel the further growth of the modern sectors of their economies. The governments of the ASEAN countries are seriously engaged in a search for development programs that would meet their commercial energy needs over the next two decades. Those energy development programs have certain common elements:

1. Heavy emphasis on central government planning and government control of capital allocation, within the general structure of decentralized market economies;
2. Discovery and development of indigenous commercial energy resources on a very tight schedule and under severe capital constraints;
3. The introduction of intermediate-technology and intermediate-scale commercial energy producing units that are compatible with the existing industrial infrastructure, that are capital-efficient, and that meet the projected consumption needs of the economy.

This list of requirements for the energy development programs of the ASEAN countries is not at all unfamiliar to students of China's energy and industrial development. Quite to the contrary, the list looks

very familiar and contains some of the basic elements of China's energy development program as that program has been implemented over the past thirty years. It is precisely because of the difficulties of energy development in the PRC, and the Chinese adjustment to those difficulties that Beijing may have something to offer in the way of advice for the energy development of other countries of the region. Take the Chinese emphasis on intermediate technology production facilities, for example in the electric power industry. Chinese factories, operating under what in the West would be considered impossible equipment, supply, and maintenance standards, produce the great bulk of generating equipment used in Chinese power plants. Power generators are mass-produced in many locations according to standard specifications. The generators produced are relatively small, simple, and easy to install. They may not be as classy or as efficient as custom-built U.S. generators, but they are a damn sight cheaper and can be produced now in Chinese factories. The same goes for petroleum equipment and coal mining equipment produced in the PRC. China has and continues to produce the backbone elements of its own energy industries in domestic equipment manufacturing plants. Most of the equipment produced is simple, rugged, and would be considered obsolete in Western industry. But it fits Chinese energy development needs admirably, at least until the PRC begins to require greater efficiency, high-voltage transmission technology, and larger generating units, and comparable advances in other energy industries.

The Chinese "model" may, therefore have applicability in commercial energy development programs in other Third World countries, despite deficiencies in the model itself. The conditions from which Chinese energy development took place are very similar in many respects to

conditions throughout Asia and in other parts of the Third World as well. It is true, of course, that China has an unusually large land mass and is richly endowed with natural energy resources. Commercial energy development involves certain elements of scale and geology which give larger countries a natural advantage. But this fact is simply an argument for greater regional cooperation among developing countries in the exploitation of energy resources and does not eliminate the relevance of the Chinese energy development experience. I would guess, for example, that the aggregate energy resources of Southeast Asia are roughly comparable to those of China and that these resources could supply regional commercial energy needs if properly developed.

Nor am I arguing that "cutting edge" technology is irrelevant to the needs of Third World countries. Several of the ASEAN countries, for example, have substantial geothermal resources. Most energy analysts would still consider geothermal power a "cutting edge" energy technology. But I suspect that for the next twenty years, the bulk of energy development in ASEAN and elsewhere in the Third World is likely to involve the application of conventional commercial energy technologies such as coal mining and hydropower development to the extraction of existing and untapped domestic energy resources. It is precisely in the area of these conventional technologies, operating under severe capital, manpower, and transportation constraints, that the Chinese energy development experience becomes immediately relevant.

Energy, Security, and Conditional Aid:

In closing, let me return to some of the themes and propositions suggested at the outset. I trust that by bludgeoning you with the sheer weight of historical evidence and current analysis adduced in these pages I have convinced you that China has a dual role as both donor and recipient of international assistance in energy development, and that American assistance to the modernization of China's energy industries is good for the American economy and for international trade (Propositions 1 and 2). If you are not convinced, I would be happy to subject you to more of the same treatment.

But what of the other two propositions? How can it be shown that assistance to China's energy development is in the security interests of the United States and the industrial democracies? And what, if any, conditions should be attached to such assistance?

It is now widely recognized in the international community that there is a relationship between international energy problems and international security problems. I call this relationship the "energy-security interface." The energy-security interface is far deeper and more complex than simple security of supply. It is becoming increasingly clear that industrial and military capabilities are contingent on massive commercial energy development, that the security of the industrial democracies is contingent on successful navigation of the transition to non-petroleum fuels, and that energy dependency is a prelude to political impotence. The energy systems of the United States and the other industrial democracies are passing through an era of great vulnerability, precisely at a time when the Soviet energy system is stable, if not efficient; has plentiful if

inaccessible resources; and is supporting the largest program of military production and construction in history.

But even if you grant this grim perception of reality, what does it have to do with energy aid to the People's Republic of China? I am arguing in a number of forums that the world is witnessing the development of what I call "tacit regional security coalitions."[20] These coalitions function without the benefit of formal alliance agreements to provide forums for the airing of common security concerns and to allow the coordination of security policy among countries that may have substantial political or ideological differences. Based on my current research, I believe that there are two tacit regional security coalitions in operation in Asia -- the China-Japan-U.S. triangle, and the ASEAN group. Neither of these groups is constituted as a formal alliance of any sort. And yet there are serious discussions at the cabinet level within both groups of common security concerns, and under the pressure of events such as the Soviet invasion of Afghanistan or the Vietnamese border raid from Cambodia into Thailand, both coalitions are capable of concerted action and policy coordination.

Both the China-Japan-U.S. triangle and the ASEAN group share another critical characteristic. They both function at the overt level through economic cooperation programs that are designed to enhance the prospects for trade and development throughout the region. Because of the importance of the energy crisis to economic development throughout the region, energy cooperation is at the top of the list of priorities for concerted action and interchange in both coalitions. China and Japan have a substantial trade relationship that turns around the exchange of crude petroleum for steel, energy plants and equipment, and other industrial technology and components.

Japan and the United States have a traditionally strong trade relationship and are now cooperating in a $10 billion program of research and development in advanced coal conversion technologies and controlled thermonuclear fusion. China and the United States are exchanging high level energy technology and are cooperating in the exploitation of China's continental shelf. The ASEAN group is also moving toward exchange of experience in energy development and toward the coordination of their national energy policies.

To put the matter bluntly, it is important to the development of our security policy in Asia that energy and economic cooperation within the region prosper. The development of Sino-American energy relations is particularly important in this context. Soviet pressure on the northern Chinese border, Soviet naval expansion in the Western Pacific, Soviet intransigence regarding the northern islands issue and other security matters of concern to Japan, the Soviet use of Cam Ranh Bay and support for the Vietnamese occupation of Cambodia, and other developments in the region provide all the incentive that is needed for the development of the new tacit security coalitions in Asia. But because of the political, ideological, and cultural distance among participants in these coalitions, formal cooperation agreements are limited for the most part to energy and other economic programs. If any evidence is needed that events are moving in this direction, one need only cite recent developments in U.S. policy regarding the sale of military technology to China. Since the invasion of Afghanistan, the United States not only casts a blind eye toward European negotiations with China for the sale of military hardware, but now permits the direct sale of American "dual-use" technology such as computers and communication gear, and "defensive" military support equipment like helicopters, trucks, and weapons racks.

Direct government-to-government technical assistance to China's energy industries has an important role to play in the development of our tacit security coalition with the PRC. Direct aid helps to bridge the distance between private commercial transactions and a coordinated political and security policy. Energy aid to China should be designed in a manner which avoids usurping private technology sales contracts and private engineering or consulting services, but which still controls and manages the key elements of our energy relations with Beijing. We want to be able to step up the pace of energy cooperation when needed to accelerate the growth of a framework for security cooperation, and to set a more gradual pace of energy cooperation if problems develop in political and security relations. This is not simply an effort to keep China on the string or to in any way to interfere with the pattern of China's domestic political and economic evolution. Rather it is a recognition that the relationship between our two countries must be based on mutual accommodation and cooperation, not on a Chinese version of Lend-Lease.

This brings us to the question of conditional aid. As an American scholar, I naturally see the emerging relationship with China from the perspective of the world's largest industrial democracy. I think that few are more committed than the people in this workshop to the prospect of positive and cooperative relations with the PRC and to the hope that China's modernization program will succeed even beyond the expectations of the current Chinese leadership. Nonetheless, there are long-range political risks inherent in the process and in the cooperation between the two countries. Speaking bluntly again, neither country wants to repeat the experience that we are having with the direction of Soviet modernization. Both sides should therefore attach realistic conditions to the further progress of the relationship, even when these conditions are largely unspoken.

Technical assistance and other forms of aid, as amply demonstrated in relations with much smaller countries than China, do not provide much leverage for specific policy objectives. Nonetheless, aid programs can be used to convey a message of general satisfaction or displeasure with the overall state of the relationship and can also be used to signal our own business community regarding the direction of official policy. At the present time our relationship with China is still very much on the upswing, as Beijing promotes the most rapid pace of domestic change of any communist country and as the two countries forge a common strategic perspective on underlying security needs. We should avoid disrupting this atmosphere by meddling in China's domestic evolution or by giving Beijing public lectures on its own foreign or domestic policy. But I think we should also be clear with ourselves that extensive assistance with China's modernization program is conditional on at least the following political and economic conditions:

1. That the present, self-directed, evolution of the Chinese political system continue in a direction favorable to democratic reform and greater openness in Chinese society;
2. That China continue its present cooperative attitude in foreign policy and establish a general political alignment with the industrial democracies that is capable of enduring temporarily adverse conditions in the international system or another shift of regime in Beijing;
3. That Beijing provide guarantees against heavy damage to American industry (e.g. the textile industry) as trade expands;
4. That the Taiwan issue be resolved peacefully on the basis of conditions laid down by both sides in the Shanghai Communique and through direct contact between Beijing and Taipei (particularly important to assistance with offshore oil development in the East China Sea);

5. That Beijing continue to exhibit responsible behavior in meeting contract obligations, protecting patents, and avoiding disruption of international monetary or energy markets;

6. That China itself provide technical assistance and other aid to energy, industrial, and agricultural development in other countries;

7. That sensitive technologies and equipment (military technology, "dual use" technology, and nuclear technology) not be reexported to third countries without our explicit approval in each case.

I doubt that anyone in China would find these conditions difficult to meet, but I'm not suggesting mailing them the list.

This concludes our review of the role of technical assistance and other forms of international aid in the emerging energy relationship between China and the United States and in China's other international energy relations. To restate the theme suggested in the opening pages of this paper, the pace of development in the relationship between our two countries is overwhelming to both sides and may continue to be a bit jolting for the next few years. Even Kissinger may have been surprised by the scope and pace of changes in the Sino-American relationship that ensued during the decade following his historic secret visit to Beijing. But Kissinger correctly perceived that the root of the new relationship is in the changing global strategic balance. Common security concerns, in the last analysis, bring Beijing and Washington together. That accounts for the peculiar intensity of the experience, and for the flexibility that both sides must exhibit in further development of U.S.-China relations.

Footnotes:

1. For an account of this trip, see: Committee of Concerned Asian Scholars, China! Inside the People's Republic (New York: Bantam, 1972).

2. Kim Woodard, The International Energy Relations of China (Stanford, Ca.: Stanford University Press, 1980) p. 51. Much of the historical detail in this paper can be found in my book, which should be available this month (December 1980) from the Stanford University Press, Stanford, Ca. 94305.

3. "Twelve Glorious Years," New China News Agency Daily Report (Jan. 4, 1973) p. B-7. Reprinted in H.C. Ling, The Petroleum Industry of the People's Republic of China (Stanford, Ca.: Hoover Institution Press, 1975) pp. 230-33.

4. Woodard, The International Energy Relations of China, pp. 67, 345.

5. Liu Lixin, "On the Use of Foreign Funds," Peking Review 23, no. 24 (Aug. 25, 1980) pp. 23-25.

6. Woodard, The International Energy Relations of China, pp. 44-45.

7. For detailed statistics on China's energy commodity trade, see: Ibid., Chapters 20 and 21.

8. China Business Review 7, no. 1 (Jan.-Feb. 1980) p. 36.

9. Woodard, The International Energy Relations of China, p. 236.

10. "Time Will Tell the True from the False," Peking Review 21, no. 30 (July 28, 1978) pp. 26-29.

11. Liu Lixin, "On the Use of Foreign Funds," op. cit.

12. David Denny, colloquium at the School for Advanced International Studies, Johns Hopkins University (December 4, 1980). Also: Dori Jones, "China's Offshore Oil Development," China Business Review 7, no. 4 (July-Aug. 1980) pp. 51-56.

13. "Technology Transfer Via Licensing Options," China Business Review 7, no. 2 (Mar.-Apr. 1980) p. 56.

14. James B. Stepanek, "China, the IMF, and the World Bank," China Business Review 7, no. 1 (Jan.-Feb. 1980) pp. 55-63.

15. Kathleen Teltsch, "Peking in a Shift, is Seeking U.N. Aid," New York Times (November 16, 1978) p. A-5.

16. "U.N. Aid for China's Computer Modernization," China Business Review 7, no. 5 (Sept.-Oct. 1980).

17. "Private Sector Balks at U.S. Hydro Agreement," China Business Review 7, no. 3 (May-June 1980) pp. 21-22.

18. Nicholas H. Ludlow, "Harnessing the Yangtze," China Business Review 7, no. 3 (May-June, 1980) pp. 16-21, 23.

19. Fereidun Fesharaki, "Global Petroleum Supplies in the 1980s: Prospects and Problems," OPEC Review 4, no. 2 (Summer 1980) pp. 27-49.

20. Kim Woodard, "The Second Transition: America in Asia under Carter," SAIS Review (forthcoming).

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THE TRAINING FOR ENERGY PLANNING IN THE PEOPLE'S REPUBLIC OF CHINA

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I. THE GENERAL ENERGY SITUATION IN PRC

The People's Republic of China is a developing country known for her vast territory and enormous population. The economy of PRC has achieved great progress since liberation, and is now forging ahead towards the goal of "Four Modernizations" (i.e. modernization of industry, agriculture, science and technology, as well as defence). The national gross industrial and agricultural products and the energy production have increased 13 and 27 times respectively since 1949. About 646 million tons of coal eqivalents (tce) of various energy commodities were produced in the year 1979, among which 70.7% was coal, 23.2% oil, 3.0% natural gas, and 3.1% hydraulic power. At the same time, the PRC is self-reliant on indigenous energy resources and is exporting some of her energy products. However, her population is so large that the energy consumption per capita is still very low, i.e. about 0.6 tec of commercial energy per capita.

The future energy demands of PRC in the course of the "Four Modernizations" will be enormous. It is estimated to be 1.3-1.6 billion tce by the year 2000. the main supply will come from coal and the fractional contribution from oil will still be low as compared with many developed countries. In order to meet such tremendous demands, the PRC has already found plenty coal and hydraulic resources, but the extent of her oil and natural gas resources are still under investigation. However, it should also be noted that the distributions of both coal and hydraulic

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resources are remarkably uneven geographically, and serious transportation difficulties will then arise and the adoption of alternative solutions would be justified. For instance, in one of the richest regions of China, the South-East eight provinces and one city (Shanghai), where lives 36.6% of the total China's population and produce some 40% of the GNP, only 2% of the coal reserves has been found after many years of exhaustive efforts of exploration. Therefore, nuclear power is now considered indispensable for solving the future energy problems in such regions, especially in the province of Guang-dong, Liao-ning and the Eastern China. On the other hand, the ultra-high fraction of coal in China's energy structure will result in serious environmental problems in addition to the very low end-use efficiency. Any attempts to improve such energy structure require substantial increase in the production of oil and natural gas, or large-scale implementation of coal gasification and liquifaction, which will constitute another difficulty in China's future energy strategy.

The problems in rural regions will be quite different. Of the total 970 million population, over 80% live in the rural regions. Non-commercial fuels constitute the major supply there, and such fuels can hardly meet the future demands of the modernization of agriculture. The fraction of commercial energy supply to rural regions is expected to increase considerably, and at the same time the conversion of the biomass fuels into more efficient ones (e.g. biogas) will be carried out at unprecedented large scale. Also some of the non-conventional energy (e.g. solar energy) are indispensable for the solution of our rural energy problems.

Conservation of energy now plays an important role in the energy strategy of PRC. Due to various reasons, both of technical and managerial origins, the end-use efficiency is very low at the present time. The potential of energy conservation could be there-

fore considerable, should appropriate measures be taken to improve the existing situations. Great success has been achieved last year through adjusting the economical and energy structures, as well as technology and management improvements. Million tons of fossil fuel have been saved, yet the production increased steadily.

The energy prospects in China is optimistic, and she will cotinue to take the policy of self-reliant on indigenous energy resources. However, it seems not so easy to solve all the problems, among which including financing, managing and updating in each link of the whole chain of the energy system, from exploration, exploitation, conversion, transportation, distribution, to final utilization. Enormous number of qualified and experienced staffs are needed for carrying out such complex task. Therefore, the training in energy planning and management is considered in China a prerequisite for further expansion of the energy system in PRC.

II. TRAINING NEEDS FOR ENERGY PLANNING IN PRC

The People's Republic of China adopts central planning economy. Consequently there are both long- and short-term plans for each sector of economy. Committees and Ministries of central government compile the national plans, and every provinces and enterprises will work out their own plans accordingly. Thus, the balancing between energy demands and supplies plays a very important role in our national economy. It is recognized now that the lack of scientific methodology and associated data sets has already hindered the compilation of a reliable, complex national or regional plan. The training of the energy planners as well as managers is cosidered vital to our future economical developments.

In PRC the National Committee of Planning has long been set up to be responsible of the compilation of national plans. Recently

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National Committee of Energy has been placed in charge of the planning and managing the production, distribution and utilization of energy commodities. In close connection with the two Committees mentioned above, National Committee of Economy and National Committee of Agriculture are also involved in the energy planning procedures in PRC. National Committee of Science and Technology is now undertaking the research work of both policy and technologies. Besides, under the leadership of the State Council, there are a series of energy-concerned Ministries, e.g. the Ministry of Coal, Oil, Power, Water Conservancy, the 1st and the 2nd Machine Building (Nuclear Power included). Special Departments are also set up in other Ministries, such as the office for Energy Conservation, to handle the energy affairs. As a consequence, the national energy planning itself would connect with hundreds of senior officers from scores of Ministries and Committees. The training of these staffs already presents an enormous effort.

Moreover, the number of the energy planners and managers to be trained in the province and enterprise level will be an order higher than the figures mentioned above. In PRC there are 30 provinces, autonomous regions and municipalities directly under the center government (include Taiwan). These energy planners will face situations as complicated as that faced by the national planners. For instance, the most energy-starving province, Guang-Dong, has a population comparable to that of the FRG, yet her energy consumption per capita accounts less than one tenth of that of her European counterpart. Solutions for such a province are complex enough for energy planners. Besides, the great differences existing in local energy situations make the task even more complecated. Thus,

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one single province, Shan-Xi, possesses more than one third of the national total coal reserves. Another province, Hei-Long-Jiang, produces one half of the crude in PRC. These two provinces serve as bigest energy exporters for the whole coutry. In contrast, many provinces in East and South China have to import tens of million tons of fossil fuels from thousands of kilometers away. Thus the compilation of a regional energy plan would be no easier task than that of a medium size developing country. Energy planners of such level have to be trained as thoroughly as those for the national planning.

Energy planners and managers will work not only in tens of thousands industry units but also in hundreds thousands agriculture brigades for compilation and implementation of respective energy programs within their enterprises. The effectiveness of the activities in energy conservation and in popularization of non-conventional energy sources (e.g. solar or biogas) depends upon how well the local energy managers have been trained. The total number of such staffs may sum up to several hundred thousands.

In short, the energy planners and managers to be trained in the huge network of economy in PRC are enormous in number and stringent in quality. They can be roughly classified into three levels: i.e. the National, Regional and Institutional; and each level can be subdivided into three grades: High, Medium and Low. The estimated number within each category is shown in Tab.1. The total number sum up to hundreds of thousands, about 0.04-0.06% of the population.

TAB.I. THE DEMANDS OF ENERGY PLANNING STAFFS IN PRC

LEVEL / GRADE	NATIONAL	REGIONAL	INSTITUTIONAL
HIGH	DUTY: National policy-making; examination of National energy plans. POST: Directors of Bureaux in central government and higher. NUMBER: Hundreds	DUTY: Examination and approval of regional energy plans. POST: Directors of Bureaux in provincial government and higher. NUMBER: Thousands	DUTY: Examination and approval of enterprise energy plans and management. POST: General managers of companies or chairmen of the people's communes NUMBER: Tens of thousands
MED.	DUTY: Compilation of National energy plans. POST: Section leaders in energy-concerned Bureaux of central government. NUMBER: Hundreds	DUTY: Compilation of reginal energy plans. POST: Section leaders in energy-concerned Bureaux of provincial government. NUMBER: Thousands	DUTY: Compilation and implementation of enterprise energy plans. POST: Workshop or Agriculture Brigade leaders. NUMBER: Hundreds of thousands
LOW	DUTY: Technical and research work for energy planning. POST: Senior specialists in energy-concerned Bureaux of central government. NUMBER: Thousands	DUTY: Technical and research work for energy planning. POST: Senior specialists in energy-concerned Bureaux of provincial government. NUMBER: Tens of thousands	DUTY: Direct leadership of the production or utilization of energy. POST: Senior specialists in energy-concerned fields in Workshops or Agriculture Brigades. NUMBER: Hundreds of thousands

III. THE PRESENT SITUATION OF TRAINING IN ENERGY PLANNING IN PRC

Energy problems have been attached great importance in PRC for the last 30 years. In accordance with the rapid developments of her energy industries, tens of thousands technical specialists in energy-related fields have been trained in universities and colleges. The science of energy planning and management, however, is still very young in PRC, and only in a few universities and colleges the Departments of Energy Management or Economy Management have been set up in recent years. In the year of 1979, the Energy Research Association of China was proposed to be organized to launch a program for systematical investigations of the national energy policy and making suggestions. The ERA also supports the energy training programs in PRC, for instance, in August 1980, under the sponsorship of the National Association of Science, a series of introductory courses on energy policy were given by ERA to some 1500 senior officers of the central government. (Roughly corresponding to the National- High and Medium categories in Tab.1). General informations about energy planning, management, conservation as well as the scientific basis of non-conventional energy sources were presented systematically in this program. Regional training programs concerning energy conservation and thermal balancing of factories, etc., have also been organized. Some universities like the Qinghua Univ. show interests in organizing more short-term training programs for senior and junior officers.

International cooperation of training in energy planning and management have also been launched in recent years. Three officers for energy planning were sent to the US to study in the training program given in Stony Brook last June and July. More people will be sent there in subsequent years. In Oct. 1980, about 50 officers and specialists attended a training program held in Guang-Dong

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organized according to a bi-lateral arrangement between China and FRG. Training program is also included in the Agreement recently finalized between ERA of China and IER of Stony Brook, USA, for a regional energy planning program in Zhe-Jiang province. Through such cooperation we learn a lot about the advanced experiences of training in foriegn countries.

It should be noted, however, the numbers of energy officers and specialists needed to be trained, as shown in Tab.1, are so enormous that the present training efforts depending mainly on foreign countries are far from sufficient. The task for training tens of thousands of energy staffs will be carried out on a self-reliant basis. A standing organization set up inside China, e.g. in Beijing, will be necessary to operate a national training center to give training programs in our native language to facilitate the enormous participants. This center will also take care of the training of the leaders and lecturers coming from regional training centers from most of the provinces. Then these peoples will be able to operate scores of local training centers throughout China and accommodate thousands of trainees each year.

According to the experiences in the US, such training center had better be operated by some institute in universities which had been involved in the research work for energy planning. Existing educational facilities and teaching staffs could then be utilized to maximum extent through such arrangements. For instance, the Qinghua University, Beijing, has already set up a series of energy related Departments along with the Department of Management. There is also a research group for Energy System Analysis in the Inst. of Nuclear Energy Technology which has involved in the energy policy study and planning activities. This University expressed interests in giving such training programs as a part of her education activity. Besides, this University has enrolled hundreds of

foreign students, which provide the possibility to accommodate also trainees for energy planning from other Asiatic countries.

The number of students for each 2-3 months program will be about 30-40, and different emphasis may be given to different programs. First of all, senior staffs of the central government, who are now in charge of the compilation of the National energy plans and taking part in policy-making, should be trained. For such trainees, the program should consist of basic scientific and economic knowleges and methods in energy planning and policy-making, as well as the informations on world energy situation and the different features of the energy policies of typical foreign countries. Next, the leaders and lecturers of regional training centers will be trained, and they need to know more details in some specialized areas. Examples of typical regional energy planning will be given as exercices, by which the trainees could get familiar with the general methods adopted in regional planning. Thirdly, training programs on specific subjects may be organized to give special knowleges to staffs working in specified areas either for the urgent or the long-term needs, for instance, in energy conservation, rural energy, popularization of non-conventional energy, environment protection for energy systems and some typical regionwise or sectorwise planning. Such programs will be carried out twice a year, thus within five years about 400 trainees will be graduated from the training center.

V. THE INTERNATIONAL COOPERATION OF THE TRAINING IN ENERGY PLANNING

The energy problems are important international issues, so is the training in Energy Planning. The indigenous training center to be operated in China needs some foreign specialists to give lectures

not so familiar to Chinese specialists, e.g. the energy situations in certain foreign countries as well as the world. On the other hand, foreign trainees could be accommodated in such center also to cover the needs of other developing countries not having their own training centers.

Being a developing country, the PRC has to take all necessary tasks within a rather short period. Financing of new projects are always the most difficult problem now encountered. Training in Energy Planning, however, will be costly according to the estimation following some foreign experiences. It is reported some 5000 US dollars per trainee is needed. The living expenses in China may be lower, but taking into account the expenditures needed for inviting foreign lecturers and accepting foreign trainees, together with some initial investments on educational facilities, the cost for training per capita would not differ much in the Chinese case. Therefore a sum of about 2 million US dollars will be needed for the above mentioned five year's plan to train 400 people, and sponsorship from UNDP or other international foundations would be necessary to promote such training programs.

DIGESTERS FOR DEVELOPING COUNTRIES
—WATER PRESSURE DIGESTERS

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DIGESTERS FOR DEVELOPING COUNTRIES —WATER PRESSURE DIGESTER

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Seven million digesters have been set up in our country since 1970. As these digesters were built, great changes have taken place in the rural areas where fuel runs short.

Firewood and straw are common fuels in our countryside. In the countries near mountain areas, every family has to spend tens of work-days in a year for wood cutting, while to those in the plains, fuel is even more lacking that valuable straw is often burnt away.

However, in the countryside, there is a great amount of organic waste to generate methane. Pigs are raised and chickens and ducks are fed by each peasant family, while the production teams feed cattles and possess collective pig farms. Animal and human ordure was composted in manure dumps or put in exposed manure pools to ferment, and then utilized for manure. Besides this, most of organic wastes like crop sticks, fallen leaves and grass are all able to generate methane. When digesters were set up, all these could be degraded in the digesters to generate methane. Digested supernatant and sludge are still good manure. Considering the aspect of nitrogen, reserved nitrogen in digested manure is in greater amomnt than that in manure from ordinary treatments. The reason of this is that ammonia nitrogen evaporation is reduced. Thus the utilization of manure is more reasonable where digesters were set up.

In areas where there biogas is with widespread utilization, prominent effects are attained: work spent on woodcutting and transporting as well as other domestic affairs are saved, treatment of manure and agricultural waste being more reasonable, effective fertility increased, environmental sanitation improved. Hence the utilizing of biogas is well accepted by the peasants.

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水压沼池

What Are Water Pressure Digesters? And How They Work?

Why could we set up millions of digesters in a few years, and how could they play the important role in solving rural fuel problem? It was nothing but we had built digesters of 'water pressure type' instead of floating cover type, with consideration of local conditions, using local construction material, and comparatively simple way of building. Thus we had set up digesters in various provinces, with minimum metal material and low capital cost, and with local rural workmanship.

A water pressure digester is more or less a Kipp's generator (see Fig. 1&2), the digesting chamber and the high position tank of our digester corresponding to the reactor at the lower end and the small global container at the upper part of the Kipp's generator respectively. While in digestion, biogas produced goes up into the gas dome. As biogas pressure increasing, the digested liquid is being pressed into the high position tank through the outlet. Biogas pressure is related with the head of liquid between the liquid levels in the digesting chamber and in the high position tank. This may be shown by

$$P = r\Delta h \qquad \text{.....(1)}$$

where P is pressure of biogas (in cm. water column),

r is gravity of digesting liquid (in g/cm³),

Δh is the head of liquid between the liquid levels in the digesting chamber and in the high position tank (in cm.).

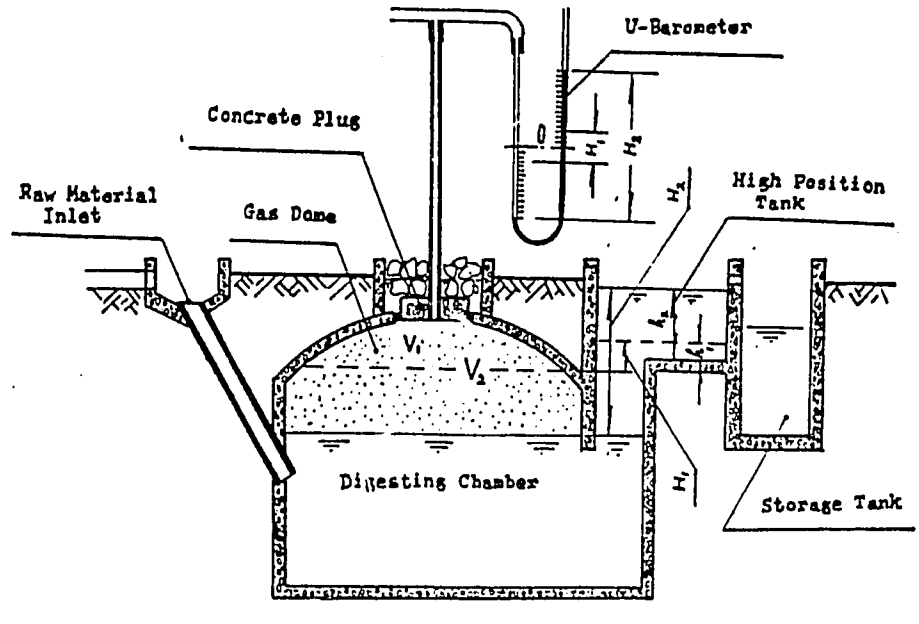

Fig. 1. WATER PRESSURE DIGESTER

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When biogas is to be used, the outlet valve is opened and the liquid in the high position tank moves back into the digesting chamber, thus pressed biogas out through the outlet pipe. The exhaustion of gas continues unti the liquid levels inside and outside the digesting chamber get even. Though the gas dome is still filled with biogas above the liquid level, biogas there could not be used since it could not be pressed out without sufficient pressure. Considering this phenomenum, while designing the gas dome, it is prohibited to make the part of which above null pressure liquid level too large. The condition of design is just to assure the outlet pipe would not be blocked by the scum.

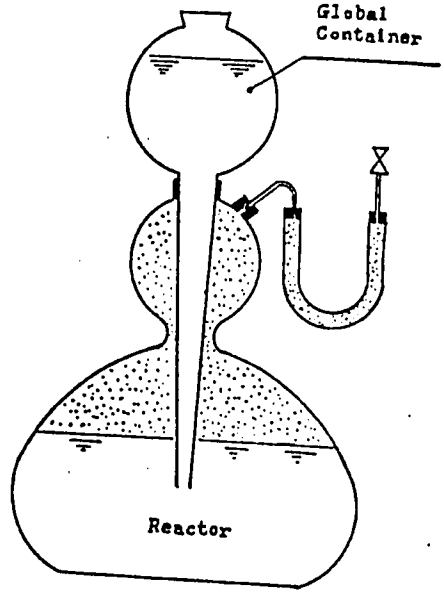

Fig. 2. KIPP'S GENERATOR

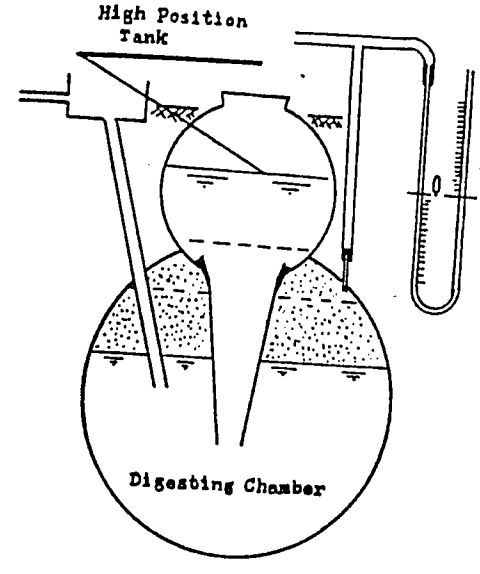

Fig. 3. GLOBAL WATER PRESSURE DIGESTER

It is rather difficult to equip flowmeters in a large scale in the villages to measure the amount of gas produced from digesters. Therefore we had proposed a simple formula for the peasants to count it:

$$V = V_2 - V_1 + 0.001(H_2 \cdot V_2 - H_1 \cdot V_1) \quad \text{(in m}^3\text{)} \qquad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

where V is the gas production (in m^3);

V_2 is the consequent volume of biogas in the gas dome after further gas production (in m^3);

V_1 is the original volume of biogas in the gas dome (in m^3);

0.001 is compress coefficient (in $cm.^{-1}$);

H_2 is the consequent biogas pressure in the gas dome after further gas production (in cm. water column);

H_1 is the original biogas pressure in the gas dome (in cm. water column).

Where $V_2 - V_1$ shows the volume of digesting liquid pressed out from the digesting chamber into the high position tank, thus it may be expressed with the liquid volume increased in the high position tank, that is,

$$V_2 - V_1 = (h_2 - h_1) \cdot F \qquad \text{.....(3)}$$

where h_2 is the consequent liquid level in the high position tank (in m.);

h_1 is the original liquid level in the high position tank (in m.);

F is the area of high position tank (in m^2).

Substitute (3) into (2):

$$V = (h_2 - h_1) \cdot F + 0.001(H_2 \cdot V_2 - H_1 \cdot V_1) \quad \text{(in } m^3\text{)} \qquad \text{.....(4)}$$

As a result of calculation according to common digester sizes, the second item in formula (4) is generally 15—20% of that of the first item. Thus formula (4) may be simplified into;

$$V \approx 1.15 \sim 1.20(h_2 - h_1) \cdot F \quad \text{(in } m^3\text{)} \qquad \text{.....(5)}$$

It is apparent that h_2, h_1 and F in formula (5) are easily measured by the peasants.

The digesters we have are mostly of 'lateral reversed type', that is to say, the high position tank is located at one upper side of the digester, instead of located on top of it.

The digesters of this type are constructed below ground surface, being convenient to feed raw material, to keep higher temperature, and to balance internal fluid pressure to avoid wall material from tensile stress, and steel bar is saved thereby.

Shortcomings of the Water Pressure Digesters

Since a part of digesting liquid is pressed into the high position tank while generating gas, this part of liquid is outside the chamber and gas produced from that part of liquid is out of collection. Furthermore, the possibility of escape of ammonia nitrogen contained in the digesting liquid within the high position tank increased, bad odour of the liquid will contaminate the vicinity. The defect is relaxed with the use of a cement cover.

While generating gas, liquid movement causes a notable head of liquid between the liquid levels in digesting chamber and in the high position tank, and thus the inner surfaces of the digesting chamber bear a considerable outward pressure. If the said head of liquid is 1 meter, the gas pressure within the digester would be 100g/cm^2. However small the pressure would be on the engineering aspect (merely one tenth of an atmospheric pressure), the total press force pressing against the top and the wall of the digesting chamber would surpass ten thousand kilograms, since the surface area of the smallest chambers should be at

least ten square meters. And put the case that the chamber weren't solid enough, that the landfill around the chamber weren't compact enough, that soil covering the top weren't thick enough, then hazard of destruction always occurs. Besides, as gas pressure is high, the demand of anti-leakage rises.

And another defect is that digesting liquid flows in and out of the digesting chamber while the tank is in operation, consequently blockage will happen when the digesting liquid is too thick. To prevent this, the digesting liquid must be dilute, thus brings the defect of low gas production rate. In the province of Guangdong, the average gas production rate of such small rural digesters is around 0.15 cu.m.gas/cu.m. · day (higher in summer and lower in winter).

Despite of the shortcomings, such kind of digesters are widely utilized in rural areas, as many advantages they still possess. They can be built with common material. The construction is simple. Steel and iron are not likely needed. No movable parts exist. And they are durable with proper construction quality.

Building of Water Pressure Digesters

The present living standard of the peasants in our country is still low, and so is their demand for energy supply. One cubic meter of biogas a day is more or less enough for a family of five for cooking and water boiling.

According to the gas production rate of the said digesters, a 6—7 cubic meter digester is well sufficient for the family.

Such small digesters are generally made with bricks or lime-slime-sand 'three-in-one soil' as main material for the digester structure. For a brick digester, the global top is also made of bricks, and the bricks are laid in circles, one circle after another (no mould board is needed).

All the inner walls have to be coated with cement paste and cement mortar to prevent any gas or water leakage. This is especially true for the part of the gas dome, where demands are even higher for coating quality against gas leaking. At the center of the top of the dome, a manhole of 50 cm. in diameter is prepared for construction and maintenance in the digesting chamber. The hole is sealed with clay soil around the slits of a concrete plug, and, the plug should be pressed with rocks, while the sealing clay soil must kept wet to avoid breakage. An aluminum tube is to be set at the center of the plug as a gas outlet. While designing, it should be considered that the top should be built no less than 30 cm. beneath ground surface, in order to make enough rooms for refilling to balance the internal

gas pressure of the digesting chamber. The bottom of the high position tank should be 10 cm. higher than the designed liquid level in the digesting chamber, i. e., the standard liquid level while the gas dome is in null pressure, so that a pressure of no less than 10 cm. water column could be obtained at the terminal period of gas exhausting. The volume of the high position tank should be corresponding to a half day gas production, that is, the said volume of a small digester of 1 m^3 daily gas production can be designed as a little larger than 0.5 m^3.

According to the present condition in Guangdong, the material and work for the building of a 6 m^3 domestic digester are shown in Table 1.

Global digesters are developed recently. The digesting chamber of which are perfect spheres, and the high position tanks are small balls on top of the digesters. Such digesters look more like Kipp's generators (see Fig. 3.). Construction materials run less as the surface areas of the globes go smaller. As the digester structures bear less compressive stress than that of other shapes of digesters, so they are less destructible. In some digesters wooden #-shape cross racks have been set fixed to a position a little lower than the designed liquid level to prevent scum generation. When scum is moving up and down with liquid level, it is reduced to fragments and precipitates.

Digesters With Balloon Gas Holder—Another Kind of Digesters Without Floating Covers

Water pressure digesters mentioned above are appropriate for rural domestic digesters of small size, with a maximum volume of 50-60 m^3 and a daily gas production of ten odd m^3. Further larger ones bring a lot of difficulties in construction and operation. Now we have set up some digesters of tens of cubic meters for production teams, and an experimental biogas power station has been set up at Foshan City. All of these weren't of water pressure type, gas produced was stored in plastic film balloons instead.

PVC films of 0.24-0.28 mm. thickness are welded with high frequency welding to form balloons. Biogas produced from the digester flows into the balloons directly through pipelines, without any need of high position tanks. So that the internal gas pressure of the digester is low, and the hazards of breakage and leakage caused by gas pressure is limited. The digesting chamber is null pressure until the balloon is filled. When the balloon is filled and biogas production goes on, the gas pressure is consequently increasing. To safeguard the balloon, a safety valve is set to limit gas pressure below 3 cm. water column. The safety valve is simple, a branch tube from the pipeline put into water with a depth of 3 cm. will do. When gas pressure surpasses 3 cm. water column, it will not further increase

as gas gets out of the branch tube.

The defect of gas storage with balloon is lacking of gas pressure. Gas pressure is to be increased to expel gas out while using, or a small blast is needed to blow gas. However, if gas produced is to drive a combustion engine, so much the better, since the engine sucks biogas into its cylinders, requesting no pressure of gas. On the contrary, when biogas from a water pressure digester is to feed a combustion engine, gas pressure should be eliminated to avoid gas escaping into the air in the three strokes out of suction, or causing explosive vibration of the engine by overdense biogas in the mixed gas.

The largest balloon being used is about 120 m^3 in size. The balloons are kept in rooms to prevent natural damages. Since chafe of the balloon against the walls will happen when the balloons expand and contract while feeding and exhausting, it is necessary to smooth the inner wall surfaces of the rooms. The longest life time of our balloons surpasses two odd years.

Comparing with steel plate floating covers, the balloons are much cheaper. The 120 m^3 storage balloon costs only ¥450, while a steel floating cover of the same volume costs as high as ¥12,500. In addition, construction, installation and maintenance for the latter are much more complicated. Further, the life time of balloons will be protracted with a matted fibre coat, and thus further overwhelming the steel floating covers.

Table 1. The Materials And Work For The Building Of A Typical 6 m^3 Domestic Digester

Material or Work	Standard	Unit	Amount	Usage
Cement	* 400	kg	366 (231)*	Concrete, Coating.
Lime		kg	88 (350)	"3-in-1 Soil," Mortar.
Sand		m^3	1.73 (1.4)	"3-in-1 Soil," Mortar.
Gravel	2-4 cm	m^3	0.725	Concrete.
Brick	24 × 12 × 6 cm	ea.	795 (166)	Wall, Top.
Steel Bar	ϕ 6 mm	kg	4 (4)	High Position Tank Cover,
Ceramic Pipe	9 in.	ea.	3 (3)	Raw Material Inlet.
Aluminum Tube	ϕ 6 × 400 mm	ea.	1 (1)	Gas Outlet.
Plastic Tube	ϕ 6-8 mm	m	30-50 (30-50)	Gas Tube.
Gas Valve		ea.	1 (1)	
U-Barometor		ea.	1 (1)	
Burner		ea.	1 (1)	

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Material Preparing	Workday	3 (3)
Soil Digging	Workday	3-4 (3-4)
Brick Laying	Workday	8 (2)
Concrete Casting	Workday	1 (1)
"3-in-1 Soil" Packing	Workday	(6)
Cement Coating	Workday	10 (10)
Soil Refilling	Workday	1 (1)
Miscellaneous	Workday	2 (2)
Total Work		31-32 (31-32)

30×8 = 240 人-時

*The numbers in brackets are for a digester using "three-in-one soil" as its main building material.

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A BIOGAS POWER STATION IN FOSHAN
ENERGY FROM NIGHT SOIL

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A BIOGAS POWER STATION IN FOSHAN —ENERGY FROM NIGHT SOIL

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Keywords: Anaerobic Digestion, Night Soil, Electricity Generation

Abstract—A biogas power station has been built in Foshan, Guangdong. It was originally a night soil treatment plant that did not collect any biogas generated. In the year of 1974 it was transformed into a biogas power station with an output of 90 kw. The station has been operating normally for 4 years. Successful experiences have been acquired in the aspects of leak-proof and anti-corrosion on the walls of gas domes of the digesters, gas storage with balloons, automatic overflow to minimize pumping, and making attachments in easy ways.

INTRODUCTION

Nowadays, countries in all parts of the world are paying full attention to the exploitation of energy sources and studying them on a large scale. Energy via bioconversion is an important one of the available energy sources. Scientists of many countries have made wide studies in this field. In rural areas of our country anaerobic digestion has been studied, tested and popularized for years. More than 7 million rural digesters have been built since 1972, and they have brought about excellent results—better solving of the fuel supply problem for commune members, providing more and better fertilizer and improving the sanitary condition of the countryside. In many places biogas is utilized to drive motors and generate electricity. Studies on biogas production from urban industrial and domestic waste water, as well as biogas utilization to generate electricity, are also being carried on.

The Foshan Environmental Sanitary Management Agency, together with this institute, had studied the anaerobic digestion of night soil and the utilization of biogas to generate electricity. And then we transformed the original Junqiao Night Soil Treatment Plant into

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a biogas power station with an output of 90 kw. The plant began to work in thes ummer of 1974, and has been operating normally for 4 years. Although the said power plant is very small, its success provides new experiences for the treatment of urban waste water and for the building and operating of commercial biogas power plants.

Biogas power plants are different from other power plants. As one biogas power plant was built, three plants were functioning at the same time: a power plant, a fertilizer plant and a waste water treatment plant. Hence the building of such plants is a matter of great realistic importance.

TECHNOLOGICAL PROCESS

As the original Junqiao Night Soil Treatment Plant was to treat night soil and provide fertilizer for sanitary and agricultural purposes, while projecting the technological process, we had to consider the original sanitary and agricultural demands, the construction characteristics of the originai treating tanks as well as the local conditions. We tried our best to minimize the reconstruction work, simplify the equipment, convenience the operation and economize the investment. In regard to the digestion process, we made it similar to that of three-stage septic tanks and kept the sludge overflowing automatically from feeding to discharging. The flow sheet of this biogas power plant is shown in Fig. 1.

The raw sludge of night soil is sent to the station by tank trucks every night. After releasing from tank trucks to the feeding basin, the raw sludge runs into the digesters through the channels and the inlets. At the same time, an equal volume of digested sludge overflows from the outlets on the other side of the digesters into the sedimentation tanks. Similarly, an equal volume of supernatant overflows from the sedimentation tanks into the storage tanks. Every morning the digested liquid in the storage tanks flows automatically into the fertilizer boats through valves, drainning channels and a measuring box. When the precipitate in the sedimentation tanks accumulates to a certain extent, it is released periodically, and flows into the fertilizer boats, too. The digested liquid and the precipitate are all sent to the countryside for fertilizer.

Axial flow pumps and pipelines form the stirring equipments. The digested liquid is pumped from the storage tanks to the nozzles of the 'T' tubest submerging below liquid level of the digesters through the pipelines and dividing into two currents, gushes out from the said nozzles to dash against the scums floating on the surfaces of the contents in the digesters. Thence two eddies are formed in every digester and the contents in digesters are well mixed.

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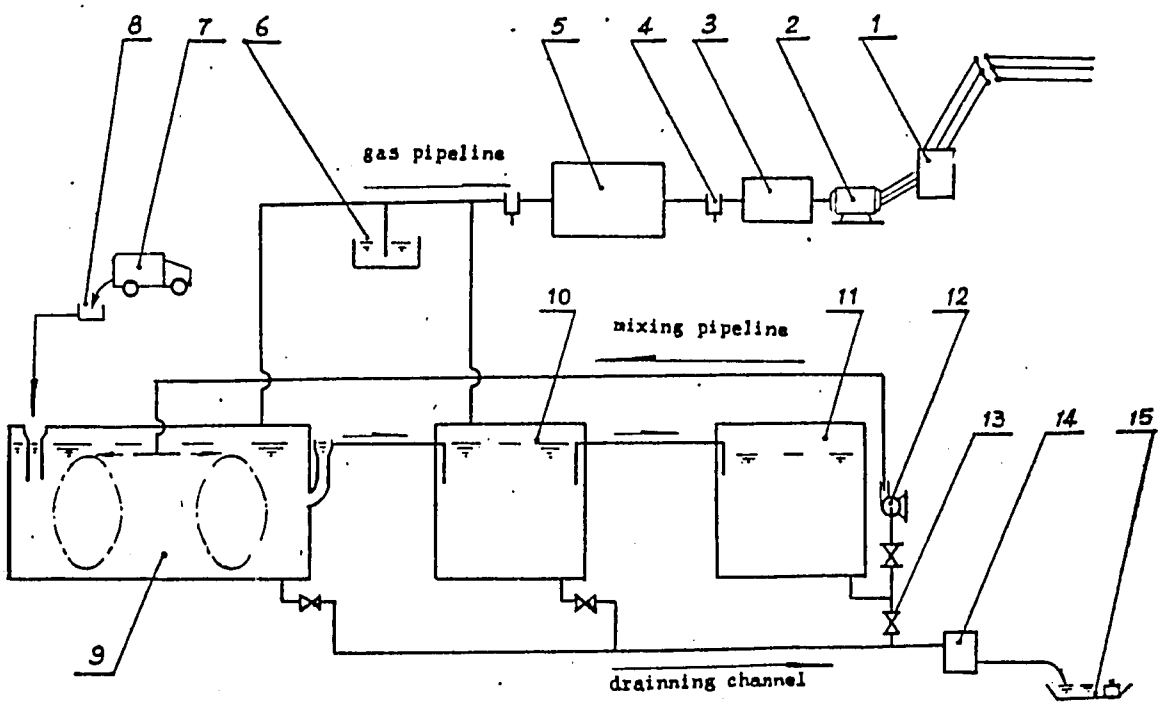

1. Switch board	2. Generator	3. Combustion engine	4. Water seal valve
5. Balloon	6. Safety valve	7. Tank Truck	8. Feeding Channel
9. Digester	10. Sedimentation Tank	11. Storage Tank	12. Mixing Pump
13. Stop-Valve	14. Measuring Box	15. Fertilizer Boat	

Fig. 1. FLOW SHEET OF JUN QIAO BIOGAS POWER STATION

The biogas generated from the digesters flows into two storage balloons and then to the combustion engines. There are water seal valves, which are specially designed, among the digesters, balloons and the engines. The electricity generated by the combustion engine-generator sets is sent to the local power grid through switch boards.

EQUIPMENTS

1. DIGESTERS.

The digesters are transformed from the original rectangular treatment tanks. There are 28 digesters in this power station with a volume of 47 cu.m. each, and the total volume of the digesters is 1316 cu.m. The bottoms and roofs of the digesters are made of concrete and the walls are made of bricks. Ceramic pipes produced locally are used as inlet and outlet pipes of the digesters while PVC pipes as biogas pipelines. In order to prevent any possible gas leakage from the digesters, the inner surfaces of the gas domes are well coated with three layers: the first layer is of common cement mortar, the second layer is of cement mortar mixed with 5% (to cement by weight) of polyvinyl acetate latex and the third layer

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is of cement paste mixed with 10% (to cement by weight) of polyvinyl acetate latex. Furthermore, bituminous painting is used as anti-corrosion coating on the cement paste layer. It has been verified through operating practice of late years that the anti-leakage and anti-corrosion results of these coatings are excellent and no leakage has been found. This is also a successful experience of preventing gas leakage on a large surface of concrete structure without any need of lining plastic or metal plate. The diagram of each digester is shown in Fig. 2.

2. GAS HOLDERS.

There are two gas holders in this plant, with a volume of 120 cu.m. each. Actually, they are two balloons made of PVC film with a thickness of 0.28 mm. Characteristics of the balloon holder are stated as follows:

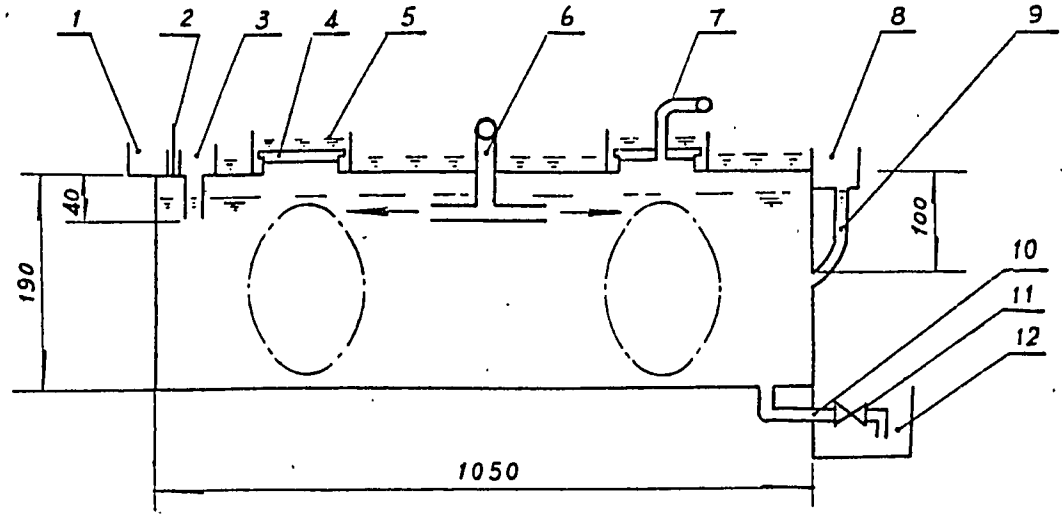
a. The whole gas system kept in an extremely low pressure below 1 mm. water column till the balloons are full of biogas. Even when the balloons are filled, the highest pressure of the whole gas system will be kept at 3 cm. water column by the safety valves. Consequently, the demands on construction of the digesters are limited. The digesters are very easy to be built with common materials and by ordinary methods. For example, the roofs of the digesters in this plant is made of concrete with a thickness of only 5 cm.

b. The materials making the balloons are cheap and easy to obtain. The balloons can be made simply and installed conveniently. The two balloons, having a total volume of 240 cu.m., cost only RMB 900 yuan. Comparing with a floating cover, having a same volume, which would cost as high as 25,000 yuan and still would be difficult to be manufactured and installed.

c. As the pressure of the gas system is very low, it is easy and cheap to make absolutely reliable stop valves and safety valves. (See Fig. 3, water seal valves and Fig. 4, safety valves.)

The balloons should be kept in rooms. The floors, walls and roofs of the rooms should be smooth and clean to avoid grinding through the balloons by sharp things, such as sand. There is no any other requirement besides this. On the contrary, in our case, the floating covers require water tanks of the same volume, because all digesters have their own concrete roofs and no floating covers should be allowed to float directly on top of the digesters. It is obvious that to build a water tank is more difficult and expensive than to build a usual room for the balloon.

At first, we simply joined the openings of the gas pipelines to the balloons, but it did not take very long before we found that the films adjacent to the outlets would stick



1. Feeding Channel 2. Sluice Board 3. Inlet 4. Removable Cover 5. Manhole
6. Mixing Pipeline 7. Gas Pipeline 8. Overflow Channel 9. Outlet
10. Discharging Pipe 11. Discharging Valve 12. Drainning Channel

Fig. 2. DIAGRAM OF DIGESTER

the opening of the gas pipelines and cut the pipelines off due to the suction of the engines. In order to prevent this we inserted the gas pipelines through the balloons from the inlets to the outlets and drill holes on the tubes of the gas pipelines, thus make them like flutes within the balloons.

3. WATER SEAL VALVES AND SAFETY VALVES.

Owing to the exceptionally low pressure of the gas system, we have designed two kinds of special plastic valves (water seal valves and safety valves) which possess many advantages—the producing material being easy to obtain, simple manufacturing, being convenient to operate, being cheap and reliable, no abrasion, and anti-corrosion.

The water seal valve is shown in Fig. 3.

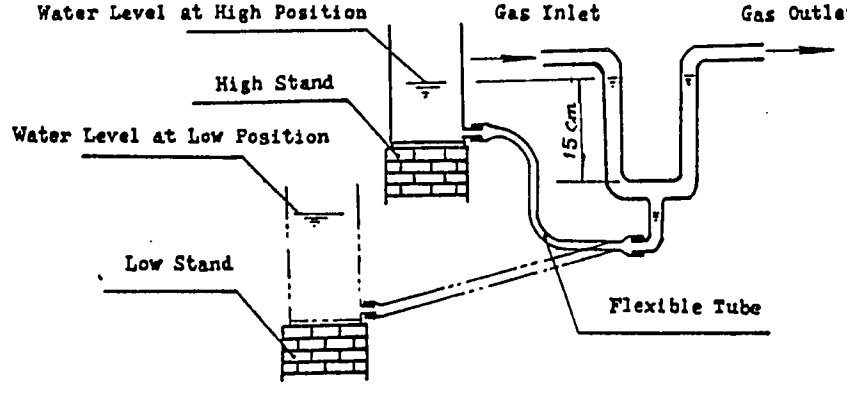


Fig. 3. WATER SEAL VALVE

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A plastic tube is bent into the shape of the letter U. A water seal valve is formed by means of connecting the bottom of the 'U' and a pail with a flexible tube. Two stands have to be built for the pail, one of them is low and the other is high. When the pail is put on the higher stand, the water flows from the pail to the U-tube, thus the water level raises to a height about 15 cm. over the bottom of the U-tube and the valve is closed to cut off the pipeline. When the pail is put down on the lower stand (as shown with dotted lines in Fig. 3.), the water flows from the U-tube to the pail, thus the water level drops to a height below the bottom of the U-tube and the valve is open to make the pipeline through.

The safety valves are designed to guarantee the safety of the digesters and the balloons. The principle is similar to that of the water seal valves. The safety valves are formed simply by connecting several branch pipes to the gas pipelines and submerging the openings of the branch pipelines into water about 3 cm. below the water surface (as shown in Fig. 4.). When the balloons are filled, the pressure of the gas system gradually increases till it reaches 3 cm. water column and then the biogas gets out from the openings mentioned above and keeps the pressure unchanged (at about 3 cm. water column), and prevents the balloons from breakage.

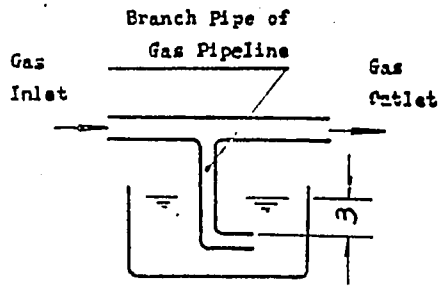

Fig. 4. SAFETY VALVES

4. INTERNAL COMBUSTION ENGINE-GENERATOR SETS.

There are two sets of generators in the station. One is a Diesel engine-generator set rating at 50 kw, the other is a gas engine-generator set rating at 40 kw. Both sets are ignited by spark plugs. The Diesel engine has been reconstructed, the fuel oil injection system has been dismantled; spark plugs are used in place of the nozzles; a distributor, and a mixer (Fig. 5.) for gas were placed in the air inlet, an ignition coil and a storage battery were added. After the reconstruction, the Diesel engine gives good result. There is no need to reconstruct the gas engine.

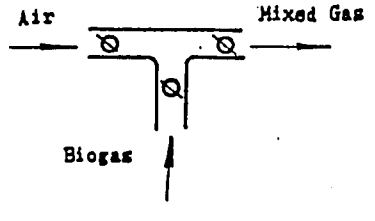

Fig. 5. GAS MIXER

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(2)

OPERATION AND DETERMINATION

1. FEEDING AND DISCHARGING.

The feeding of night soil is 60 tonnes per day and the discharging of digested night soil to fertilizer boats is of the same quantity. Owing to the large quantity of lavatory water, the content of dry material in night soil is merely around 2%, and volatile solid is about 1.7%, so the fluidity of night soil is good. Furthermore, we properly utilized the terrain by building the digesters upon the highest spot to keep the discharging outlet higher than the water level of the river at any time, so that the sludge overflows automatically from feeding to discharging without pumping. Thus made the cost of construction low, the operation easy, and the local power consumption drops down (to 6% of the total power generated), while net output increases.

2. DIGESTION AND GAS PRODUCTION.

According to the design, the detention time of night soil is 22 days in the digesters.

Foshan is situated in the south of Guangdong Province, having a subtropical climate. High temperature period is very long there—about 8-9 months. In this period, the range of temperature of the contents in the digesters is about 25-30°C. In consideration of the speciality of climate and the difficulty of reconstruction, no heater and insulator are built so far. When the content temperature is 30°C, the average daily gas production rate is 0.3 cu.m. per cu.m. volume of tank and the total gas production is about 400 cu.m. per day without stir. When it is stirred continuously, the gas production rate increases considerably, up to 0.55 cu.m. per cu.m. volume of tank per day, and the daily production attains about 720 cu.m. To compare with the case without stir, the production increases by 80%. In winter, the lowest temperature of the contents drops to about 14°C, and the gas production decreases to a half of that in summer.

3. GAS ANALYSIS.

The composition of biogas produced without stir is: CH_4 71-72.5%, CO_2 26-27% and a small amount of H_2S, CO, etc. The data of analysis show that agitation has nothing to do with the composition of biogas produced.

4. GAS CONSUMPTION ON ELECTRICITY GENERATING.

According to our determination to the gas engine-generator set, one cubic meter of gas at 40°C may provide 1.5 kwhr. of electricity, i.e., one cu.m. of gas in standard state provides 1.73 kwhr. of electricity. The total heat efficiency is 24.3%.

5. SANITATION EFFECT.

The expertise of Foshan Epidemic Prevention Center (in Table 1.) shows that the effect of parasite eggs sedimentation in digesters of this station is quite well. It is the same as in the three-stage septic tank. The death percentage of parasite eggs is relative to the detention time of night soil in the digesters. But the value of coli-bacillus is far from the criterion of harmlessness.

TABLE 1. SANITATION EFFECT

Sampling Parts	Number of Parasite Eggs	Parasite Eggs Removal	Die-off Parasite Eggs	Value of Coli-bacillus
Inlet of Digester	396	0%	38.75%	10^{-6}
Sedimentation Tank	116	70.7%	62.8 %	10^{-4}
Outlet of Storage Tank	31	92.2%	68.06%	10^{-3}

6. THE FERTILITY OF THE SLUDGE.

In order to check the change of the fertility before and after fermentation (represented by nitrogen, phosphorous and potassium) to provide a reference datum for the agricultural section, we sent the samples to the Guangdong Institute of Soil and Fertilizer for analysis. The results are shown in Table 2.

TABLE 2 CONTENTS OF N, P, K IN RAW SLUDGE AND DIGESTED LIQUID

Sample	Total Nitrogen	Ammonia Nitrogen	P_2O_5 g/1	K_2O g/1
Raw sludge	1.049	0.620	0.512	0.340
Digested liquid	1.009	0.860	0.204	0.340

As shown in the above table, the content of ammonia nitrogen increases about 40% after digestion, but there is little change in total nitrogen and total potassium. The reason why the total phosphorous reduces so obviously is that part of phosphorous is in state of insoluble compound exists in the precipitate, and the amount of precipitate in the digested liquid is very little.

7. THE EXPERIMENT ON USING WASTE HEAT TO MAKE NIGHT SOIL HARMLESS.

Biogas, after generating electricity, releases a large amount of waste heat. According to our calculation, burning one standard cu.m. of biogas from this station will release 4,600 kcal. of waste heat after generating electricity. Hundreds of cu.m. of gas are consumed in Junqiao Power Station every day. Therefore, a great amount of waste heat can be utilized. Recently, we have made some experiments on using waste heat to heat raw night soil to

make it harmless, and have brought about some expectant results. The night soil, passing through a heat exchanger, may be heated up to 60°C with waste heat, and then the die-off of parasite eggs is 100% while the value of coli-bacillus is 0. These results attained the standard of harmlessness. This experiment is still going on for the time being.

DISCUSSION

1. Agitation may increase the gas production and shorten the detention time. The power for agitation is 2.8 kw. and daily electricity consumed is about 67.5 kwhr. It means that 44.8 cu.m. of biogas is required every day, that is only one seventh of 320 cu.m. of biogas increased from agitation. Obviously, continuous stirring of the fermenting content is favourable.

2. When a digester is cleaned, a very thick scum layer could always be found. In the scum layer there is still much organic matter which has not yet been utilized. The scum not only occupies the volume of the digester but also hinders gas production. This problem has to be solved. There is a possibility to obtain a better result, if a pressure pump is used to rush the scum and stir the digesting content.

3. The preliminary results of the experiment shows that the using of waste heat from gas engine to make night soil harmless is available. In addition, heated raw night soil may elevate digester temperature and thus increases gas production. 充氧化

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