JPRS-CEN-91-001
16 JANUARY 1991

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JPRS Report

Science & Technology

CHINA: Energy

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NATIONAL TECHNICAL INFORMATION SERVICE
SPRINGFIELD, VA. 22161

Science & Technology
China: Energy

JPRS-CEN-91-001 | 16 January 1991

CONTENTS

Work Begun on 500KV Taiyuan Substation

91P60058 Taiyuan SHANXI RIBAO in Chinese 4 Dec 90 p1

[Text] Construction work recently began on China's first 500KV substation just north of Taiyuan City, marking a major stride forward for Shanxi Province in the areas of larger power machinery, higher voltage lines, and larger power grids.

The entire project will cost 116 million yuan, of which Shanxi will pay 60 percent. After the substation becomes operational, its role will be to step up the electricity generated by the Shentou No. 2 power plant and transmitted via the Shentou-Taiyuan 500KV high tension power line.

Hydropower Development in Yunnan; Power Transmission From Yunnan to Guangdong

916B0006 Beijing SHUILI FADIAN [WATER POWER] in Chinese No 9, 12 Sep 90 pp 4-8, 3

[Article by Duan Shihang [3008 0013 5300] of the Kunming Survey and Design Academy: "Research on Hydropower Development in Yunnan and Power Transmission to Guangdong"]

[Text]

I. Introduction

The Kunming Survey and Design Academy began studying hydropower development in Yunnan Province and power transmission to Guangdong in 1984. It also conducted research in 1985 on the economic benefits of hydropower on the Lancang Jiang in Yunnan Province and power transmission to south China and on the benefits of connecting the Yunnan Provincial and South China Grids. In 1986, the academy debated the scope of power supply and targets of power supply in conjunction with the "Program for the Middle and Lower Reaches of the Lancang Jiang". It concluded that the scope of power supply from Lancang Jiang hydropower should be southwest and south China and that the key target of power supply should be Yunnan and Guangdong Provinces. In 1989, with cooperation and support from the relevant units, the Kunming Survey and Design Academy restudied a program for hydropower development in Yunnan Province and grid integration for power transmission. This article will integrate with an introduction of the primary research achievements regarding the transmission of power from Yunnan to Guangdong as a reference for the related areas.

II. Primary Research Achievements

Yunnan Province has abundant hydropower resources and sufficient coal resources, so it is a province of China with superior energy resource conditions. Guangdong Province, on the other hand, has a shortage of energy resources as well as rather rapidly growing industrial markets and investment advantages. Thus, research on transmitting power from Yunnan to Guangdong has been under consideration for many years as a way to foster fully the advantages of each. As for the actual size of the technical economics benefits from transmitting power from Yunnan to Guangdong and how these benefits can be achieved, the answers can be outlined thusly based on the research in this article:

A. Compensation benefits after integrating Yunnan Province's hydropower station clusters with grids in adjoining provinces

This part of the research includes three level years, 1995, 2000, and 2015, for seven types of optimized compensated regulation composed of hydropower station and reservoir clusters in Yunnan, Guangdong, Guangxi, Guizhou, and Sichuan. A series-parallel mixed connection hydropower station optimized dispatching and compensated regulation multi-goal multi-level model and SOMP- RS2 software package was also used. Synchronized hydrological data for 27 years was used for the first four types and synchronized hydrological data for 24 years was used for the latter three types. The primary calculated results are in the following areas:

1. Increased system guaranteed output power

Integrated grid compensated regulation calculations for four hydropower stations in Yunnan (the four cascades on the Yili He and four cascades on the Xier He are each calculated as one station) and five hydropower stations in Guangdong from 1995 show that after the grids are connected their guaranteed output could be increased by 80.9MW (23.1MW in Yunnan and 57.8MW in Guangdong), equal to 7.2 percent of total guaranteed output in these two provinces (1,119.7 MW). Integrated grid calculations for five hydropower stations in Yunnan, seven hydropower stations in Guangxi and on the Hongshui He, and seven hydropower stations in Guangdong for the year 2000 show that after the grids are connected, their guaranteed output could be increased by 245.2MW (increases of 42.5MW in Yunnan, 79.7MW in Guangxi, and 123.1MW in Guangdong), which is 10.3 percent of total guaranteed output (3,982.3MW) in these three provinces (autonomous regions).

Calculations after integration of the grids for 16 reservoirs and 29 power stations in Yunnan, Guangdong, and Guangxi for the year 2015 show that their guaranteed output could be increased by a total of 589.1MW, equal to 6.7 percent of the total. When the grids are connected after the addition of Nuozhadu in Yunnan and Dateng Gorge in Guangxi (17 reservoirs and 31 power stations), the calculated increase in guaranteed output is 568.1MW, equal to 4.7 percent of the total. By 2015, after the grids are connected for 22 reservoirs and 38 power stations in Yunnan, Guizhou, and Sichuan, the calculated increase in guaranteed output is 1,414.1MW, equal to 7.4 percent of the total.

2. Increased power output during dry years, reduced differential between wet and dry years

After integration of the Yunnan and Guangdong Grids in 1995, power output in these two provinces during dry years could be increased by 1.696 billion kWh (790 million kWh in Yunnan and 907 million kWh in Guangdong), equal to 15.7 percent of the 10.764 billion kWh of total power output in these two provinces. After integration of the Yunnan, Guangxi, and Guangdong grids in 2000, power output in these three provinces (autonomous regions) during dry years could be increased by 3.770 billion kWh (3.009 billion kWh in Yunnan, 659 million kWh in Guangxi, and 100 million kWh in Guangdong), equal to 10.3 percent of total power output in these three provinces (autonomous regions). In 2015, after integration of the grids for the 16 reservoirs and 29 power stations in Yunnan, Guangdong, and Guangxi, their power output during dry years could be increased by 9.675 billion kWh, equal to 14.4 percent of total power output in these three provinces (autonomous regions). When the grids are connected after Yunnan adds Nuozhadu and Guangxi adds Dateng Gorge, power output during dry years could increase by 12.950 billion kWh, equal to 14.4 percent of total power output in these three provinces (autonomous regions). When the grids are connected for the 22 reservoirs and 38 power stations in Yunnan, Guizhou, and Sichuan provinces in 2015, perennial average yearly power output in these three provinces could be increased by 1.686 billion kWh, equal to 0.8 percent of total power output in these three provinces. Tables 1 to 3 show the increase in guaranteed output and power output during dry years from integration of two provincial grids for 1990, 1995, and 2000, respectively [as published].

Table 1. Compensated Regulation Benefits from Connecting Yunnan and Guangdong Grids in 1995

Hydropower station	Guaranteed output (guarantee rate 97.5%)			Power output during dry years		
	When divided by province (MW)	After grids are connected		When divided by province (billion kWh)	After grids are connected	
		Total (MW)	Increase (MW)		Total (billion kWh)	Increase (billion kWh)
1. Yili He	193.0	200.2				
2. Xier He	169.9	177.0				
3. Lubuge	110.9	118.3				
4. Manwan	438.8	440.3				
Total for Yunnan	912.7	935.8	23.1	9.542	10.332	.790
1. Xinfeng Jiang	101.7	132.6				
2. Fengshuba	43.3	51.8				
3. Nan Shui	21.6	35.2				
4. Liuxi He	16.3	17.9				
5. Changhu	24.1	27.3				
Total for Guangdong	207.0	264.8	57.8	1.222	2.129	.907
Total for both provinces	1,119.7	1,200.6	80.9	10.764	12.460	1.696

Table 2. Compensated Regulation Benefits from Connecting Yunnan, Guangdong, and Guangxi Grids in 2000

Hydropower station	Guaranteed output (guarantee rate 97.5%)			Power output during dry years		
	When divided by province (MW)	After grids are connected		When divided by province (billion kWh)	After grids are connected	
		Total (MW)	Increase (MW)		Total (billion kWh)	Increase (billion kWh)
1. Yili He	202.8	188.0				
2. Xier He	174.9	166.8				
3. Lubuge	108.2	116.3				
4. Manwan	406.4	437.9				
5. Dazhao Shan	390.4	416.2				
Total for Yunnan	1,282.7	1,325.2	42.5	15.509	18.518	3.009
1. Xinfeng Jiang	111.0	127.2				
2. Fengshuba	46.6	47.1				
3. Nan Shui	22.4	39.8				
4. Liuxi He	16.2	17.7				
5. Changhu	18.8	69.2 (includes Mashi)				
6. Feilai Gorge	55.9	74.6				

Table 2. Compensated Regulation Benefits from Connecting Yunnan, Guangdong, and Guangxi Grids in 2000 (Continued)

Hydropower station	Guaranteed output (guarantee rate 97.5%)			Power output during dry years		
	When divided by province (MW)	After grids are connected		When divided by province (billion kWh)	After grids are connected	
		Total (MW)	Increase (MW)		Total (billion kWh)	Increase (billion kWh)
1. Yili He	202.8	188.0				
2. Xier He	174.9	166.8				
3. Lubuge	108.2	116.3				
7. Lechang Gorge	26.3	44.6				
Total for Guangdong	297.1	420.2	123.1	2.056	2.156	.100
1. Tianshengqiao first cascade	490.6	540.9				
2. Tianshengqiao second cascade	824.3	916.0				
3. Yantan	526.6	510.8				
4. Dahua	268.4	262.3				
5. Xijin	105.2	92.2				
6. Mashi	43.2					
7. Baise	144.4	160.1				
Total for Guangxi and Hongshui He	2,402.6	2,482.3	79.7	18.994	19.653	.659
Total for three provinces	3,982.3	4,227.5	245.2	36.559	40.329	3.770

Table 3. Compensated Regulation Benefits from Connecting Yunnan and Neighboring Provincial Grids in 2015

Number of hydropower stations and reservoirs	Guaranteed output (guarantee rate 97.5%)				Power output during dry years			
	When divided by province (MW)	After grids are connected			When divided by province (billion kWh)	After grids are connected		
		Total (MW)	Increase (MW)	Rate of increase (%)		Total (billion kWh)	Increase (billion kWh)	Rate of increase (%)
16 reservoirs and 29 stations in Yunnan, Guangdong, and Guangxi	8,746.5	9,335.6	589.1	6.7	67.364	77.039	9.675	14.4
17 reservoirs and 31 stations in Yunnan, Guangdong, and Guangxi	12,058.3	12,626.4	568.1	4.7	90.157	103.107	12.960	14.4
14 reservoirs and 25 stations in Yunnan and Sichuan	16,384.0	17,252.6	868.6	5.3	*173.004	)p*171.371	*-1.633	*-0.9
16 reservoirs and 27 stations in Yunnan and Guizhou	9,788.1	10,198.4	410.3	4.2	*95.885	*95.926	*.041	*0.04
22 reservoirs and 38 stations in Yunnan, Guizhou, and Sichuan	19,090.8	20,504.9	1,414.1	7.4	*201.735	)sup*203.42	*1.686	*0.8

Note: *Is power output and perennial average for Yunnan, Guizhou, and Sichuan

3. Monthly output during a year evened out, increased output during dry periods

After the Yunnan, Guangxi, and Guangdong grids are connected, average monthly output during the dry season (November-April) will rise and the differential between maximum and minimum output will be reduced. After connecting the three provincial (autonomous region) grids in 2015, for example, the ratio between maximum and minimum output will be 1.69, whereas during independent operation the ratios would be 1.72 in Yunnan, 2.13 in Guangdong, and 1.83 in Guangxi. The benefits from grid integration are most apparent in Guangdong.

After connection of the Yunnan, Guizhou, and Sichuan grids, average dry season output for hydropower stations in Sichuan, which have rather poor regulation capabilities, would increase 550 to 1,180 MW, an increase of 3.5 to 7.5 percent.

B. Load peak staggering benefits

Because of differences in geographic location, climatic conditions, schedules, and load structures, there will rather obvious peak staggering benefits after connection of the Yunnan, Guangdong, and Guangxi grids. According to analysis and calculations for operating data from 1980 to 1983, the maximum yearly load time rate between the Yunnan Grid and South China Grid is 0.956, so deduction indicates that the peak staggering benefits will be 386 MW in 1995 and 540 MW in 2000. Computer calculations for hourly load information from 1 Jan to 31 Dec 87 for the Yunnan and Guangdong power systems made by Kunming Hydropower Academy and the B.A. Gurevi computation formula from the Soviet Union indicate that the total peak staggering benefit will be 135 to 160 MW when the maximum yearly load in the Guangdong system is 2,792 MW and the maximum yearly load in the Yunnan system is 1,112 MW, which is a relative figure of 3.5 to 4.1 percent. It can be deduced from this that in the year 2000 when the maximum load is 13,000 MW in the Guangdong system and 3,600 MW in the Yunnan system, the total peak staggering benefit could reach 600 to 700 MW. The two peak staggering benefits calculated above are within a yearly maximum load range of 3.5 to 4.4 percent. Although there are differences in the computation methods and data used in 1985 and 1989, the peak staggering benefits as a percentage of maximum load will be about the same. Moreover, because the maximum load projected for 1985 was somewhat low, the number of MW was also slightly smaller.

C. Interconnection and reliability of the Southwest and South China power systems

According to estimates based on current distributions and interconnected electric power system production models for connecting the Yunnan, Guizhou, Sichuan, Guangdong, and Guangxi grids between 2000 and 2015, there would be definite benefits from connecting the grids of these five provinces and autonomous regions, and it would be necessary to connect them together to form a single grid around 2000. The power exchange between Yunnan and Guizhou is rather small. Between Yunnan and Sichuan, it would mainly involve transmitting some electricity from Yunnan to Sichuan during the winter, which also could be supplied to Sichuan from Guizhou. Thus, there does not have to be a direct connection of the Yunnan and Guizhou and the Yunnan and Sichuan grids prior to 2000. They can be indirectly connected via Guizhou. There are three grid interconnection programs for the Yunnan, Guangdong, and Guangxi grids: 1) Yunnan could be connected to the Guangxi grid via a single 500 kV circuit and connected directly to the Guangdong grid via a plus or minus 500 kV DC circuit. The Guangdong and Guangxi grids could be connected via three 500 kV circuits. 2) Yunnan can be connected to the Guangxi grid via two 500 kV circuits (they would already be interconnected via four 220 kV circuits before 2000). Guangdong and Guangxi could be interconnected by two 500 kV circuits and one plus or minus 500 kV DC circuit. 3) Yunnan could be connected to the Guangxi grid via two 500 kV circuits, while Guangdong and Guangxi could be interconnected by four 500 kV circuits. The capacity for transmitting power from Yunnan to Guangdong in Program 1 could be 1,800 to 2,000 MW, and estimates indicate that the pace of electric power construction in Yunnan will not be this rapid. Program 3 would involve more circuits to interconnect Guangdong and Guangxi, which would pose problems for subsequent development, so Program 2 is more favorable for development.

After either the huge Xiaowan or Nuozhadu power station goes into operation between 2000 and 2015, it would be best to use a plus or minus 600 kV DC circuit to transmit power to Guangzhou. When both of these huge power stations go into operation, power should be transmitted to Guangzhou via two plus or minus 600 kV DC circuits.

Interconnection of the Guangdong and Sichuan grids through Yunnan, Guizhou, and Guangxi could improve the power shortage situation and substantially increase reliability. Calculations for appropriate interconnecting circuits indicate that in 2000 Sichuan's LOLE (expected time of insufficient power) could be reduced to 0.08 days/year from 36.44 days/year prior to grid interconnection and its EENS (expected period of insufficient power output) could be reduced to 34,080 kWh/year from 31.25 million kWh/year prior to connecting of the grids. The benefits for Guangdong would be even larger in the year 2000. Its LOLE would be reduced from 354.09 days/year prior to grid integration to 0.10 day/year and its EENS would drop from 4,124,150,000 kWh/year prior to grid integration to 806,954 kWh/year. The computed figures for 2015 to 2020 are approximately the same as those for 2000, but a corresponding increase in connecting circuit capacity would be required at that time.

D. An obvious reduction in yearly operating costs after the grids are connected

A random production model computer program was used to simulate the various production costs for grid connection and independent operation. In the calculations, the difference in power generation costs for hydropower and thermal power stations, the load peak staggering benefits after grid connection, the hydropower compensation benefits, reliability benefits, and other things were combined. The simulated computed yearly operating cost differentials for connection of the Yunnan and Guangdong Grids and for each operating independently showed that grid integration could reduce yearly operating costs by 742 million yuan in 1995, by 1.274 billion yuan in 2000, and by 9.615 billion yuan in 2015. These calculated figures are related to the speed of growth in load levels in Yunnan and Guangdong and to the expected pace of hydropower and thermal power station operationalization. If there are significant differences between actual developments and these forecasts, there may be substantial changes in the figures, but the trend toward reduced yearly operating costs after grid connection can be confirmed.

E. Analyzing power transmission from Yunnan to other areas

Forecasts and research results by the Kunming Survey and Design Academy for hydropower and thermal power construction and load development in Yunnan show that, based on balancing in average water years, the amount of electric power that Yunnan could transmit to other areas would be 20 to 480MW in 1991 (the lower figure is during the dry season and the higher figure is during the flood season, the same is true for subsequent figures), 980 to 1,130 W in 1995, 990 to 1,440MW in 2000, and 2,840 to 3,020MW in 2015. Based on balancing in dry years, the amount of power that Yunnan could transmit to other areas would be 60 to 210MW in 1991, 750 to 1,090MW in 1995, 500 to 1,400MW in 2000, and 2,500 to 2,720MW in 2015.

These projections do not take into account a special situation of successive dry years. If Yunnan experiences successive dry years, its capacity for transmitting power to outside areas would not attain these projections. Moreover, predictions based on the current situation in Yunnan indicate a possibility that the pace of power station construction and speed of load development may be slower. If cooperative management of power between Yunnan and Guangdong proceeds smoothly, there is a possibility that the pace of power station construction may be achieved.

F. DC power transmission transmitted out of Yunnan and from Tianshengqiao to Guangzhou

On the basis of a Ministry of Energy Resources electric power program design program, the Kunming Survey and Design Academy analyzed a "three thermal power and one hydropower" (Qujing thermal power plant in Yunnan, Panxian and Huangtong thermal power plants and Tianshengqiao first cascade and Tianshengqiao second cascade hydropower plants in Guizhou) AC power transmission and mixed AC-DC power transmission program for Yunnan, Guizhou, Guangxi, and Guangdong. In conjunction with Yunnan's characteristics, it proposed the following points: 1) With the exception of Yunnan's Qujing thermal power plant, the "three thermal power and one hydropower" power transmission program for these four provinces should reconsider 600 MW of power transmission to Guangdong following operationalization at Lubuge and Manwan; 2) It supported the program for mixed AC-DC power transmission with a larger transmission capacity, meaning that the original 1,200MW at plus or minus 500 kV DC would be changed to 1,800MW; 3) It proposed that the AC centralization and decentralization location and DC current conversion station be placed at the Tianshengqiao first cascade hydropower station. This is feasible and could conserve about 50 million yuan in investments.

The "three thermal power and one hydropower" mixed AC-DC power transmission program is an important step for connecting the four provincial grids. It can provide the benefits of power transmission from the "three thermal power and one hydropower", and can transmit surplus electric power from Yunnan, Guizhou, and Guangxi to Guangdong and attain preliminary benefits from integrating the hydropower and thermal power grids of these four provinces. As a result, all four provinces support this program.

G. DC power transmission from Xiaowan to Guangzhou

Feasibility research by the Kunming Survey and Design Academy and South- Central China Electric Power Academy concerning a program for DC power transmission from Xiaowan to Guangzhou indicates that if the preliminary choice of installed generating capacity for Xiaowan Hydropower Station is 4,200MW, at a power transmission distance of 1,550 km from Xiaowan to Guangzhou, a transmission capacity of 2,000 to 2,500MW, and yearly power output of 9 to 11.3 billion kWh, and if a plus or minus 600 kV power transmission voltage is used, 4 X LGJQ-600 DC power transmission lines and a bipolar quadruple-bridge connecting line could be completed in 3 years. Its annual power transmission efficiency would be 93.21 percent and the estimated total investment for the project would be 2.146 billion yuan (including 1.095 billion yuan for the DC power transmission lines, 426.2 million yuan for rectification stations, and 441.9 million yuan for retransformation stations). The investment for power transmission would be 858.5 yuan/kW. If the benefits of grid integration are not included, when the yearly interest rate on loans does not exceed 10.2 percent and the profit from electricity sales is 0.045 yuan/kWh, the entire loan could be repaid in 10 years.

H. Integration of power and mining in Yunnan and transmission of power from Yunnan to other areas

Yunnan has abundant mineral resources. Of the 156 known types of minerals at present, Yunnan has 110 types and ranks first in China in reserves of 20 types. Moreover, Yunnan has abundant energy resources, so it is entirely correct for Yunnan to move ahead first with electric power, integrate power and mining, and develop energy-laden industries. On the surface, there would appear to be a contradiction between developing energy-laden industries and transmitting power to Guangdong and it could even be stated that selling power is not as economically sound as developing energy-laden industries. Given basic conditions in Yunnan, however, Yunnan has a rather weak industrial foundation and cannot attain the conditions and development pace for processing industries and energy-laden industries like the coast and Guangdong in the short term. Moreover, Yunnan's electric power industry has conditions and advantages that the coast does not have, so it may be able to develop somewhat more quickly than the coast. In the original plan, Manwan Hydropower Station and a 300,000-ton yellow phosphorous project were to be built simultaneously. Now, construction at Manwan has already begun and plans call for it to generate power in 1992, but the feasibility research report for the yellow phosphorous project has not yet been examined and approved. Only 60,000 tons had been examined and approved by 1990, and plans call for it to begin operation in 1993. This shows that it will be rather hard for the development pace and scale of yellow phosphorous, lead, and other energy-laden industries in Yunnan to match that of electric power. Now, prior to completion of the perennial regulation reservoir at Manwan, Yunnan's electric power riches are mainly wet season hydropower, so it would be both uneconomical and impossible in terms of the forces available to rely on Yunnan Province itself to build energy-laden industries that could absorb large amounts of hydropower during the rainy season. There is a 2-month difference between the wet season and dry season for hydropower in Guangdong and Yunnan and the highest yearly loads also alternate with Yunnan. Thus, it would be possible for most of the wet season electric power transmitted from Yunnan to Guangdong to be converted into effective electric power which could play an important role in Guangdong. Moreover, Yunnan's energy-laden industries cannot bear a relatively high electricity price like the 0.16 yuan/kWh price of electricity from Lubuge, so it will also be hard for yellow phosphorous to bear it, whereas Guangdong's processing industries are entirely capable of bearing the new electricity prices for newly built power stations, so this provides favorable conditions for Yunnan to accumulate capital to develop new power stations. Moreover, Yunnan is very rich in energy resources and has 20 times the per capita developable hydropower and 23 times the per capita coal resources that Guangdong does. This is especially true for hydropower, which is a renewable energy resource, and development 1 year earlier could provide benefits 1 year sooner. Each year 70 billion kWh of power flows away unused on the middle and lower reaches of the Lancang Jiang alone. If it could cooperate with Guangdong, a big energy user with a higher investment capacity, to develop its energy resources as quickly as possible, Yunnan could develop its energy resources more quickly and it would be able to play its role as an energy resource province much sooner. This would also help the development of energy-laden industries in Yunnan. These points show clearly that transmitting power from Yunnan to other areas and integrating power and mining in Yunnan to develop energy-laden industries are not opposed but are instead mutually complementary.

Transmitting power from Yunnan to other areas conforms to stipulations in the Ministry of Energy Resource Medium-Term Energy Resource Development Program. The "Program" stipulates that in order to reduce pressures on railway and maritime transport, we should accelerate the development of coal and power base areas and hydropower base areas, substitute power transmission for coal haulage, substitute hydropower for coal, and use more hydropower and thermal power from western China. Key hydropower stations on the middle and lower reaches of the Lancang Jiang in Yunnan have already been included as key national hydropower development targets and Yunnan's Diandong [east Yunnan] Coal Mine and Zhaotong have been included as key development points for southwest China. The development of electric power sources in Yunnan should meet both the industrial development needs of Yunnan Province itself and the urgent needs of energy-short Guangdong Province. This is entirely in conformance with the requirements and stipulations in the "Program". To reverse China's national energy resource shortage, we must not reduce electric power projects in Yunnan but instead should try to increase the number of projects as much as possible and accelerate electric power construction in Yunnan. In reality, there has been a gradual decrease in the number of electric power projects in Yunnan in the past several years. If Yunnan is unwilling to transmit power to other areas or to push ahead with projects arranged by the state, it might be possible to reduce electric power projects in Yunnan.

Much work is required to transmit power from Yunnan to other areas and it can be achieved only by overcoming several irrational phenomena in the present system. Moreover, it must be carried out in steps.

III. Conclusion

1. On the basis of developable power output, Yunnan has 20.5 percent of China's hydropower resources, second only to Sichuan and second place in China. It is also second only to Tibet in developable per capita capacity and holds second place in China, and it has 20 times as much as Guangdong does. Yunnan holds ninth place in China in coal reserves and second place in south and southwest China (second only to Guizhou), and it has 23 times as much as Guangdong in terms of per capita reserves. Yunnan has abundant hydropower resources

and sufficient coal resources, so it is one of China's energy resource provinces. For this reason, accelerated development of Yunnan's energy resources, especially hydropower, would play an important role in reversing China's and especially Guangdong's long-term electric power shortage.

2. Guangdong Province has a severe energy resource shortage and it is a province which has rapidly developing industry opened to the outside world as well as investment advantages. There would be considerable technical economics benefits and social benefits from transmitting power from Yunnan to Guangdong and connecting with the Guangdong and Guangxi Grids. It would seem that the distance involved in transmitting power from Yunnan to Guangdong is quite long, but actually after the four-province grid takes shape, transmitting power to Guangdong via the Guangxi EHV grid would fall within the scope of conventional power transmission. Later, using EHV DC power to transmit power directly from Manwan to Guangdong would also be a reasonable scope of power transmission.

3. The program for transmitting power from Yunnan to Guangdong: Initially, two 220 kV lines would be built from Lubuge to Tianshengqiao and from Qujing to Tianshengqiao. In the middle-term, another 500 kV line would be built from Kunming to Tianshengqiao. In this way, the initial and medium-term programs should fully utilize and suitably increase the transmission capacity of the 500 kV AC line and the plus or minus 500 kV DC line from Tianshengqiao to Guangdong. In the later period, a plus or minus 600 kV DC line could be built directly from Xiaowan to Guangdong.

4. In 1988, Yunnan and Guangdong signed an agreement for cooperative development of Yunnan's energy resources and power transmission to Guangdong which was a start to opening up a new situation in energy resource development in Yunnan. We hope that this agreement will be fully implemented, that the pace of transmitting power from Yunnan to Guangdong will be speeded up, and that immediate solutions can be found to problems with policies and grid integration.

Sichuan Seeking International Partners To Develop Hydropower Resources

40100020A Beijing CHINA DAILY (Business Weekly) in English 17 Dec 90 p 2

[Article by Huang Xiang: "Sichuan Seeks To Be Nation's Top Hydropower Supplier"]

[Text] Sichuan, China's most populous province, but one which is also power-short, is seeking international partners to develop itself into the nation's top hydropower supplier in the next 10 years.

The province plans to boost its hydropower generating capacity to 12 million kilowatts by the year 2000 from the present 3 million kilowatts.

Leading provincial officials are now calling for more technology and funding from outside to launch more hydropower projects on major tributaries of the Yangtze River, which passes through the southwest corner of the province from the west.

Most of the hydraulic undertakings on the blueprint will be located on the Dadu, Jingsha and Yalong Rivers, major tributaries on the upper reaches of the Yangtze River in Sichuan Province.

Exploitable hydraulic resources on the three rivers amount to 70 million kilowatts, 78 percent of the water resources in the province or 20 percent of the nation's total.

There are already two major hydropower stations with a total capacity of 3.9 million kilowatts under construction on two of the rivers.

According to Zou Guangyan, deputy director of the province's planning commission, preliminary works on several large stations are going on as scheduled while another half-dozen medium-sized ones are awaiting approval from the central government.

Zou said that investors, Chinese and foreigners alike, will definitely benefit by funding these projects, which are expected to cost a total 10 billion yuan ($1.9 billion).

To overseas investors, which are so far still reluctant to invest in any hydropower undertaking in China, Zou especially recommended launching joint ventures combined with compensation trade.

He explained that Sichuan has rich mineral resources to supply overseas traders and manufacturers. And besides, foreign capital may also be repaid in the form of processed minerals, produced with the electricity generated from the joint venture.

For Chinese investors, Zou pledged that all investment will be repaid in 10 years starting from the formal operation of its first generating units.

"Here (Sichuan) is the nation's most profitable place for investors to fund a hydropower project," he said.

The province's intention has been reportedly to be highly recommended by the State Energy Investment Corporation (SEIC), which oversees the funding of coal and electricity projects.

Sichuan is known to be scarce in such common resources for power generation purposes as coal, crude oil and natural gas.

Proven coal deposits, China's mainstay in power production, stand at a mere 10 billion tons, about 1 percent of the nation's total.

Corporation statistics reveal that power consumption in Sichuan is about half of the nation's average, which has left 70 percent of its machines running below capacity.It is estimated that the province is short of 7 billion kilowatt hours of electricity, 2.5 million tons of coal and 600 million square metres of natural gas every year.

Apart from the sense of urgency felt by the provincial authorities, the corporation believes that the rich experience in building all sorts of hydraulic stations is an obvious advantage.

Er'tan Station on the Yalong River in the Western part of Sichuan is the largest hydropower station now under construction in China. Six generating units of 550,000 kilowatts each are being installed in the underground powerhouse—an annual generation of 16.2 trillion kilowatt hours of electricity.

Local government also gains much experience from building 1,600 small hydropower stations, which are located on almost all of Sichuan's 1,000-plus rivers.

Fengzhen's First 200 MW Unit Completed

906B0108B Hohhot NEIMENGGU RIBAO in Chinese 28 Jun 90 p 1

[Article by reporters Li Shuxiu [2621 3219 4423] and Zhao Ruijin [6392 3843 6930]: "Smooth Completion and Trial Production at No 1 Generator at Fengzhen Power Plant, Strengthen the Command System, Do Good Technical Management, Power Output of 593 Million kWh in One-Half Year, Stable and Full Output Achieved"]

[Text] The first 200MW generator in the first phase project at Fengzhen Power Plant, a key state construction project, has smoothly completed one-half year of trial production and had generated 593 million kWh of power up to 21 May 90, achieving 164 days of safe production. This is a rather good achievement compared to similar generators throughout China.

The first 200MW generator at Fengzhen Power Plant shifted to trial production on 21 Nov 89. Over the past half year, the power plant has overcome problems with new equipment, new personnel, and other things and ensured that the generator has passed through winter safely. It also used the spring heating season to take the initiative in eliminating over 2,000 equipment problems left over from capital construction and generated during the operation process, and it has carried out many items of technical transformation to attain 3,357 hours of generator operation and a utilization time of 2,966 hours, which are higher than similar generators throughout China.

As soon as this generator began operating, the plant department proposed stable generator operation measures of "a stronger command system, reinforced technical management, consolidated operations work, and a focus on supplementary training for operations". A nighttime plant leadership shift system was formulated to ensure that someone was on duty at all production posts for 24 hours. They formulated an operations assistant senior engineer, chief shift leader, and workshop technical cadre shift system to be responsible for technical supervision, and resolutely implemented on-site primary leadership stipulations for startup and shutdown, major operations, and accident response. While ensuring safe production, they also actively adopted measures, tried to achieve economical generator operation, and reduced coal consumption for power supply each month. From April to May 1990, it was reduced to 395 g/kWh, so they have already attained the average coal consumption level for similar types of generators in China as a whole.

One-half year of trial production has confirmed that the situation is excellent in Inner Mongolia's design, installation, debugging, and management of the primary and auxiliary equipment for this 200MW generator.

Building Pit-Mouth Plants in Huge Huolin-He Coal Field

906B0108D Hohhot NEIMENGGU RIBAO in Chinese 29 Jun 90 p 3

[Article by Wang Xu [3769 2485], commander of the Huolin-He Mining Region: "Build Pit-Mouth Power Plants, Implement Joint Management of Coal and Power, Explore Ways To Develop Huolin-He Mine"]

[Text] Huolin-He Coal Field is located in the eastern part of Inner Mongolia Autonomous Region. Its coal quality is old lignite and it has total proven geological reserves of 13.1 billion tons. After 1976, following 5 years of preparation and 3 years of construction, the No 1 Strip Mine with yearly output of 3 million tons was turned over for operation in 1984. Construction began for the 7 million ton second phase expansion project in the mining region in 1988 and completion is expected in 1992. To date, the mining region has received 1.415 billion yuan in state capital construction investments. Large imported equipment is used entirely for the overall production system and the level of mechanization is above 90 percent. Auxiliary production systems for equipment overhaul, materials supply, production transport, and so on have taken shape. There have been rapid changes in the living, cultural, public health, and commercial services conditions for employees of the mining region. The 400 km long Tong-Huo [Tongliao-Huolin He] Railroad and Tong-Huo Highway are now formally open to traffic. The 220 kV Tong-Huo HV line has now been put in place and is supplying electricity. It can be said that Huolin-He Mine now fully has the internal and external conditions for accelerated development.

Over the past few years, it has become increasingly apparent that Huolin-He Mining Region is being restricted by factors in two areas. The first lies in construction of the mining region itself. Historically, it has formed a lopsided posture of "one bureau and one mine with a heavy head and light feet". This posture has resulted in a very high fixed cost ratio in coal production in the enterprise over a long period in which they account for about one-half of costs. This has severely restricted internal vitality in the enterprise and the returns to capital already invested. The second factor is that the power generation plant built in conjunction with development of the mining region was constructed in the suburbs of Tongliao City, over 300 km from the mining region. It goes without saying that this is a groundless increase in this transport cost item and has created a lack of matchup in haulage capacity. The design transport capacity of the railway is 10 million tons and the production capacity of the mining region is 3 million tons. In addition, the industrial and agricultural economy along the rail line is relatively backward and the local transport capacity is extremely small. In this type of situation, the railway has been forced to implement a special shipping price per ton/km in order to guarantee its costs. This has resulted in many coal users crying shortages despite the large amounts of coal and has posed unbearably perplexing problems for coal, power, and transport.

How can we get out of this mess and allow the capital that has been spent and will be spent by the state to be more effective? I feel that there is only one way out: built pit-mouth power plants and implement joint management of coal and power.

There are many regional advantages and conditions for building pit-mouth power plants in the Huolin-He Mining Region.

1. It has abundant fuel. Huolin-He Coal Field has total geological reserves of 13.1 billion tons. They include 2.58 billion tons of reserves in the Shaerhure prospecting region that have been surveyed in detail. Calculated on the basis of yearly output of 20 million tons, they could be mined for more than 120 years. Moreover, the coal seams are buried at relatively shallow depths and the stripping ratio is about 1:3, so it is extremely well suited to large scale open-cut extraction.

2. It has abundant water sources. According to the firm belief of the Shenyang Coal Design Academy set forth in its 1978 SHUIYUAN KANCHA BAOGAO [Water Sources Reconnaissance Report] for this region, the mining region has total groundwater reserves of 234,900 m^3. Its main surface water source is Huolin He, which runs through the mining region and has a yearly flow rate of 17.34 million m^3 and is entirely capable of meeting the water use needs of the first phase power plant project. The water needed for the second and third phase power plant projects can be taken from Wulaigai-He Reservoir 48 km from the power plant.

3. It has ideal plant sites. The Zhusihua plant site which has been inspected and approved by many parties is just 4.1 km from the South Strip Mine and the fuel coal can be shipped directly into the plant by conveyor after crushing. The plant site is just 1 km from the mining region employees' residential area. It has many public facilities that would not have to be built again and there is considerable surplus heat from the power plant that could be used in a comprehensive way.

4. The completion and opening to traffic of the Tong-Huo Railroad and Tong-Huo Highway provides complete and convenient external transport conditions for power plant construction and production. Moreover, the 500-plus highway transport trucks purchased and imported from foreign countries during the peak of capital construction could be fully utilized and could meet the transport requirements during the initial stages of plant construction.

5. The 220 kV Tong-Huo power supply line was completed and began supplying power in 1985. When the time comes, it will be able to ensure sufficient power sources for plant construction and it can solve some of the problems in transmitting power to other areas during the first phase for the power plant.

Besides the above conditions, the sand, stone, bricks, and other materials needed for basic structures at the power plant can be obtained locally. Moreover, the chosen plant site is in the wilderness in the city suburbs and would take up no farmland or require any structures to be moved.

Construction of this project would of course require a certain investment, but with the obvious economic benefits from this project, the enterprise could form a rather strong self-compensation and self-development capability after it receives a certain amount of construction investments. After the first phase power plant project is completed and goes into operation, it could enter a benevolent development period of relying entirely or partially on production to support capital construction.

Construction of pit-mouth power plants at Huolin-He Coal Mine would have obvious economic and social benefits. After the entire project is completed and goes into operation, the coal mine's yearly production capacity would be 20 million tons and its annual gross value of output would be 214 million yuan. The power plant's annual gross value of output would be 1.5 billion yuan. The total for the two would be 1.714 billion yuan and total annual profits and taxes would be 840 million yuan.

Huolin-He Coal Field is located in a frontier region inhabited by minority nationalities. Its economy is relatively backward but it has great development potential. Expansion of the coal mine and construction of power plants could be effective in promoting development of local industry.

Moreover, building power plants and expanding the mining region could completely transform the economic and technical situation in Huolin-He Mining Region itself, and it could bring vitality to the Tong-Huo Railroad and Tongliao Power Plant.

The most important thing is still the long-term energy resource shortage in northeast China. Projections indicate that demand for electric power in the entire northeast China region will be about 220 billion kWh at the end of this century. At that time, the amount of coal used to generate power will be about 85 million tons, so the only way to solve the shortage is to transport it from inside Shanhaiguan, which will mean squeezing onto China's transport "bottleneck", the Da-Qin [Datong-Qinhuangdao] rail line. From the long-term perspective, the energy resource shortage in northeast China must first of all be based on developing resources within the region. Construction of the Huolin-He Coal Mine and Electric Power project fits nicely with this need.

First Unit of Sichuan's Longqiao Plant Now Operational

906B0108C Chengdu SICHUAN RIBAO in Chinese 8 Aug 90 p 1

[Article by Wang Dingguo [3769 1353 0948] and SICHUAN RIBAO reporter Yang Qingwen [2799 3237 2429]: "Fuling

Longqiao Power Plant Begins Producing Benefits, Construction Enters Peak for No 2 Generator Installation, No 1 Generator Already in Operation, About 80 Percent of Total Project Investment Completed"]

[Text] By the first third of July 1990, the steam turbine platform and boiler air jacket for the No 2 generator in the first phase of Fuling Longqiao Power Plant were both in place and installation of the large boiler component crane was completed. This indicates that the peak construction stage has begun in equipment installation work for the No 2 generator.

Fuling Longqiao Power Plant is one of two large state electric power projects to provide support to poor areas in Sichuan Province during the Seventh 5-Year Plan. The installed generating capacity is 2 X 25 MW at a total investment of more than 130 million yuan. Since the formal start of construction on 20 Aug 88, the project has progressed smoothly through the efforts and struggle of several 1,000 builders. On 4 Jan 90, the No 1 generator was completed, connected to the grid, and began generating power and was formally turned over for production on 6 Mar 90. After appraisal by the Project Startup Committee, this generator was named as a superior project. The two matching 110 kV power transmission lines that run for a total length of 86 kilometers from Longqiao to Dianjiang and to Daping and two 31.5 kV transformer stations at Daping and Wenhua have been completed and are transmitting power. By the end of June 1990, the primary machinery and equipment for the No 2 generator had basically all arrived and over 80 percent of the total investment for the entire project had been completed.

In an effort to regain time lost during the previous period due to several rainy days and the effects of power and water outages, the project headquarters and Sichuan Province Third Power Construction Company readjusted their construction deployments and strengthened their combination of forces in an attempt to ensure construction progress. Since 17 May 90, the construction personnel have worked both day and night to fight for time and push forward more quickly and have worked over 10 hours a day almost every day. After the beginning of July, when temperatures at the construction site were as high as about 38° C, the employees of the Sichuan Third Provincial Power Construction Company worked hard while sweating to ensure that installation of the No 2 generator will be completed before 30 Sep 90 and that it will be placed into formal operation during October.

When the first phase project at Longqiao Power Plant is completed, it will greatly alleviate the serious power shortage during the dry season in Fuling Prefecture and play an important role in economic construction in that region.

Work Accelerated on Ulanhot Power Plant

906B0108A Hohhot NEIMENGGU RIBAO in Chinese 13 Jul 90 p 2

[Article by reporter Du An'ge [2629 1344 7041]: "Construction Accelerating at Ulanhot Heat and Power Cogeneration Plant, First Generator Expected To Begin Operating By End of 1990"]

[Text] Construction of the Ulanhot Heat and Power Cogeneration Plant is now moving forward smoothly at a faster pace and with excellent quality.

With state approval, construction of the Ulanhot Heat and Power Cogeneration Plant at a total investment of 118 million yuan formally began on 19 Aug 89. Because of the concern of all levels of leadership and the indomitable spirit of struggle in learning from Dazhai and learning from the Iron Man by the Second Metallurgical Construction Company in the Ministry of Metallurgical Industry, which was responsible for the main construction tasks, and the wholehearted coordination and shoulder-to-shoulder battle waged by the construction units, ideal progress is now being made in the pace of project construction. By mid-May 1990, assembly of the 60-ton tower crane had been completed. The foundation of the No 1 steam turbine generator, the foundation of the 100 meter tall smokestack, the absorbing layer of the water tower, the viaduct river current return ash pipe bridge, primary excavation of the foundation for the first level of the building, part of the foundation of the 66 kV power transformer station, the first level of the crushing station, part of the foundation of the coal haulage system, the foundation of the chemistry workshop, the first floor of the chemistry building, assembly of the boiler platform, the 8 meter platform level, and other primary projects have been completed or are nearing completion. It is expected that by the end of 1990, two boilers and one generator will be in place, the smokestack and water tower can be topped off, and the entire public system can be completed. Installation has begun for part of the transformer station and the dedicated railway line transformation tasks may be completed in October 1990.

When the entire Ulanhot Heat and Power Cogeneration Plant goes into operation, it will generate about 120 million kWh of power annually, which is equivalent to one-half of all the power supplied in Xing'an League at the present time. At that time, it will play a major role in economic development in Xing'an League and in reducing atmospheric pollution in Hongcheng Town. The decentralized heat supply in Hongcheng Town will be converted to centralized heat supply and the heat supply area will exceed 1.20 million m^2. The supply of steam to industry may reach 100 tons/hour in the winter and 74 tons/hour in the summer. This can conserve 80,000 tons of coal each year.

Work Begins on Big 1200MW Wuhan Plant

91P60071 Beijing RENMIN RIBAO in Chinese 20 Dec 90 p 1

[Text] Another major national energy project—the Wuhan Yangluo power plant—formally got under way on the 18th of December. The Yangluo power plant is located in Wuhan's Xinzhou Xian and is a joint investment construction project involving the Hua Neng Power Company, Wuhan City, and Central China Power Management Bureau. The huge thermal power plant has a design installed capacity of 1.2 million kilowatts and will be built in two stages. The first stage will have a capacity of 600 megawatts and involves the installation of two 300MW coal-fired units manufactured domestically or imported. They will be able to deliver some 3.3 billion kilowatt-hours of electricity a year. The power plant is expected to be completed by the end of 1994.

Breakthrough Claimed in East China Sea Exploration

906B0103C Beijing KEJI RIBAO [SCIENCE AND TECHNOLOGY DAILY] in Chinese 24 Jun 90 p 1

[Article by reporter Li Xigen [2621 0823 2704]: "Major Breakthrough in Oil and Gas Exploration in East China Sea; Jiang Zemin and Li Peng Send Congratulatory Telegrams""]

[Text] A series of major breakthroughs have been made in oil and gas prospecting in China's East China Sea. CPC Central Committee general secretary Jiang Zemin and State Council premier Li Peng sent congratulatory telegrams to the East China Sea Oil and Gas Prospecting Victory Commendation Meeting held on 23 Jun 90 in Shanghai.

Oil and gas prospecting in China's East China Sea began in 1974. The Marine Geological Survey Bureau of the Ministry of Geology and Mineral Resources has collected geophysical data covering 518,000 kilometers of survey lines and drilled 17 wells with a total drilling footage of more than 65,000 m in the East China Sea to date. The first industrial oil and gas flow was drilled from the "Pinghu 1 well" in 1983 and several oil and gas achievements have been made in the 7 years up to now. High output oil and gas flows were obtained from three wells in 1989, the "Pinghu 4 well", "Baoyunting 1 well", and "Canxue 1 well". The "Pinghu 4 well" produced 1,892.85 m^3 of superior quality crude oil and 1.486 million m^3 of natural gas daily. It is China's highest daily output single offshore well.

Work over many years and comprehensive research using a large amount of information has convinced experts that the East China Sea has excellent oil and gas resource prospects. In regions with a higher degree of exploration work, one oil and gas well and four petroliferous structures have been discovered, which has provided an important basis for early development of oil and gas resources in the East China Sea.

In petroleum prospecting in the East China Sea, several advanced collectives which have been fighting silently on the marine petroleum geology battlefront have appeared. The Ministry of Geology and Mineral Resources and the Shanghai Municipal People's Government commended them today.

China's Potential Natural Gas Resources and Their Exploitation

916B0011 Chengdu TIANRANQI GONGYE [NATURAL GAS INDUSTRY] in Chinese Vol 10, No 5, 25 Sep 90 pp 1-7

[Article by Qi Houfa [2058 0624 4099] of the China Petroleum and Natural Gas Corporation Exploration and Development Scientific Research Academy: "An Exploration of China's Potential Natural Gas Resources and Exploration Directions"; manuscript received 3 Jan 89, revised draft returned 30 Nov 89]

[Text] Content Summary: On the basis of an outline of the characteristics and distribution of different categories of gas source rock in China and using the "generation and accumulation method" to make a preliminary forecast of China's prospective natural gas resources, this article focuses on the geological characteristics and the formation and reservoiring conditions of natural gas in each of China's large petroliferous basins and uses them to point out favorable directions of exploration for them.

Main Terms: China, natural gas, gas source rock, resource amounts, petroliferous basins, geological conditions, exploration directions

China has substantial potential natural gas resources and optimistic exploration prospects, but their geological conditions are complex and exploration and research are rather difficult. In this situation, good initial resource assessments and selection of key exploration directions for all of China's natural gas are very important for accelerating the development of China's natural gas industry. For this reason, this article offers some preliminary analysis based on existing information to encourage attention from the relevant areas and discussion by colleagues.

I. Distributional Characteristics of Gas Source Rock

China's main gas source rock is in the three categories of coal-bearing strata, continental facies oil-generating rock, and marine facies carbonate rock. They vary in distribution, parent rock categories, degree of thermal evolution, and gas generation potential.

A. Coal system gas-generating rock

In China's geological history, with the exception of pre-Devonian sapropelic coal, there were a total of eight coal formation periods from the early Carboniferous to the Tertiary for humic coal which resulted in extremely widely developed coal-bearing strata in China. I will focus here on assessing our four main coal systems, the Carboniferous-Permian, late Permian, Jurassic, and Tertiary.

The Carboniferous-Permian coal system is north China's main coal system. It is mainly distributed between the two huge Kunlun Shan-Tianling Shan and Tian Shan-Yin Shan folded mountain systems which have an east-west strike. It is marine-continental interchange facies-continental facies coal-bearing formations that underwent stable subsidence and do not vary substantially in thickness. The rich coal seam segments are in gradually higher positions as one moves from north to south.

The late Permian coal system is located south of Tian Shan-Yin Shan and is bordered roughly by Kunlun Shan-Qinling. The overall sedimentary environment has a "marine in the south, continental in the north" configuration.

The early and middle Jurassic coal system is mainly distributed in northwest China in the Junggar, Tarim, Turpan, and other large basins. The late Jurassic coal system is mainly distributed in small fault-subsidence basins in northeast China. Both of these systems are inland lake facies basin sediments.

On the continent, the Tertiary coal system can be divided into two large south and north coal-bearing regions. The coal formation period in the northern region was mainly in the early Tertiary and it is mainly distributed in the northeast and north China regions. The coal formation period in the southern region was mainly the late Tertiary and it is distributed in southwest China, the southern part of south China, in Tibet, and on Taiwan. Southeast China and the East China Sea are also regions of Tertiary coal system development.

The organic matter in the coal systems has two types, a centralized type (coal) and a decentralized type (scattered in dark argillaceous rock in the coal system). Their concentrations of organic matter are universally higher than in oil-generating rock systems. The former usually has an organic carbon content of 60 to 80 percent while most of the latter is 1.5 to 3 percent.

The type of organic matter in these coal systems is mainly humic, the element composition of its dry casein base is poor in hydrogen and rich in oxygen, its chemical structure is primarily aromatic ring structures, and the side chains it contains are limited in number and short. These characteristics determine that the coal systems produced mainly gaseous state hydrocarbons during their thermal evolution. Heat simulation experiments show that lignite that evolves into 1 ton of anthracite can generate 210 to 450 m^3 of methane and that under similar conditions 1 ton of organic matter in coal system mudstone can generate 330 to 440 m^3 of methane.

B. Continental facies oil-generating rock systems

It should be pointed out first that oil-generating rock systems and gas- generating rock systems cannot be completely separated. One can only say that a system is primarily oil-generating or gas-generating. Thus, oil-generating rock is also a type of gas source rock and the gas generation potential of continental facies oil-generating rock systems in particular cannot be ignored. Here, I will assess Mesozoic and Cenozoic continental facies oil-generating rock systems.

Late Triassic oil-generating rock systems are mainly distributed in the Ordos, Sichuan, Chuxiong, Tarim, Junggar, and other large basins and were commonly sedimented as a set of dark mudstone interbedded with oil shale or coal seams. They have a high organic carbon content (> 1 percent) and the parent material is mainly sapropelic or humic in type.

Cretaceous oil-generating rock systems are mainly distributed north of 35° north latitude in the Songliao, Erlian, Liupanshan, Jiuquan, Tarim, Junggar, and other basins and they are subject to obvious control by ancient latitudinal damp climate zones. All of these basins contain relatively thick black mudstone and the parent material is of a sapropelic or transitional type. It should be noted that there is a transitional zone between the ancient damp zones north of 35° north latitude and ancient arid zones in low latitudes. There are still definite oil-generating rock distributions in the Cretaceous in the Jianghan, Subei, southern Huabei [North China], and other basins and in the western part of the Huabei Basin.

Tertiary oil-generating rock systems are widely distributed in all of the basins in east and west China. Lower Tertiary system oil-generating strata are the most widely distributed. Continental and lake facies oil-generating rock systems are widely distributed near the sea in north and south China. The development of lake facies oil-generating rock systems has been confirmed at the southwestern edge of Qaidam Basin and in the southern part of Junggar Basin. Only the lower Tertiary oil-generating rock systems in the subsidence in the southwestern part of Tarim Basin are marine facies sediments. Late Tertiary continental facies sediments are also found in all of China's basins, but the depression in the western part of Qaidam Basin is the only inland location having definite oil generation conditions, whereas in marine areas enormously thick upper Tertiary oil-generating rock systems were accumulated on the continental shelf of the South China Sea and East China Sea, and they have considerable gas generation potential.

C. Marine facies carbonate rock strata systems

Marine facies carbonate rock strata gas source rock is very widely distributed. It developed in the middle and upper Protozeroic and in the Cambrian and Ordovician on the north China platform. During the middle and upper Protozeroic, this region was mainly in an intertidal littoral continental clastic beach, intertidal sand and mud flat, intertidal semi- occluded algal beach, and coastal sand bar-open marine platform shallow sea environment. Its sediments are mainly a set of clastic rock interbedded with carbonate rock. The Cambrian and Ordovician systems are mainly alternating clastic rock and carbonate rock sediments from a land surface sea shallow water environment.

Carbonate rock developed widely on the Yangzi platform from the Sinian to mid- Triassic. The lower Paleozoic saw the development of both basin facies and littoral facies but was mainly shallow sea platform facies sediments. With the exception of the lower Cambrian and Silurian systems which are clastic rock, its lithology is mainly carbonate rock. With the exception of the lower Devonian and upper Permian systems which are mainly clastic rock, the upper Paleozoic is mainly carbonate rock.

The concentration of organic matter in carbonate rock is universally lower than in argillaceous oil-generating rock. On the north China platform, the organic carbon content is 0.06 percent in the middle and upper Protozeroic and 0.12 percent in the Cambrian and Ordovician. On the Yangzi platform, all of the strata beneath the middle Triassic are generally about 0.1 percent. The parent material of marine facies carbonate rock is mainly sapropelic and the degree of thermal evolution is universally rather high. Most has entered the highly-mature and overly-mature stage in which they generate mostly gas.

II. Projected Potential Natural Gas Resources

Given that the inadequate degree of exploration and research at the present time, projected resource amounts of course are not sufficiently accurate. On the basis of certain information, however, using identical methods to make preliminary resource forecasts and make comparative assessments for the entire country or large regions, and selecting basins or regions to focus on for exploration has a role that cannot be underestimated.

We have used the "generation and accumulation method"[1] in a unified fashion to forecast China's prospective natural gas resources at 33 quadrillion m^3. The projected resources have the following distributional characteristics:

1. In terms of categories, the three categories of coal-formed gas and oil- type gas (that part in continental facies petroliferous basins), and overly- mature gas in carbonate rock each account for about one-third;

2. In terms of strata positions, natural gas resources are mainly distributed in the Carboniferous to Permian systems and these resources account for 36.02 percent of the total resources. The second largest distribution is in the Jurassic, Triassic, and Tertiary systems, each of which account for > 11.11 percent of the total resources. It should be pointed out that the accumulation of natural gas is definitely not distributed according to gas- generating strata systems, so the distributional characteristics of the resources in terms of their strata positions can only be viewed in a relative sense;

3. In terms of region, our natural gas resources are concentrated in the four large Sichuan, Tarim, Junggar, and Ordos inland basins and in basins on the continental shelf in the East China Sea and South China Sea. Their resources account for more than 80 percent of China's total resources. China's Bohai Sea Basin and Songliao Basin, which have a higher degree of exploration, account for a small proportion of natural gas resources, 5 percent and 3 percent, respectively, of our total resources.

III. A Discussion of Directions for Natural Gas Exploration

China's geological structure is divided into eastern and western regions and southern and northern blocks, and the different regions and blocks have different natural gas geological conditions. I will now describe the basic geological conditions for natural gas in each of China's primary regions and primary directions for exploration based on existing information.

A. East China petroliferous region

Although there are major differences in the Paleozoic geological structures of each of the basins of east China, all of them belong to rift valley systems that developed during the Mesozoic and Cenozoic. The structural and sedimentary development of these rift valley or fault-subsidence basins plays an enormous controlling role over the formation and accumulation of gas reservoirs.

1. Bohai Sea Basin. This basin is a Mesozoic and Cenozoic fault-subsidence basin that formed on top of the Paleozoic North China platform. It has three main sets of gas source strata systems, the lower Tertiary, Carboniferous- Permian, and lower Paleozoic-middle and upper Protozeroic. There is also definite gas generation potential in the locally distributed Mesozoic. Because of the limited volume of highly-mature and overly-mature oil- generating rock in the lower Tertiary, the oil-generating rock volume with $R_O > 1.3$ accounts for 19 percent of the total oil-generating rock volume, which restricts its potential for original gas generation. Although the degree of maturity of Carboniferous-Permian and lower Paleozoic-middle and upper Protozeroic oil-generating rock is relatively high, the long period of erosion caused by Caledonian and Indosinian movement may have resulted in the loss of most of the gas that was generated during previous periods, and the regions that could provide gas sources could only be next to the Mesozoic and Cenozoic, which subsided a great deal and caused secondary or even more generations of gas generation[2].

In this region, there was intense fault-block activity during the Cenozoic which was extremely unfavorable to the preservation of gas. With the exception of regions with good capping strata conditions, faults at different levels could have caused substantial losses of gas. Thus, preservation conditions are the key question in the ability of gas reservoirs to form and concentrate in abundance.

The depressions that formed during the Mesozoic and Cenozoic in this region all formed their own sedimentation systems and their gas reservoirs were controlled by gas generation centers. The natural gas did not migrate over long distances and the traps formed by block faulting activity were rather small. These basic conditions determined that the gas reservoirs in this region were mainly moderate and small in size.

The Tertiary in this region is the most realistic strata system for increasing natural gas reserves and output in the short term. The area around deep depressions, beneath regional capping strata, and structural zones and phase transition zones in the direction of oil and gas migration are favorable regions to search for gas. These deep depressions include the Dongpu, Banqiao, Qikou, Bozhong [central Bohai Sea], and other depressions. Projections indicate that besides being able to find oil and gas pools "generated and reservoired in the same rock" in the lower Tertiary and secondary gas pools in the upper Tertiary in these depressions, it may also be possible to locate "gas pools generated in older rock and reservoired in newer rock", that is, Paleozoic secondary generation gas that has migrated upward along faults to accumulate in Tertiary traps. An example of this category is Wenliu gas pool in Dongpu depression.

The Paleozoic does not have secondary gas generation conditions in areas where it is buried at shallow depths and preservation conditions are poor. In regions where it is buried at greater depths, the structures are complex and our understanding of the laws of natural gas distribution is not adequate at the present time. This requires solid research and prospecting work before doing large-scale exploratory drilling. Preliminary analysis indicates that we should first select sloping zones near Paleozoic secondary gas generation centers and ancient buried hills or structural zones which have regional capping strata for exploration. Examples include Yangcun slope in Jizhong [central Hebei] depression, Yanxia slope in Dongying depression, and others.

2. Songliao Basin. This basin is a Jurassic and Cretaceous fault-subsidence and subsidence basin that developed on top of the Hercynian folded basement. The basin contains two oil and gas-generating strata systems. The top one is a Cretaceous depression-type generating strata system and the bottom one is a Jurassic fault-subsidence-type coal-bearing strata system. The lower Cretaceous is a set of river and lake facies oil-bearing formations with a maximum thickness $>$ 4,000 m. This includes very thick dark oil-generating rock with high concentrations and good categories of organic matter. Because the degree of maturity is not high (R_o is generally $<$ 1 percent), however, most of it is in the oil-generating stage and most of the small amount of gaseous hydrocarbons it has produced are gas dissolved in petroleum. It should be noted that a substantial part of the oil-generating rock in the Cretaceous in the western and northern parts of the basin is in the immature stage and there may be a possibility of finding organic gas pools. Organic gas has already been discovered in the Mingshui group in the Honggang Oil Field. The gas in the gas-bearing zones at Fulaerji-Alaxin-Yingtai may also be associated with organic gas. Thus, organic gas in shallow strata of the Cretaceous system should be a new realm in the search for gas. However, the primary realm to search for gas should still be the Jurassic.

The Jurassic system in this basin is divided into over 40 small fault- subsidence basins which cover a total area of $>$ 60,000 km^2, including 13 which are $>$ 1,000 km^2 in area, so they provide a very large area for exploration.

River, lake, and marsh facies coal-bearing formations developed widely in the middle and later parts of the late Jurassic. They have very thick dark mudstone ($>$ 700 m at Deshen 1 well) and are rich in organic matter. The parent material is humic in quality and there are several interbedded coal seams (total thickness 10 to 20 m), so it is an excellent gas-generating strata system. The degree of thermal evolution of this coal system is universally rather high ($R_o > 1$ percent), so it has very good gas-generating potential. In the Dehui and Lishu fault-subsidences, for example, the gas generating intensity is universally $>$ 4 billion m^3/km^2 and the maximum is 10 billion m^3/km^2.

The capping strata conditions of Jurassic system natural gas are very good and the large set of mudstone and shale in the Cretaceous Qingshankou group are excellent regional capping strata. The rather thick interbedded mudstone in the upper Jurassic also could serve as capping strata.

Quantou group and Denglouku group sandstone could serve as reservoir strata for Jurassic natural gas. Industrial gas flows have been obtained from the Yi'an and Maoshan structures in the southeastern part of the basin and in Quantou group sandstone in the Songzhan-Wangjiatun region in the northern part. Sandstone, the weathered bedrock crust, and volcanic rock bodies in the Jurassic also could serve as reservoir strata. Gas flows have already been obtained from drilling in the granite weathered crust at the Zhaoshen 1 Well.

The key problem in searching for Jurassic system natural gas is the universally poor quality of reservoir strata, so during future exploration attention should be given to searching for favorable accumulation zones and zones of suture development. Given our inadequate understanding of conditions in Jurassic basins at the present time, it would be best in the short term to make a dissection focused on Dehui and Lishu depressions and on the Songzhan- Wangjiatun region where industrial gas flows have already been seen. We also should do more intensive surveys and comprehensive assessments of other primary basins and gradually begin exploration.

B. Central China petroliferous region

This region is an area of relatively stable crust in China and mainly includes the Ordos, Sichuan, Qinshui, Chuxiong, and other basins. All of these basins are Mesozoic and Cenozoic basins that developed gradually on a foundation of a Paleozoic platform syneclise. The Mesozoic and Cenozoic formations are generally rather complete, which was favorable for further thermal evolution of organic matter and preservation of oil and gas in structures and strata beneath them, so they are favorable regions to explore for Paleozoic gas.

1. Ordos Basin. There are only limited proven gas reserves in this basin at present, but industrial gas pools or gas wells have been discovered in the upper and lower Paleozoic in recent years which reveal that there are excellent prospects for oil exploration in the Paleozoic.

The basin contains three sets of oil and gas formation combinations. The top combination is in the Triassic and Jurassic systems and has poor preservation conditions due to the low degree of maturity ($R_o < 1$ percent). Only a few low-output oil pools have been discovered so far and they are an oil-forming combination. The middle and lower combinations beneath them are two important gas-forming combinations.

The middle combination is a Carboniferous-Permian coal system. With the exception of being rather thin in the central and northern parts, the dark mudstone in this coal system is universally > 70 m and the coal seams generally have a total thickness of 10 to 20 m. Moreover, they have a high degree of thermal evolution (R_o increases from 0.6 percent to more than 3.0 percent moving from the edges to the center of the basin) and rather strong gas generation intensity, generally from 3 to 5 billion m^3/km^2 and as high as 7 billion m^3/km^2 in the western part.

There is widely distributed sandstone in the coal system which could serve as reservoir strata. The porosity is 3 to 18 percent, so it is reservoir strata of moderate and low porosity. In addition, limestone in the Taiyuan group also could serve as reservoir strata. Upper Shihezi group mudstone is widely distributed and very thick (140 to 160 m in the eastern and western parts, 40 to 60 m thick in the southern and northern parts), so it is excellent regional capping strata.

The Liujiazhuang and Shenglijing gas pools have already been found at the western edge and the Zhenchuanbao gas pool in the eastern part. Projections indicate that the northern part of Tianhuan depression, the southern slope of Yimeng uplift, and the "Sanbian" [three boundaries] region are favorable regions to explore for gas associated with the coal system.

The lower combination is the lower Paleozoic. Preliminary analysis indicates that this combination has the basic geological conditions for the formation of large gas pools:

a. Oil-generating rock has developed, the organic matter concentration is high, and the gas generation potential is great. At the southwestern edge of the basin, the Jixian system has 400 to 2,000 m of dark algal dolomite, the Cambrian system has > 400 m of dark gray limestone, and the Ordovician system has dark mudstone and limestone with a total thickness > 1,000 m. The organic carbon content of these carbonate rock is universally > 0.1 percent, the degree of thermal evolution is high ($R_o > 1.6$ percent), and the maximum gas generation intensity is > 2 billion m^3/km^2;

b. The capping strata conditions are good. Carboniferous-Permian and Mesozoic argillaceous rock has developed within the basin and is excellent regional capping strata. The Ordovician system in the eastern part of the basin has thick interbeds of gaoyan [5221 7770 gypsum-halite] strata that could serve as excellent capping strata for the eastern region;

c. The top of the Ordovician system is a regional ancient weathered crust. Carbonate rock ancient weathered crust is excellent reservoir strata for natural gas as well as a channel and site for the regional migration and rich accumulation of natural gas. High-output gas flows were recently obtained from the Shan 1 Parameter Well and Yu 3 Well at the eastern tip of the central ancient uplift, which indicates that the ancient weathered crust at the top of the Ordovician has excellent gas-bearing tendencies over a large area.

Deductions from information indicate that between the gentle eastern slope of the central ancient uplift and the region of gaoyan distribution in the eastern part, there may be favorable reservoir facies zones in the Ordovician, so in the future we should expand exploration achievements southward and westward from the Shan 1 Parameter Well and Yu 1 Well where gas has already been found. Moreover, in the region between the southern tip of the central ancient uplift and Weibei uplift near the hydrocarbon generation center, if there is a good matchup of traps and preservation conditions, it would be extremely favorable for the formation of large gas pools, so we should actively undertake regional exploratory prospecting.

2. Sichuan Basin. This basin is China's biggest natural gas industry base area as well as the main region for increasing our natural gas reserves and output in the short term.

This basin is a polycyclic basin within a craton which has sedimentary rock with a total thickness of 12,000 m. Fifteen oil-producing strata have been discovered from the Jurassic to Sinian. Among them, with the exception of continental facies clastic rock in the Jurassic and upper Triassic, the remainder are all marine facies carbonate rock. Analysis of existing proven gas reserves and projected resource amounts indicates that the Triassic, Permian, and Carboniferous systems are the primary strata systems for increasing reserves and output in the short term, whereas east Sichuan, south Sichuan, and southwest Sichuan are key exploration regions.

The material properties of the carbonate rock reservoir strata in the basin are all rather poor and local structures formed late, which determined that this basin has a large gas-bearing area in which the individual gas pools are small and scattered. This characteristic shows that there is still great potential for already explored strata systems. Besides anticlines, which have been explored to a higher degree, there are also concealed structures, fault noses, organic reefs, suture systems, Carboniferous system weathered crust, and many other types of targets for exploration. It also shows that in the existing exploration realm, it will be rather difficult to find large gas pools and achieve a significant leap in natural gas reserves and output. Thus, there is an urgent need to develop new realms for exploration.

The new realms of this basin which should be explored include the Leshan- Longnusi ancient uplift and the lower Paleozoic on its southeastern slope region. There may be two categories of natural gas accumulations in these regions. One is accumulations in the lower Paleozoic ancient weathered crust. Before the Permian era, the Sinian to Silurian systems outcropped in the central part of the ancient uplift and there would certainly have been ancient karst development under the effects of long-term weathering and leaching. Intermittent erosion before the Permian would not be favorable for the preservation of natural gas formed during previous periods, but natural gas that reformed during subsidence after the late Paleozoic could have accumulated. Besides anticlines, the types of traps for this category of accumulation also could include stratigraphic, lithologic, and other types of traps and the favorable region for them would be in the area of Weiyuan, Anyue, Hechuan, and Tongxian. The second is accumulations in folded-type anticline traps. Anticline folded zones developed on the southeastern slope of the ancient uplift, so the lower Paleozoic has rather thick Silurian argillaceous rock that could serve as capping strata which would aid in the formation of anticline-type gas pools. The favorable formations include Xiangguosi, Xishan, Macaoba, and other anticlines.

In addition, strata in the lower part of the upper Triassic overlap successive strata moving from west Sichuan to central Sichuan, so it is possible that large stratigraphic and lithologic trap gas pools may have formed, and we should actively undertake exploration.

C. West China petroliferous region

This region has a complex geological structure with a structural configuration of alternating rows of large compound basins and folded mountain systems. The structures within the large basins are all relatively stable and the regional structures form large uplift, large subsidence, large slope, and large fracture characteristics. Local structures are broad, gentle, and integral, cover large areas, and have many oil-generating rock systems of great thickness with rich oil and gas sources, so they have the geological conditions for formation of large oil and gas pools. Thus, these large basins are important reserve regions for developing natural gas in China and future exploration and research work should focus on the search for large gas pools.

1. Junggar Basin. This basin may contain mostly oil in the thrust fault zone on its northwestern margin, the eastern structural region, and shallow strata at the southern edge, whereas it may be mostly gas in the central part of the basin and in deep strata at its southern margin. It also has the basic geological conditions for the formation of large oil and gas pools.

The central part of the basin refers to the region from the southern slope of Sangequan uplift to the Zhongyang [central] uplift zone and covers an area of about 20,000 km^2. This region was in the primary oil-generating region during the Carboniferous, Permian, Triassic, and Jurassic. The degree of maturity is high in both its Jurassic coal system and the Permian system, its primary oil-generating strata, and they could provide rich gas sources. The oil-generating region has four large positive structures, the southern slope of Sangequan uplift, Mosuowan uplift, Zhongguai uplift, and Dabasong uplift, which surround the oil-generating depression. There are large traps in the Permian and Triassic systems on these uplifts, and large sets of Triassic and Jurassic mudstone can serve as regional capping strata, so the reservoir formation conditions are quite superior. The material properties of the Permian and Triassic system reservoir strata in this region may be rather poor, which is the key geological problem in regard to whether or not large oil and gas pools were formed. The most favorable structural zone in this region is the group of anticlines on the southern slope of Sangequan uplift. The anticline traps here cover a large area (Shinan No 3 anticline, for example, covers an area of nearly 300 km^2) and the target strata are buried at relatively shallow depths (the bottom of the Triassic system is about 4,000 m deep). There are regional strata overlaps in the Permian, Triassic, and Jurassic systems which may have formed large stratigraphic traps, and there are stratigraphic unconformable surfaces and weathered crusts which are conducive to the regional migration and accumulation of oil and gas. On Mosuowan uplift, most of the faults extend into the bottom of the Cretaceous and oil and gas indications have already been discovered in the Cretaceous and Jurassic systems in the Luliang anticline zone on this uplift, which shows that oil and gas pools also may have formed in shallow strata, but it is possible that their traps are smaller than traps in deeper strata.

The main targets for exploration at the southern edge of the basin are deep strata west of Urumqi. New seismic data indicates the presence of a fracture zone at the southern margin of the basin. Its deep strata are fault-steps, the upper part is an anticline zone, and there are relatively consistent high points on the deep and shallow strata structures. The oil-generating rock in the premontaine depression at the southern margin is very thick, especially the Jurassic coal system which has an oil-generating intensity > 20 billion m^3/km^2. Below, there are faults which connect oil and gas sources in many strata and above are anticline traps which developed that accumulate oil and gas, some of which may have formed large oil and gas pools.

2. Tarim Basin. This basin is a Mesozoic and Cenozoic superposed basin which developed on top of a Paleozoic platform. The Paleozoic is 5,000 to 12,000 m thick and is mainly shallow sea platform facies carbonate rock. The Mesozoic and Cenozoic are inland basin sediments and are mainly distributed in subsided regions at the margin of the basin. The basin contains four sets of oil and gas-generating strata systems, the Cenozoic, Mesozoic, upper Paleozoic, and lower Paleozoic. So far, only the Kekeya condensed oil and gas pool has been found in the upper Tertiary at the southwestern depression.

The main regions having the geological conditions for the formation of large oil and gas pools are Tabei [north Tarim] uplift, Shamo low uplift, and the southwest depression.

Tabei uplift covers an area of 36,600 km^2 and is located between Manjiaer depression and Kuqa oil-generating depression, which makes it favorable for capturing oil and gas. There are three sets of oil-generating strata systems in the basin, the Cambrian-Ordovician, Carboniferous-Permian, and Triassic-Jurassic, and they have rich oil and gas sources. Analysis of the history of their thermal evolution and parent material categories indicates that the Cambrian-Ordovician and Jurassic systems mainly generated gas while the Carboniferous, Permian, and Triassic systems mainly generated oil. There are many types of traps on the uplift and the traps cover large areas. The four structures and ancient buried hills on top of them cover a total area of 1,455 km^2 and the two largest stratigraphic unconformable cone-shaped bodies cover an area of 1,400 km^2. Although the Silurian-Devonian system capping strata on top of the uplift may have been eroded away, upper Permian lake facies mudstone also can serve as capping strata for natural gas reservoired in the lower Paleozoic. High-output oil and gas flows have already been drilled from four structures, Yakela, Lunnan, Sangtamu, and Yingmai No 1, and some wells have produced large amounts of gas, which indicates a possibility that large oil and gas pools may have formed in this region.

Shamo low uplift is located on the eastern half of Tazhong [central Tarim] uplift and formed mainly during the Caledonian and early Hercynian periods. On the north, it is close to the Pujiaer oil-generating depression and it is a guide region for oil and gas migration. There are two large structures, the Tazhong No 1 and No 2 on top of it. Deductions from the scale of the formation and the strata contact relations indicate that it may have formed large anticlines or stratigraphic unconformity oil and gas pools.

The southwest depression region is another favorable region to explore for large gas pools. Kekeya gas pool has already been found in this region, and it deserves further exploration.

D. Continental shelf petroliferous region

Economic geography conditions determine that development of natural gas in marine areas must be based on large gas pools. Of China's many marine basins, those with the conditions for formation of large gas pools include the East China Sea, Yingge Hai-Qiongdongnan, Zhujiangkou [Pearl River mouth], and other basins.

The Cenozoic in the East China Sea Basin has a maximum thickness of 12,000 m. The lower Tertiary is marine-continental interchange facies and shallow sea facies or shallow lake facies sediments. The upper Tertiary is marine- continental interchange facies and river and lake alternating facies sediments. The parent material is mostly humic. The early Miocene in Xihu depression is littoral marsh facies and developed coal-bearing formations. This basin has a high ground temperature gradient (3.4 to 3.75° C/100 m) and the oil-generating rock in deep depressions is already in the highly- mature stage, which is conducive to the formation of large amounts of natural gas. Structural traps cover large areas and 21 structures > 100 km^2 have already been discovered. Good sandstone reservoiring strata have developed, which is conducive to the formation of large gas pools. This is confirmed by high-output gas flows that have already been discovered in the Oligocene in Pinghu depression. The best region to explore for large gas pools in this basin is Pinghu depression and Diaobei depression.

Yingge Hai-Qiongdongnan Basin and Zhujiangkou Basin have a high temperature gradient (the average ground temperature gradient in several wells in Yacheng depression, for example, is 4.15° C/100 m). Lower Tertiary oil-generating rock in deep depressions has already entered the highly-mature stage and the lower Tertiary in some regions is coal-bearing formations with good gas source conditions. In Ya'nan depression, for example, the gas generation intensity of the lower Tertiary is universally > 8 billion m^3/km^2. The gas formation periods in these two basins were new and the Tertiary itself has good reservoiring and capping conditions, which is conducive to the rich accumulation and preservation of gas. The large Ya 13-1 gas pool has already been discovered in Qiongdongnan Basin.

It deserves special mention that the upper Tertiary and part of the Quaternary in the South China Sea continental shelf basin has very thick marine facies mudstone sediments. The upper Tertiary in the southeastern part of Yingge Hai Basin is > 5,000 m thick. All of the upper Tertiary is in the immature or low maturity stage, so it could have formed large amounts of organic gas. If it is associated with large turbidity current sand bodies, large organic gas pools may have formed. The high-pressure water-dissolved gas eruption from an upper Tertiary sand body at Ledong 30-1-1A well is a gas indication that deserves attention. Large organic gas accumulations in this region may become an important new realm in the search for gas in China.

In summary, China has very large potential natural gas resources and we have an overall understanding of the main directions of exploration. The main problems at present are that we have not done enough research on or gained a clear understanding of the actual pool formation conditions and regional distribution laws for natural gas under different geological conditions because of a rather low degree of exploration, so it is hard to recommend exploration goals, or the goals that are recommended are not sufficiently accurate. This is truly a topic that urgently requires attacks on key problems in the future.

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Deep, Large-Diameter Wells Drilled in Northern Tarim

906B0103D Urumqi XINJIANG RIBAO [SCIENCE AND TECHNOLOGY DAILY] in Chinese 10 Jul 90 p 1

[Article by reporters Zhao Zunxiu [6392 1415 4423] and Li Wan'en [2621 8001 1869]: "First Successful Large-Diameter Casing and Well Cementation in a Deep Well in North Tarim Oil Field, Borehole Operation Technologies Pushed Up to a New Stage in China's Oil Wells"]

[Text] Braving temperatures over 40° C in the Tarim Desert, the Ministry of Geology and Mineral Resources Joint Command Prospecting Team fought hard day and night on 28 Jun 90 to complete a 24 cm diameter and 5,350 m deep casing installation and well cementation task without problems at the Sha 15 well and pushed borehole operations technologies in China's oil wells up to a new stage.

To obtain complete and accurate geological oil and gas data for deep strata in the Yakela structure in North Tarim, the North Tarim Oil and Gas Prospecting Joint Command of the Ministry of Geology and Mineral Resources designed the Sha 15 well, the deepest exploratory well in North Tarim. This well was drilled to a depth of more than 5,350 m with a 30 cm diameter drill bit and the core extraction rate from the primary oil strata was 91 percent. To obtain oil and gas data for deep strata for the entire 5,350-plus meters, the technical requirements called for a 24 cm diameter steel casing, but all the well casings used in China's large oil fields at present are smaller than 20 cm. This was the most difficult and deepest borehole engineering technology, both in North Tarim and in all of China.

Leaders in the Command Department and large numbers of technical personnel faced problems like very difficult construction, high expense, a lack of experience, backward technical equipment, and so on. Through careful design and calculations, they tried to reduce the load on the big hook of the drill rig. They also assigned key personnel to learn from experience and invited over 20 in-well engineering experts from the Ministry of Geology and Mineral Resources to visit the site and discuss operational programs and technical measures. To ensure that insertion of the casing went smoothly and safely, they used a large amount of glass spheres and other mud treating agents and a 500-ton pneumatic slip-type elevator, large hydraulic tongs, and other new techniques and new technologies imported from the United States. By making meticulous deployments and inserting the casing at a pace of more than 50 pieces per 24 hours over the conventional pace, the 9001 Drilling Team which had contractual responsibility for the Sha 15 well completed the 5,350 meters of large-diameter well casing 10 hours ahead of the original plan. The Northwest China Petroleum Geology Bureau's Borehole Operations Team completed the first stage of well cementation with superior quality and high efficiency at 1800 hours on 27 Jun 90, and they completed the second stage of well cementation on the morning of 28 Jun 90. Experience confirmed that the quality of construction in both stages of well cementation for the entire well met the expected requirements.

Production Increased at Zhongyuan Fields

906B0103A Changsha HENAN RIBAO in Chinese 8 Jul 90 p 1

[Article by reporter Huang Xijing [7806 6932 2529]: "Stable Growth in Petroleum Output at Zhongyuan Oil Field, Foster the Spirit of Daqing, Exploit Production Potential"]

[Text] All the cadres and employees at Zhongyuan Oil Field have been fostering the spirit of Daqing and exploiting production potential in the old oil region to move petroleum output out of a deep valley. Since the last third of June 1990, daily crude oil output has exceeded 18,000 tons, an increase of more than 630 tons over the average daily output during May 90.

A few months ago, a landslide began appearing in petroleum output at Zhongyuan Oil Field. The top leadership at the oil field led technical personnel for extensive visits to the oil extraction plants and oil deposits to join with cadres and workers in analyzing the causes for the failure of petroleum output to rise. They learned that in a situation of insufficient investments in petroleum construction and inadequate reserve strengths at the oil field, it would be quite difficult to increase petroleum output simply by drilling new wells. For this reason, they focused on fully exploiting production potential in the old oil region and tried to increase outputs with fewer inputs and raise economic results. The No 1 Oil Extraction Plant established and perfected a strict management system and implemented responsibility down to individuals. The workers fostered the "three honests and four stricts" working style [be honest in thought, word, and deed, set strict standards for work, organization, attitude, and observance of discipline], inspected equipment according to schedule, increased the number of well patrols, extracted complete and accurate information, effectively reduced oil well shutoff rates and leakage rates, lengthened the operating time of oil and water wells, and increased the oil extraction time rate from 87 percent to more than 90 percent, and there was a stable increase in crude oil output.

To exploit production potential in wells which have stopped producing and in low-output wells, the oil field began a battle to support retired wells and transform low-output wells. In just over 1 month, after implementing pressure cracking, acidification, consolidated elasticity compensation perforation, and other technical measures in over 130 retired and low-output wells, retired wells were restored to production and low-high wells became high-output wells.

Completion Near on Phase One of Major Sichuan Gas Field

906B0103B Chengdu SICHUAN RIBAO in Chinese 25 May 90 p 1

[Article by Wang Nenggui [3769 5174 6311] and reporter Chen Yuehai [7115 1471 3189]: "Moxi Gas Field Combines Exploration and Development To Supply Gas Ahead of Schedule, Construction of First Phase of Project May Be Completed By End of 1990, Daily Natural Gas Output May Reach 500,000 Cubic Meters"]

[Text] Several 1,000 employees at Moxi Gas Field, a key construction project in Sichuan Province, are responding to urgent national needs, overcoming difficulties, and combining exploration and development. They have transmitted 7 million m^3 of natural gas to the state since 1 Jan 90.

Moxi Gas Field is located between Suining, Lianxi, and Dongnan. It is Sichuan's third largest gas field. The Central Sichuan Mining Region of the Sichuan Petroleum Management Bureau formally began construction of Moxi Gas Field in July 1988. With a budgeted investment of several 100 million yuan, the design called for drilling 110 wells, building 13 gas collection stations, laying 90 kilometers of transmission pipelines, and building a desulfurization plant. Planned completion of construction is in 1993, it will produce 500 million m^3 of natural gas yearly, and it will operate continuously for more than 25 years.

During construction of Moxi Gas Field, several 1,000 petroleum employees fostered the Daqing spirit of "moving forward when conditions permit and moving forward when the conditions do not permit by creating the conditions". They used an arrangement that combined exploration and development, discovered the Xiangxi group gas strata in the primary gas producing strata, and drilled eight wells. On 21 Feb 90, they drilled the first 1 million m^3 daily output grade large gas well in the history of the Central Sichuan Mining Region. At the same time, the employees of Moxi Gas Field overcame capital shortage problems, guaranteed quality, fought for time, and accelerated progress in construction of the gas field. Drilling has been completed at over 30 gas wells and the 90 kilometer long transmission pipeline has begun operating. They have deployed 20 single wells and eight gas collection stations are now under construction. Construction of the primary trunkline project that will pass through the Fu Jiang has now successfully been pushed to completion prior to the arrival of floodwaters. On 16 May 90, the 50,000 m^3 per day transmitted through Beihuan on the trunkline to Chengdu was increased to 100,000 m^3 to provide timely help for industrial and agricultural production.

The first phase project at Moxi Gas Field may be completed by the end of 1990. If it is, it will supply 500,000 m^3 of gas to Chengdu each day.

Pressure Test at Qinshan Said Successful

916B0015A Beijing RENMIN RIBAO in Chinese 7 Nov 90 p 1

[Article by reporters Lu Yaling [6424 7161 3781] and Hu Nianqiu [5170 1628 4428]: "Successful Water Pressurization Test at Qinshan Nuclear Power Plant, Quality of Design, Manufacture, and Installation Excellent, Debugging Imminent"]

[Text] Water pressurization tests were successfully carried out on the primary systems at Qinshan Nuclear Power Plant on 5 Nov 90. With this, full debugging of this large nuclear power plant designed and built by China herself will begin.

According to information from the China Nuclear Industry Corporation, after starting water pressurization tests at Qinshan Nuclear Power Plant at about 0300 hours in the early morning of 5 Nov 90, the pressure of the primary system rose to 21.5 MPa (219 kg of force/cm^2). This pressure was held stable for the stipulated amount of time based on the requirements of strength tests. Next, the pressure was reduced to 17.2 MPa (175 kg of force/cm^2) and sealing tests were carried out. All the experiments went smoothly and no leaks or other abnormalities were discovered.

The water pressurization test was an important way to inspect for leaks of radioactive materials in all of the various operating systems of the nuclear power plant. This test was a major milepost in construction of Qinshan Nuclear Power Plant. The successful test showed that the quality of the design, manufacture, and installation of the operating systems and equipment at Qinshan Nuclear Power Plant was excellent and it will play a very important role in safe operation of the nuclear power plant.

Experts assigned by foreign businesses who supplied the relevant equipment for Qinshan Nuclear Power Plant carried out on-site services and observed the entire process during this test. Based on requirements in China's nuclear safety laws and regulations, the State Nuclear Safety Bureau's Shanghai Supervision Station organized a special supervision group to carry out supervision throughout the entire process for this test.

Second Stage of Qinshan Approved

40100020b Beijing CHINA DAILY (Business Weekly) in English 17 Dec 90 p 2

[Text] A 300-megawatt nuclear reactor will be built as part of the second stage of the Qinshan Nuclear Power Plant in east China's Zhejiang Province, according to Jiang Xinxiong, manager of the China Nuclear Industry Corporation.

The plan has been recently approved by the government. The original plan for the second stage of the 300-megawatt Qinshan plant would include two 600-megawatt pressurized water reactors. The small reactor will increase the capacity of the project's second stage to 1,500 megawatts.

'728' Project: Symbol of Nation's Progress in Nuclear Power

916B0004C Chengdu SICHUAN RIBAO in Chinese 31 May 90 p 1

[Article by Wang Yongcai [3769 3057 2088], Zhao Zhilin [6392 2535 2651], and SICHUAN RIBAO reporter Wang Gang [3769 0474]: "Nuclear-Powered Reactor '728' Elements Project Completed, An Important Symbol of China's Reliance on Its Own Strengths To Build Nuclear Power Plants"]

[Text] The first nuclear reactor "728" elements project designed and built by China passed project completion examination and acceptance led by the state Ministry of Energy Resources, Environmental Protection Bureau, and other relevant units at Yibin Nuclear Fuel Elements Plant on 26 May 90. This is an important symbol of China's reliance on our own strengths to build nuclear power plants and it fills a gap in the area of design and manufacture of fuel elements for nuclear power plants in China. It is at international levels of the 1980's.

The nuclear reactor "728" elements project was designed and built to produce fuel assemblies and related assemblies for China's first 300MW nuclear power plant at Qinshan. Construction of the project began in May 1975. For over a decade, the units involved in design and construction of this project and vast numbers of S&T personnel and workers at Yibin Nuclear Fuel Elements Plant have fostered the spirit of relying on one's own efforts and arduous struggle to overcome a series of technical problems and make more than 170 important scientific research achievements. At the same time, they also absorbed advanced technologies and experiences from foreign countries. The project was basically completed at the end of 1987 and placed into trial production. After 2 years of trial production, the first group from the first heat of fuel assemblies and associated assemblies for the Qinshan nuclear power plant passed state-level plant gate examination and acceptance in December 1989. In the examination and acceptance of the completion of this project, the quality of the construction project was assessed as excellent.

To ensure that the Qinshan nuclear power plant is connected to the grid and generates power on schedule, Yibin Nuclear Fuel Plant began shipping products to Qinshan in February 1990. Shipping of all of the first fuel assemblies and associated assemblies was completed at the end of July 1990, ending China's historical lack of nuclear power.

Low Temperature Heat-Supply Reactor Opens New Possibilities for Nuclear Energy

916B0015B Beijing JINGJI RIBAO in Chinese 22 Oct 90 p 3

[Article by JINGJI RIBAO reporter Wang Yadong [3769 0068 2639]: "Low- Temperature Heat-Supply Reactor Opens New Realms for Nuclear Energy"]

[Text] Not long ago, Qinghua University's experimental 5 MW low- temperature nuclear heat-supply reactor, a state project to attack key S&T problems during the Seventh 5-Year Plan that is located in the northern suburbs of Beijing, went through a 100-day period of continuous heat supply operation and passed technical inspection and acceptance and project examination and acceptance led by the State Planning Commission, State Science and Technology Commission, State Education Commission, and Ministry of Finance. This indicates that China has now entered advanced world ranks in low-temperature nuclear heat-supply reactor technologies.

A low-temperature nuclear heat-supply reactor is a special nuclear-powered device used to supply heat that has been studied and developed over the past few years. It has major significance for alleviating the energy resource and communications and transport shortages and for reducing environmental pollution. Moreover, the operating costs are lower than the operating costs for coal-fired boilers. Thus, it has broad applications prospects.

China began R&D on low-temperature nuclear heat-supply reactor technologies in the early 1980's. After several years of demonstrations by experts, a design program was determined for an "integrated natural circulation casing-type pressure self-stabilizing reactor". This type of heat-supply reactor adopted a new type of control rod hydraulic drive apparatus, passive excess heat discharge system, double pressure-bearing casing, and other advanced technologies which gave it good safety properties. It did not require huge and complicated safety facilities. Instead, the overall unit was simple and the equipment was relatively easy to manufacture. It laid an excellent foundation for the development of nuclear heat supplies in China.

Some might ask if it is different from nuclear heat supplies at the nuclear power plants China is now building at Daya Bay and Qinshan. We say that although all of them use nuclear fuel to carry out a fission reaction and generate energy, the low operating parameters of low-temperature nuclear heat- supply reactors and their relatively simple equipment compared to nuclear power plants mean that they do not require steam turbines and electric generators, but instead supply heat directly. They require lower investments and shorter construction schedules, and they can be developed by relying on China's own efforts and our existing industrial and technical foundation. In view of the shortage of heat sources now and into the future, we must develop various types of energy resources to solve our energy problems. Besides coal, petroleum, and hydropower, nuclear power is an important useable energy resource. Given that half of our primary energy resource consumption goes to supply heat, while making major efforts to develop nuclear power, using nuclear energy to supply heat is an important way to develop nuclear power.

Some have calculated that replacing a coal-fired boiler with a 200 MW low- temperature nuclear heat-supply reactor to supply heat can meet the central heating needs of 3 million m^2 of structures (equivalent to 60,000 houses). This could reduce coal and slag haulage by more than 300,000 tons per year and eliminate noxious gases, soot, and slag and improve the urban atmospheric environment. It is precisely because of these advantages that several cities and enterprises have submitted project proposals requesting construction of low-temperature nuclear heat-supply reactors to meet their central heating needs. The state has already approved construction of China's first experimental industrial 200 MW low-temperature nuclear heat-supply reactor device at the Jilin Chemical Industry Company to move development of nuclear heat supply technologies in China into a new stage.

In the long-term view, using low-temperature nuclear heat-supply reactors can provide hot water to heat urban structures and industrial steam for industrial and mining enterprises, for joint production of low-temperature power and heat supplies, and for comprehensive utilization including low-temperature nuclear cooling, seawater desalination, irradiation processing, and so on. This is especially true for substituting nuclear power for oil in north China's oil fields and solving problems of heating, heat associated with oil transmission, and warm water injection for oil extraction, so its economic and social benefits will be even more apparent.

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