ACTIVITIES OF THE PETROLEUM AND PETROCHEMICAL INDUSTRIES IN JAPAN

Present Development of Petroleum Refining*

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Introduction

The petroleum refining in Japan has a relatively long history if we include its primitive stage in it. Because Japan produced crude oil, utilization of petroleum has been studied since early days as in other oil-producing countries. Refining has been carried out by methods feasible at each time.

The development of the petroleum refining in Japan can be roughly divided into three periods. The first period begins around the time when the petroleum industry began to be recognized as a modern industry until the outbreak of the Sino-Japanese War in 1930, which is considered as prelude to the World War II. The second period covers the time of war beginning 1931 until the end of the World War II. The third is the period of peaceful development of the industry during the post-war years to date.

The First Period (up to around 1309)

Crude oil in Japan has been produced in the area facing the Japan Sea where oil fields of today are located. The exploitation must have taken place years back, as it is recorded in some old books that oil (inflammable water) was dedicated to shrines in 668 A.D. It is reported that, in 17th century, natural gas was used for fuel in the oil-producing regions and, in 19th century, crude oil was put to a lighting use. There is also kept a record that a crude distillation plant was established in 1852 applying the method of distilling sake (rice wine).

The production of crude oil in Japan as a modern industry actually began in the middle of 19th century. This apparently is closely related to the world-wide interest in the development of petroleum resources at that period. The production of crude oil was officially recorded for the first time in 1874. Since then until the end of 1958 the total output during the 85 years amounted to 110,616,000 barrels or an average yearly output of 1,300,000 barrels.

Although the amount is small, Japan has been carrying out its own crude oil production in one corner of the world.

In 1873, cable tool drilling machines were imported for the first time from the United States. Until then, digging wells had been done only by hands. These pit operators, which were quite large in number, were gradually incorporated in the drilling machine operators following the expanded use of machines and a few of them succeeded in developing into powerful oil companies. These oil companies undertook exclusively the production, pipeline transportation and refining of crude oil and thus laid foundation for the petroleum industry of today.

In 1879, an imported batch still was installed as the first crude distillation unit in Japan. In 19th century, petroleum was mainly used as lamp oil. In 1894, however, a unique method of spray combustion of heavy fuel oil was invented in Japan and this method was since widely adopted by refiners. On the other hand, Japan began to import kerosene from other countries. A certain foreign company also took part, although for a short period of time, in the Japanese petroleum industry. The Standard Oil Company of the United States had once commenced the exploitation and refining of petroleum in Japan. However, they transferred all of their facilities to a Japanese oil company in 1907 when they found out that it was more paying to export petroleum products to Japan because of the limited oil resources she has.

Beginning the early part of 20th century, automobile using gasoline became increasingly popular and the construction of hydro-electric power stations was thrived. As the result, demand for kerosene was reduced but a new demand for motor gasoline and marine fuel oil sprung up and the petroleum refining has developed in an endeavor to keep abreast with the changing social scenes. Batch stills were, however, predominantly used for petroleum refining until early 20th century, despite the various improvements made in these devices. It was not until 1920 that a pipe-still

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was introduced to Japan as the first modern distillation unit. This was the Trumble process installed by the Japanese Navy in its own refinery. As regard the vacuum distillation, two units of batch-type Schultz process were installed at two oil companies in 1927, followed by the installation of a Heckmann vacuum distillation still in 1929. The Foster two-stage topping and vacuum distillation unit introduced in 1930 was the first vacuum pipestill in Japan.

The first thermal cracking plant was set up in 1924 which was a Dubbs process and, in 1926, one each of Jenkins process and Cross process was installed by two private concerns respectively. Since, installation of two Kellogg processes and one Cross process in 1931 and one NNO topping unit, for which the patent was obtained by Nippon Oil Co., Ltd., and another Kellogg unit in 1932 successively followed.

The above course of modernization and expansion of refining facilities explains the fact that the Japanese oil companies went all out to meet the ever-increasing demand for the petroleum products within the country and, at the same time, to cope with the foreign companies making inroads into Japan.

It is interesting to observe these developments of refining facilities when we have in mind the situation of petroleum supply in those days. In 1920, 52 percent of gasoline and 74 percent of heavy fuel oil were supplied by domestic production. In 1930, however, only 37 percent of crude oil, 38 percent of gasoline and four percent of heavy fuel oil were supplied with the domestic products. As shown by these figures, the output of indigenous crude oil failed to increase in parallel with the rapidly growing demand for petroleum products. This resulted in allowing the imported products to cover the shortage of domestic supply, in spite of the expansion and development of refining facilities, making Japan a favorable market for foreign interests.

Meanwhile, the world production of crude oil greatly increased following the successive discoveries of gigantic oil fields, leading to oversupply of crude oil. This caused the major oil companies throughout the world to plunge into a severe sales competition. Within Japan, too, extreme competition was induced between the Japanese refiners and foreign companies, namely, the Standard Oil Company and the Rising-Sun Oil Company (Shell Oil of today), both of whom had already launched out into their activities on the Japanese petroleum

market during 19th century. On top of all this, a Russian oil company joined the competition in 1933 and dumped their gasoline on the Japanese market, which drove the Japanese companies into the verge of bankruptcy.

The Second Period (1931~1945)

This period was a time when Japan's petroleum refining went through revolutionary changes.

In 1931, Japan entered into the war against China in Manchuria. This war was protracted for years and developed into the World War II. This war made it imperative for the Government to secure petroleum supply to meet military requirements. In order to secure petroleum supply and also to protect and promote domestic petroleum refining, the Government enacted, in 1934, the Petroleum Industry Law. The essential points of the law existed in the establishment of an approval system on the refining industry thereby guaranteeing the possession of certain amount of refining capacity within the country and at the same time allowing the Government to have the right to determine import quantities of crude and products and crude throughput rates. Furthermore, this law imposed a duty, on the petroleum companies, of storing enough crude for six months' operation. The enforcement of this law enabled the Japanese oil companies to enjoy stabilized operation under the Government's protection but foreign oil companies suffered the restriction on their activities and they completely ceased the operation in Japan during the World War II. This control over the petroleum industry by the Government with the purpose of carrying out the war continued until the end of the war.

In order to provide aviation gasoline, aviation lubricating oil, marine fuel oil and other petroleum products for military uses, the Government newly established petroleum refineries and expanded existing facilities under direct operation by the Army and Navy. The Navy had its own refinery within the country since 1921 which, in its early days of operation, had been producing heavy fuel oil. In 1941, it established another refinery. The Navy also set up, in 1939, a joint laboratory incorporating all the existing fuel laboratories scattered around the country and launched out into research for refining techniques, the processing of aviation gasoline and aviation lubricating oil manufactures, etc. Furthermore,

it owned a coal mine within the country and a briquette manufactory, for warship use in Korea under its direct operation. It also directly administered oil fields and a refinery in Borneo. The Army, on the other hand, began operating a refinery within the country for the first time in 1943 and at the same time constructed a refinery and a synthetic petroleum manufacturing factory in Manchuria. These refineries under direct supervision by the Army and Navy mainly manufactured aviation gasoline, aviation lubricating oils and fuel oil for tanks, while the supply of heavy fuel oil was partly left in the hands of private petroleum refiners and partly depended on the resources in the occupied areas of Southeast Asia.

The refining capacity of the private petroleum enterprises was far from adequate, both in quality and quantity, to meet the military demands when the aforementioned Petroleum Industry Law was put in practice. According to the statistics, private oil companies at the end of 1930 numbered 25 with 37 refineries, and the total crude thruput capacity amounted to 22,000 BPD. Of these refineries, only four had thruput capacity of more than 2,000 BPD. On the other hand, a refinery owned by the Navy at that time had a capacity of 4,500 BPD.

To improve this situation, the Government consolidated these private oil enterprisers into eight companies, abolished small-scale refineries and called for construction and modernization of large-scale refineries. Those refining facilities set up by private concerns in line with the government and military policies included large-scale topping units, thermal and catalytic (fixed catalyst bed type) cracking equipment for processing aviation gasoline and isooctane polymerization facilities. For manufacturing aviation lubricating oils, solvent dewaxing and extraction facilities were installed adopting Barisol process, BK (acetone-benzene) process, Propane process, Duo-sol process, Furfural process, and other methods. Press-filter units were also placed for dewaxing heavy fuel oil made from the imported crude oil from South Sumatra because of its high percentage of wax content. Moreover, the private petroleum companies jointly organized two companies and built very modern refineries for those days, two in Korea and one in Manchuria, for the purpose of supplying petroleum products for military and private consumption on the continent.

During the World War II, both military and private concerns made great efforts in expansion and improvement of their petroleum

refining facilities. However, those refineries were never fully operated due to the insufficient raw material because of the fact that the import of crude oil to Japan from Southeast Asian countries were often intercepted by submarine attacks. In the mean time, the refineries within the country were bombed one after another by the American air forces. The damage was extensive and Japan lost two-thirds of the total crude thruput capacity of private petroleum refineries while the military refining facilities were almost totally destroyed.

The Navy, Army and private concerns respectively possessed the following facilities just before they were attacked by air-raids.

The two refineries operated by the Navy had the topping capacity of around 35,000 BPD, cracking capacity of 5,350 BPD (using the Navy's unique method, Cross process, Gyro process and Catalytic process), hydrogenation capacity of 4,280 BPD, isooctane polymerization (finished product of 380 BPD) plus solvent dewaxing and extraction facilities.

The refinery of the Army owned within the country was still under construction but its facilities included the topping capacity of 6,300 BPD, cracking capacity of 7,140 BPD, isooctane polymerization (finished product, 200 BPD) and a solvent extraction unit.

As regards the private petroleum companies, the total topping capacity amounted to 71,000 BPD. The eight thermal cracking units these companies operated processed 12,540 BPD, while the three catalytic cracking units possessed a combined capacity of 5,350 BPD. The number of refineries totaled 23 with an average topping capacity of 3,100 BPD which was more than three times as much as the total capacity of 37 refineries in 1930, *i.e.*, 22,000 BPD.

The Third Period (Post-war years)

Japan was in a state of bankruptcy immediately after the World War II due to the defeat in the war. For rehabilitation of the economy, immediate recovery of its mining and industrial production was imperative. The Japanese Government therefore took up the reconstruction of electric power and coal mining industries as the essential point of its industrial rehabilitation program. As regards the petroleum refining, however, the Allied Forces, taking the view that it was one of the war industries, ordered the closing of all the Pacific Coast refineries which constituted Japan's main force of petroleum refining.

Moreover, the remaining facilities which escaped the bombing were considered as possible items for war reparation or for scrapping. Only the refineries in the oil-producing areas on the Japan Sea Coast were permitted to continue the operation on a small scale. Consequently, the supply of petroleum in Japan had to be wholly dependent on, until 1950, imported products brought in with GARIOA funds and the government enforced rigid distribution control to restrict the domestic petroleum consumption to the minimum. The Allied Forces, however, shifted their previous policy and ordered the urgent rehabilitation and reopening as from January 1, 1950 of the Pacific Coast refineries with the belief that Japan should recover its economic independence with peaceable intentions and that it should supply its own necessary petroleum products. Since the announcement of this directive, planning for rehabilitation and development of petroleum refining began in full scale, gaining a new stance in the national endeavor of recovering its economic independence for the peaceful development of the country.

Following the reopening of these refineries, Japan's petroleum supply rapidly increased in parallel with the recovery and expansion of refining facilities. The supply condition of petroleum products had come to be so stabilized by the year 1957 that the Government was able to completely abolish its control over the use of petroleum. The petroleum consumption of 36,063 BPD in 1950 increased by 4.5 times in 1955 when the total output amounted to 177,655 BPD including the domestic consumption of 176,210 BPD and export products of 1,445 BPD. The domestic petroleum consumption in 1959 recorded 340,947 BPD and 28,237 BPD were exported showing the rapid increase by 10.2 times as much as in 1950 on the demands for petroleum products.

In the meantime, efforts were constantly exerted for expansion of refining facilities following the increasing trend of petroleum consumption. The topping capacity which marked 68,790 BPD at the end of 1950 or soon after the reopening of the refineries increased to 282,500 BPD in 1955 and 640,170 BPD in the end of 1959. Consequently, the majority of demands, except for heavy fuel oil, has been provided within the country in the recent years.

As of the end of 1959, the number of refining companies totaled 15 with 23 refineries, and the average crude thruput capacity per refinery

marked 27,830 BPD or about nine times of what had been produced during the war which was 3,100 BPD.

The two prominent technical developments characterized the post-war petroleum refining in Japan were the installation of premium gasoline manufacturing equipment on one hand and the placement of high-grade lubricating oil processing facilities on the other.

After the war, crude oil has been mainly imported from Middle East. The imported crude oil totaled 370,545 BPD in 1959, the places of origin and the supply percentages being Middle East 83.38 %, South East Asia 14.95 % the United States 1.14 %, South America 0.08 % and USSR 0.45 %. The crude supply percentage from Middle East has never dropped below 80 % during the years after the war to date. This necessitated the Japanese refiners to raise the octane value of gasoline either by reforming naphtha or by cracking kerosene and gas oil in order to obtain the quality for use of automobiles which were highly improved. Following the installation of two UOP platformers in February 1953 gasoline manufacturing plants were successively constructed. The daily processing capacities of these plants as of the end of 1959 were as follows:

Type of Processing	Number of Units	Daily Capacity
Thermal cracking	2	4,000 bbls
Catalytic cracking	6	41,300 "
ER & E Model IV	2	15,000 "
Houdrifiow	1	3,500 "
Shell Model	1	12,000 "
UOP Model	2	10,000 "
Catalytic reforming	13	30,700 "
UOP platformer	11	23,000 "
Houdriformer	1	3,000 "
ER & E Model fluid hydroformer	1	4,700 "
Polymerization		
CR & E gas polymerization	1	218 "
As regards the processing facilities for aviation gasoline		
ER & E alkylation (sulfuric acid process)	1	1,250 "

The octane values (F-2) of 1,139 Million US gallons of motor gasoline manufactured in Japan during 1959 were 8.8 % below 70, 76.4 % between 70 and 80 and 14.8 % above 80, adequately meeting the demands for automobile use in both quality and quantity and making the import of products unnecessary.

Since Japan had been able to produce only regular lubricating oils before the war, efforts

were exerted during the war to manufacture high grade lubricating oils but without bearing noteworthy fruit. After the termination of war, the Government emphasized the need for manufacturing high grade lubricating oils within the country in order to improve the country's balance of international payments. In compliance with this policy, the refining companies set up solvent dewaxing, deasphalting and extraction facilities which included at the end of 1959 :

Kind of Processing	Number of Units	Daily Capacity
Solvent dewaxing	11	8,990 bbls
BK	5	4,760 "
Aceton-benzene	3	2,010 "
Propane	1	1,120 "
MEK	1	600 "
Barisol	1	500 "
Extraction	9	6,830 "
Furfural	6	3,110 "
Duo-sol	2	2,000 "
Phenol	1	1,720 "
Deasphalting	2	4,160 "
Propane		

The total output of lubricating oils during 1959 amounted to 155,491,000 US gallons while improted products was 19,085,000 US gallons, the domestic consumption being 170,099,000 US gallons and the exports marking 611,000 US gallons.

The above represents a brief outline of the development of petroleum refining in Japan. According to the long term forecast prepared by the Government, it is estimated that the domestic demands for fuel oil in 1975 will be approximately 1,134,690 BPD or about 3.5 times of 322,426 BPD consumed in 1959. Besides, these figures are expected to be revised and enlarged in the course of the current year (1960).

Under these circumstances, all of petroleum refiners in Japan hold themselves responsible for further improvement and expansion of various refining facilities in order to fully meet the everincreasing demands in future.