HISTORICA

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THE SWEDISH SHALE OIL ERA. 1925—1961

My previous article [1] dealt with the different uses of Swedish oil shale through the ages. At its end some of the trials made during World War I aiming at shale oil production were mentioned. This article will deal with these activities in the period between the wars as well as within the big shale oil epoch during and after World War II.

No less than four different pyrolysis methods were used, three of them treating the shale crushed to pieces (Bergh, IM, and HG) and the fourth one (Ljungström) treating the shale "in situ", i.e. unbroken in the rock. The Bergh method was outstanding as the total heat content of the shale was utilized. The IM- and HG-methods left slightly more than half of the heat unused and were used only in combination with the Bergh method. The Ljungström method provided the extraction of the shale to a still lesser extent and required large amounts of electric power.

The Bergh Method

This method was the result of many years of scientific work in 1919—1924 [2]. A short description of its general design and way of functioning was given in the previous article [1]. It was elaborated in the time when the total global resources of petrol were still unknown. The opinion amongst experts judged these to be exhausted within a not too distant future [3]. Bergh aimed at finding a method that would be **economically feasible even in peace time** and could reach real importance when petrol sources run dry.

The hot coke formed at the pyrolysis served as the source of heating in this process, sufficient not only for the completion of the latter but also for considerable steam production. At the pyrolysis the organic substance of the shale is decomposed into hydrocarbons among which the heavy ones give oils and gasoline upon condensation, the lighter ones forms a gas of high calorific value. Roughly speaking the coke stands for half of the calorific value of the shale, oils and gasoline for a fourth, and the uncondensed gases for the remaining fourth.

The IM Method

Original author of this exceptional method was the well-known inventor J. G. Gröndal (1859—1932) who constructed a furnace for wood distillation. In the later twenties it was used in Estonia for the pyrolysis of "kukersite", a shale nearly four times as rich in oil as the richest Swedish one [4]. At pyrolysis the heating is carried out using circulating distillation gases, heated over special heating elements. Hereby cracking of the oil constituents occurs to some extent. In this lies an essential divergence from the Bergh method where the oil gases are sucked off as soon as they are formed. The shale piled on wagons with perforated bottoms is slowly carried through a 60 meter long tunnel furnace. The heating elements (tubes of heat resistent steel) are placed beside the wagons parallel with the furnace. Circulating of the distillation gases is brought about by some 20 strong exhausters alongside the furnace. The excess of distillation gases is sucked off at the end of the furnace. In Estonia part of the produced oils were used for the heating of the elements. The original intention was to use coke instead the shale, but this was never achieved [5].

After the death of Grönvall in 1932 the method was improved by Frederik Carlsson who in 1940 was granted a Swedish patent thereon [6]. The furnaces were built by AB Industrimetoder, thence the designation IM. Also in Sweden the heating was intended to be performed by burning the shale coke. This, however, proved impossible.

The HG Method

The designation alludes to G. H. Hultman and E. Gustafsson [7] whose method was outlined in the previous article [1].

In Scotland the lower part of the retort served as a gas generator whereby most of the carbon content of the coke was utilized. The hot gases formed also served for the heating of the shale in the upper pyrolysis zone of the retort. Due to the high ash content of the Swedish shale gasification is small. Instead of gas superheated steam is used. The fuel consumption is high. When Hultman made his trials in 1916—1918 he used the uncondensed gases + excess fuel (shale) for the heating.

The Ljungström Method

Frederik Ljungström, the famous inventor, launched his method in 1941 [8]. Already the following year it was tried on a big scale. It simply involves heating of the shale rock with electric power. The heating elements were placed in bore holes put in a hexagon pattern, each side of which measured two metres. The oil gases formed escape through holes in the centres of the hexagons. The power consumption amounts to some 7,500 kWh per cubic metre of oil.

The Starting of Shale Oil Industry

The first major shale oil plant built in Sweden was located at Kinne-Kleva in Västergötland, where Bergh had carried out much of his experimental work. Nearby was also an old industry for the production of calcareous earth by burning limestone in the old-fashioned way described in the previous article [1]. The owner of this factory modernized his manufacture by burning the limestone in a shaft kiln heated by burning gases from an oil plant of the newly invented Bergh design.

Such a plant with a capacity of some 500 tons of oil per annum was erected in 1925 [2]. Bergh thus had the privilege to see his new invention carried quite promptly into effect on a technical scale. The serious depression of 1929, however, was to come and the future for the little plant did not look bright.

The first Swedish shale oil factory at Kinne-Kleva (1925). From the left: the shaft kiln, crushing mill, and distillation plant

Oil Works of the Navy

Already during World War I the Navy showed an interest in shale oil. The Royal Naval Board (KMF) thus entered into a contract with AB Svensk Oljeindustri (see previous article [1]) for delivery of 2,400 tons of fuel oil and 1,200 tons of lubricating oil [9]. At that time these plans were not realized as the enterprise was never accomplished.

In 1932, however, the oil plant mentioned above was available, a plant well suited for the production of oils for long time trials on the vessels of the Navy. Due to the general depression the oil plant in 1932 was idle and offered for sale to the State. Parliament had to solve this question. In the referring procedure of the Government the Academy of Engineering Sciences (IVA) was consulted among other institutions. Quite surprisingly IVA alone adviced against the acquisition of the oil plant, arguing that money should rather be spent on testing Swedish shale according to foreign methods of manufacture (the IM method was considered). However, the transaction was concluded, which enabled shale oil production under naval supervision for many years. During this time many essential detailed problems were solved, e.g. the extraction of sulphur. Also the refinement of the crude oil was investigated viz. its conversion into diesel oil, lubrication oil, gasoline for aircraft, etc. Cracking and hydrogenation treatments were successfully carried out in Germany and in the USA.

Immediately upon the outbreak of World War II in 1939, the KMF was authorized to build a big plant at Kinne-Kleva, a plant that was erected in record time as everything was minutely prepared. In addition to a complete oil production factory also a sulphur extracting plant according to the German Alkazid-Claus-method was erected. Average production per annum was some 7,000 tons of oil, 2,500 tons of sulphur and some 10 million cubic metres of non-condensable gas of high calorific value (temporarily used for electric power production).

The Kvarntorp Works (Svenska Skifferolje AB)

The civilian development of shale oil industry in Sweden was guided by IVA. As mentioned above, already in 1932 IVA considered the IM tunnel concept a possible competitor to the Bergh method. In spite of the Estonian furnaces of this type lying idle 1929—1936 because of the depression, no attempts were made to test Swedish shale over there. At the outbreak of World War II thus time was scarce.

In a communication to the Ministry of Commerce of May 10, 1940, IVA pleaded for grants to investigate the IM method on a pilot scale. In another letter to the High Authorities of May 25 they suggested the building of a big plant of IM type, at which shale coke was foreseen for heating.

The first petition rendered a grant of some 200,000 kronor and the election of an expert committee to answer for the experimental work. Already by the end of the year the committee reported positively on oil production but negatively on coke combustion.

In November 1940 an extraordinary session of Parliament, by request of the National Fuel Commission (Bränslekommisionen) granted 15 million kronor for the building of a plant for the civilian needs of the country, which was to be based on the Bergh method. However - at the suggestion of IVA - these directives were changed and the choice of method was left in the hands of the board of directors of the new enterprise, Svenska Skifferolje AB.

The new plant was not to be built in Västergötland. Recent investigations indicated that shale richer in oil was available in Närke. Finally Kvarntorp was chosen with its abundant deposits of shale holding some 6 % of oil, i.e. well 1 % more than in Kinne-Kleva.

It was decided to use three different production methods: Bergh, IM and HG. Half of the estimated oil production should be covered by the Bergh method, half by the two others; it was claimed that this allocation should give maximum oil production. As the last two methods were not self-supporting, their heating should be performed temporarily by excess gas from the Bergh plant until a solution to the coke combustion problem would be found.

From the beginning the annual production was planned to be some 30,000 tons of oil. In April 1942, however, the Fuel Commission carried through an increase of 40,000 tons, the total production hence amounting to 70,000 tons. At this time the Ljungström method was also available, the share of which was set to some 20,000 tons.

The above allocation between the methods was considered justified due to the war situation, the aim then being maximum oil production. In peace time, however, this structure should prove very uneconomic as expensive fuel had to be spent for half of the oil production.

The aim to solve the coke combustion problem enabling the IM- and HG-furnaces to be heated by their proper coke was never accomplished. The losses thus incurred were heavy, amounting to at least two million kronor per year [10], a waste that was going to continue for nearly two decades.

During the first five years the coke was conveyed to the steadily growing waste-pile of the works. There the pyrophoric nature of the coke led to inextinguishable fires. The burning carbon was of course a loss but the burning sulphur was a real evil, becoming an environmental nuisance finally necessitating measures to be taken.

In 1945 the idea arose to use the coke for steam production. Collaboration was opened with a well-known boiler producer, Svenska Maskinverken, builders of the

Lamont system for steam generation. A trial plant was designed, characterized by steam generating tube bundles being immersed in the burning coke mass. The ashes formed could in this way be kept below sintering temperature in spite of a high combustion speed.

The experiences seemed so promising that green light was given for a large plant to be built, treating the total coke quantity of some 1,700 tons per day. In practice, however, the plant proved to be a half-measure as only about half of the carbon and sulphur contents of the coke were burnt. The ashes thus still remained an environmental problem. Steam production consequently did not correspond to expectation either. The plant was not in favour with the workmen, the transportation and handling of the hot and dusty coke being an unhealthy and dirty job. After a number of years of operation the plant was discontinued.

The above may be regarded as a failure. Nevertheless the experiences gathered in this plant finally led to a success but in quite another way than originally intended.

The reason for only about half of the combustible contents of the coke being extracted in the steam plant was the fact that the piece size of the coke was too big for full penetration. Complete burning out of coke of smaller piece size might be possible. There arose the idea to use the new technique in the Bergh furnaces where the slow burning of the coke was a bottleneck. Trials showed that the quicker burning was feasible and thus a means was found to more than double the capacity of the Bergh units. In turn this would allow closing down the IM- and HG-furnaces and simultaneously getting rid of the eternal coke problem.

The new Bergh unit, named Bergh-Kvarntorp or BK, could be housed in the old furnaces, had somewhat wider retorts made of stainless steel and Lamont tubing inserted in the fire-place. The oil and gas production was about two and half times the original one.

To make a long story short, all Bergh furnaces were rebuilt. This was a slow and difficult job as the Bergh furnaces were vital for the functioning of the works and rebuilding was therefore preferably executed with as many of them as possible kept in operation. After this had been accomplished the IM plants were closed down.

The reader may observe that the new Kvarntorp structure - after many sorrows and quite some troubles - was a variant of the one originally prescribed by the Fuel Commission in 1940. But fourteen years had elapsed and much money had been spent.

With the new units getting ready the gas production of the plant was steadily increasing and ways had to be found for the most profitable use of this gas. The way chosen implied gasol extracting by compression and cooling and thereafter converting the remaining gas to a hydrogen-nitrogen mixture for ammonia production. The investments required were costly.

It goes without saying that the evolution in Kvarntorp briefly described above draw large amounts of money. Supply estimates were presented to Parliament nearly every year and it is well-known how very successfully the management of Kvarntorp was able to obtain grants, loans, subsidies and tax reliefs which all enabled continued activity for nearly two decades.

During these years no less than three expert groups were called for (1948, 1951 and 1961). Although they were aware of the fact that much money had been wasted, the two first groups yet found excuses for its continued activity.

One of the most indefatigables critics was Bergh. In 1957 - a year before his death - he wrote a veritable anathema "Kvarntorp på villovägar" [11] and in 1960 Byttner -

the well-known journalist - published a book "Kvarntorp - en studie i slöseri" [12], both delivering a severe criticism of the irresponsible waste of money going on since twenty years.

The audit of the 1961 commission was hard [13]. The complicated accounts of Kvarntorp were thoroughly studied and regular losses of 5—10 million kronor yearly since the start were revealed. During the post-war period these losses accumulated to 111 million kronor. No reasonable means could be suggested to turn this development around. Not even emergency reasons could be advanced for a continuation. In 1961 the activities were closed down.

Kvarntorp served for some twenty years. During the war when the cost was a matter of less importance the production was imposing. The use of the Ljungström method strongly contributed to this; with comparatively cheap investments but high expenses for electrical energy the "cream" - so to say - was extracted from vast areas of shale not accessible for mining. The total Kvarntorp oil production in the best years amounted to some 100,000 tons annually, which after refining contributed to 1.7 % of the gasoline and 0.8 % of the fuel oil requirements of the country. The annual production of sulphur was some 30,000 tons and ammonia (after 1956) some 20,000 tons.

The Navy plant at Kinne-Kleva filled its mission during the critical years. In comparison with Kvarntorp it suffered from a poorer raw material and a rather small size. On the other hand, it was governed by an economical mind and the oil produced was comparatively cheap. The works were discontinued in 1946 as one plant for peace-time production was considered to be enough.

Retrospect

Looking back on Swedish shale oil production with the eyes of today gives a dark view. A renaissance does not seem probable.

Had the oil price explosion of the mid seventies occurred some ten years earlier, Kvarntorps economy might well have been saved. Had the works got a more sound structure from the beginning, they might have been profitable even with the prices as they were. But other factors would certainly have led to a discontinuation.

Sulphur pollution did cost Kvarntorp some 7 million kronor for local damages. But distant pollution was never paid. It should be remembered that also the good production methods produced immense quantities of sulphur dioxide. The emission of some 50,000 tons per annum of this gas would not have been acceptable in the long run. The oil production was not so indispensable for the country.

The uranium contents of the shale of some 0.03 % was well-known but the radon emission caused by this element was neglected. Nowadays the radon emission is considered a grave health hazard. The dust spread at the discharge of the hot coke was certainly dangerous. The use of shale ashes for brick manufacture - previously considered a possible by-product - is now out of question.

Even if a future shortage of petrol in the world eventually would call for a revival, it seems most likely that sulphur and radon would inhibit a new shale oil era in Sweden.

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