The Koppers-Totzek Coal Dust Gasification Process

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Heinrich Koppers Co. H.H. Koppers

The problem of coal dust gasification is not a new one. Since 1890 several patents were applied for and granted regarding this problem, however, of all these processes none ever attained any practical significance.

In 1938, Koppers, Essen, became active on the problem of gasifying pulverized coal in connection with the production of great quantities of synthesis gas for the Fischer-Tropsch process in the Schwarzheide-plant of the Braunkohle-Benzin A. G. The brown coal (lignite) briquettes from Saxony which were to be gasified, however, fell to pieces and thus turned into dust which could not be gasified in the usual way.

In order to find a process to use this dust for the recovery of synthesis gas Koppers built first an experimental plant in Schwarzheide, and based on the results obtained in this plant later-on a second experimental plant in West-Germany. In these plants many different kinds of fuel: caking and non-caking coal, lignite, peat, grude coke and also heavy oils, were gasified until the plants were destroyed during the war. After the war Koppers, Essen, was at first not allowed to make further research in this line.

For this reason the Koppers Company, Inc., Pittsburgh, built for the Bureau of Mines in Louisiana, Missouri, the first pilot plant based on the results of the test plants of Koppers, Essen, for production synthesis gas from coal for recovery of liquid fuel. This pilot plant was not quite satisfactory, however, with the experience gained there Koppers, Essen, could now offer and build successfully plants on industrial scale.

The first order on this kind of plant on industrial scale was placed with Koppers, Essen, by the French Government on a plant for the production of synthesis gas from 25/50 tons of coal per day for several synthesis processes. Due to shortage of building materials, however, this plant is still under construction and will start operation most probably next year.

A second order was placed with Koppers, Essen, by Messrs. Typpi Oy, Helsinki, on a plant for the production of 165,000 Nm$^3$/d of synthesis gas for a new ammonia synthesis plant ordered from Messrs. Uhde, Dortmund, Germany, for the recovery of 60 tons of ammonia per day. The synthesis gas should be produced from small size Polish long-flame gas coal with a moisture content of 2% and an ash content of 8% with 6745 kcal/kg. Koppers guarantied with a consumption of 85,200 kg of the above coal, 44,000 Nm$^3$ oxygen of 98%, 47,000 kg of steam of 2 kg/cm$^2$ and 84,000 kWh power the production of 165,000 Nm$^3$ of synthesis gas as well as 89,000 kg of 15 kg/cm$^2$ and the composition of the produced synthesis gas of...
This plant was also to be capable of producing the same quantity of synthesis gas either from lignite, peat, or, with some small alterations, from heavy oils.

The plant consists of a coal preparation plant in which lump coal is crushed first, then dried in case that the water content is too high, and finally ground to a fineness of 4,900 meshes (DIN) (corresponding to ca. 175 Tyler). This dust is stored in a central control bunker at the gasifier plant.

The gasifier plant consists of 3 sets, one of which acts as standby, each capable to produce 82,500Nm³ of synthesis gas per day. Every gasifier has two burners. From the central control coal dust bunker the coal dust is furthered by inert gas under pressure to intermediate bins at the gasifiers. All apparatus and pipe lines up to the lowest intermediate bunker are kept under inert gas in order to avoid explosions.

At the outlet of the lowest bin the coal dust is delivered by a stream of oxygen and steam through the burners into the gasifier in a homogeneous mixture with oxygen. In the gasifier a sudden burning of the mixture of coal dust and oxygen takes place developing a high temperature. A second admission of preheated steam envelopes the primary reaction zone protecting the brick lining of the gasifier.

The produced gas leaving the gasifier at a temperature of 1,300°C enters directly a radiation boiler and passes from there at about 800°C through a waste heat boiler. The temperature of the gas leaving the waste heat boiler is reduced to about 350°C. Thence the gas passes to a cyclone. Behind the cyclone the gas flows through a static washer-cooler, then to a Theisen washer, and is cooled down in a final cooler, from where it is conveyed to the synthesis gas holder by means of an exhauster. The content of dust in the finished gas is then 0.01 to 0.02 gram/Nm³, so that the gas after removal of the hydrogen sulphide and CO-conversion can be taken up by the compressors and the following apparatus of the ammonia synthesis.

As the ash is ground together with the coal to a very fine degree only about 7% of the ash falls down into the ash pan below the gasifier and is brought out from there in the usual way by the slowly rotating pan.

The greater part of the ash is entrained by the gas and conveyed through the boilers and the cyclone where about 80% of the ash dust is removed from the gas in dry state. In case that a coal with low ash content is used part of this dust can be used for heating the coal drying drum and for superheating the steam, whilst part of it can be returned to the gasifier mixed with fresh coal dust, raising the carbon gasification to 90-95% based on fresh coal dust entering the plant.

According to the order the plant of Messrs. Typpi Oy had to produce 140,000 Nm³ CO+H₂ in the synthesis gas for manufacture of 60 tons of ammonia per day. Due to the excellent of the synthesis gas, however, only 126,600Nm³ CO+H₂ were
sufficient for the production of 60m. tons of ammonia. Thus, instead of 2,305 Nm³/ton of ammonia only 2,110 Nm³/ton of ammonia were necessary so that the daily production of ammonia could be increased to 63-65 tons of ammonia per day.

After one year's operation without any trouble it was ascertained that the guarantees were not only fulfilled but surpassed. The gas was practically free of soot and ash, and could be used without any trouble for the ammonia synthesis. Thorough tests were made regarding sulphur compounds and the nitric oxide content of the gas. These tests showed that the sulphur compounds could be removed entirely by iron oxide purification and that the gas was free of gum forming constituents. The gas has a very low content of methane and heavy hydrocarbons (below 0.1% by volume). Due to the low methane and argon content no gas had to be blown off in the synthesis plant. Messrs. Typpi Oy intend, therefore, to extend the plant to double its present size shortly.

For the Koppers-Totzek process, any kind of solid fuel as caking or non-caking bituminous coal, lignite or peat can be used. The ash content is irrelevant and coal with an ash content up to 35% can be gasified economically. Oil can also be used, such a plant needs no coal preparation plant and no ash extractor below the gasifier thus rendering the erection cost cheaper.

At the moment one of the most discussed topics in Japan is the gasification of oil as at present the price of the calorie in the oil is cheaper than that in the low grade coal mined in Japan. Oil, however, must be imported inflicting US-Dollars and making Japan dependent on foreign countries.

Japan has large deposits of coal of which only a limited amount has coking properties. The small quantities of coking coal should, therefore, be used solely for the manufacture of coke for metallurgical purposes and not for gas generation so that the import of coking coal from abroad could be reduced. Gas for synthesis processes and for other purposes should only be made from low grade, cheap Japanese coal and not from coke made from imported coal or from also imported oil which means spending of US-Dollars.

There is already a shortage of oil and the price of the imported oil is rising. In case the price per calorie of Japanese low grade coal would be reduced somewhat the gasification of coal would become more economical and, moreover, would make Japan independent from US-Dollars and foreign countries.

In the following discussion some questions were answered as follows:

Question: How are the erection cost of a Koppers-Totzek plant compared with the erection cost of a coke oven plant with a water gas producer plant?
Answer: The price of a coke oven plant with water gas producer plant is about 20% higher than a Koppers-Totzek coal dust gasification plant.

In addition a good coking coal is needed for the production of coke for water gas.

Question: Can the Koppers-Totzek plant only produce synthesis gas?
Answer: Not only but mainly.

Question: What is the life of a Koppers-Totzek plant?
Answer: The only part that has to be replaced from time to time is the inner brick-lining of the gasifier, the rest of the plant should last as long as a coke oven plant, that is about 20–25 years.
Question: What kind of bricks are used for lining?
Answer: Good silica bricks.
Question: How much CO$_2$+H$_2$ is in the gas produced from oil?
Answer: The gas produced from oil contains about 90–92% of CO$_2$+H$_2$, the rest consists of CO, N$_2$, Ar, H$_2$S and hydrocarbons, the content of the latter being higher than in the gas from coal dust.
Question: Can also oil gas as used in city gas plants be produced with this plant?
Answer: No, however, the produced water gas of about 2,400 kcal could be carburetted to the calorific value of the city gas.
Question: Is it possible to lower the temperature in the gasifier in order to get more hydrocarbons?
Answer: For synthesis purposes the gas shall have the lowest possible content of hydrocarbons.
Question: Ube coal has a very low ash melting point. Can such coal also be used?
Answer: Yes, the ash is very finely ground with the coal and will not stick together. The greatest part is entrained with the gas and carried to the boilers and further apparatus. A small molten part would run down along the brick lining and form icicles. These are broken off by a water cooled arm which revolves with the ash pan, and will fall into the ash pan. There is no danger at all of ash sticking.
Question: How much fuel was required in the Typpi plant for the production of steam and for superheating of the steam?
Answer: Besides the synthesis gas the plant produces about 0.54kg of steam of 15kg/cm$^2$ per 1Nm$^3$ synthesis gas and requires for the gasification only 0.285 kg steam of 2.0kgf/cm$^2$. The superheating of this steam to about 250°C is made by burning of residue and no fresh fuel is needed.
となった。

最初の注文は、フランス政府の命により、合成原料ガス製造工として1日25～50㎥の石炭を処理する工場を目標に着手されたが、建設材料不足のため未だに建設中で、多分1954年には商業開始となるであろう。

第2の注文は、フィンランドのセメント工場で、鋳鉄協同のエンジニア合成工場に供給する原料ガスを、1日あたり165,000Nm³を作る目的をも、この考えがフィンランドに原料ガス（水分2%、灰分8%、発熱量674kcal/kg）を原料とする。この石炭82.5%、98%酸素44,000Nm³、2kg/cm²の蒸気47t、および84,000kWhの電力によって、165,000Nm³の合成ガスを15kg/cm²の蒸気89tが得られる。ガスの組成は、CO₂12.8%、CO47.0%、H₂37.8%、N₂1.8%、Ar0.5%、H₂S0.2%で、合成ガスは、電気発電、蒸気発電、金属製造、化学工業、発酵などに利用されている

原料石炭は処理、混入でもよく、また多少の変更を加えれば、電気も使用する。石炭はまず粉砕（約175ミリメートル）、乾燥する。工場はおおむね825,000Nm³の能力ある3個のセットからなり、うち1個は予備となる。第1貯槽から微粉炭は不活性ガスによって第2貯槽に送られる。最終貯槽までの全装置とパイプラインは開発をさりため不活性ガスで調節している。最終貯槽を出る時、酸素および蒸気を均一に送り、ガス化炉に至る並流に燃焼する。酸素蒸気でこの反応器を包み、ガス化炉の内壁に保護するようになっている。ガス化炉を出るガス温度は1,300℃で、微粉炭を通過する蒸気60℃、排熱イオンを通って350℃となる。サイクロン、冷却器を通してさらに冷却されガス槽に導入する。合成ガス中の微粉炭は断熱0.01～0.02g/Nm³となっているので、硫化水素を除去し、一酸化炭素ガス脱ガスエンジニア合成工場に供される。

石炭中の灰分は、石炭とともに微粉化されているので、ガス化炉で焼けられるのは灰分の約7%程度である。残りの灰分はガスとともに移動し、80%はサイクロンで除かれる。灰分の多い石炭を使う場合には、ここでの得られる燃料は、原料石炭の乾燥と蒸気加熱に使うか、またはガス化される微粉炭にもとして再利用をはかる。

フィンランドにおける最初の計画では、日産110tのエンジニアにCO₂+H₂で140,000Nm³が必要とされていたが、本法で得たガスの性質が良好であるため、126,000Nm³で充分であった。つまり1tのエンジニアに2,305Nm³を供給するだけで、1,211Nm³で完全となり、エンジニアの日産は65～65tに増大することとなった。この工場は1年間の既存の設備もなく、予期以上の成功であることが確実となったので、近く2倍規模に拡張の予定である。

ガスには実際にそれほど灰分もしく、硫黄化合物、酸化炭素、メタンなどの含量も少ない。硫黄化合物は硫酸鉱で精製できる。

日本は重油のガス化には熟心であるようにみえるが、重油を燃料には事業が必要である。蒸留と製紙の二重の作用に限られ、日本が相当量持っている低品位炭は有効なガス化法によって利用すべきである。これによって、ドルガスは節約され、日本の外国の依存性を緩和することができるであろう。

（次の講演は講演後の質問応答によって明らかにされた）

○カーボンガス炉および水蒸気ガス蒸発炉の設置費に比し、本法のガス化装置は20%安価である。

○本装置のうち、補修を要するのは内壁の脆化だけであ、それ以外は20～25年の生命があるものと思う

○重油を原料とした場合には、CO₂+H₂で90～92%であり、微粉炭の場合よりも発熱率が少し少ない。

○本装置で直接都市ガスを作ることはできない。

○発熱の点で低い石炭でも、本法によれば発熱が増える場合も考えられる

○蒸気は燃焼物としてできるから特に作る必要なく、その加熱（250℃）も蒸流の燃焼で足り、別に燃料を使う必要がない。