WINKLER GENERATORS FOR MANUFACTURE OF WATER GAS ETC.

SUMMARY

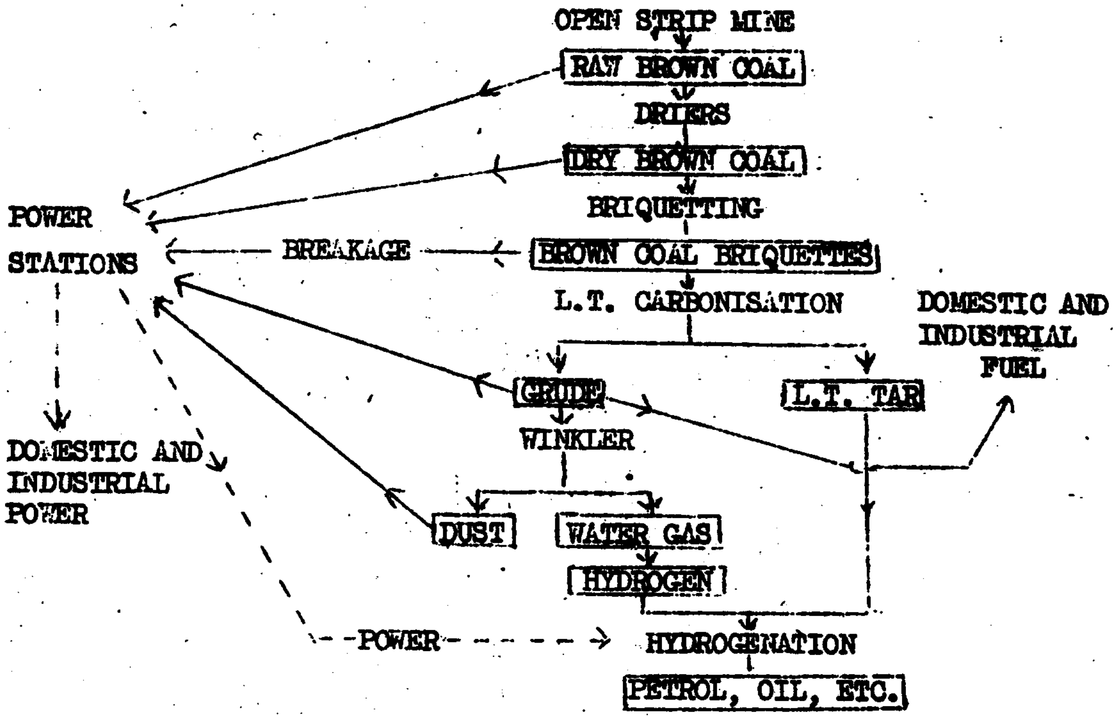
All the available information concerning Winkler generators, contained in C.I.O.S. reports and in documents brought back by C.I.O.S. missions to Germany in 1945, is collected together and combined with literature references to give a comprehensive account of the history and present status of the process. There are at least five large plants in Central Germany and Czechoslovakia using the process and possibly one plant in Japan. The process is technically sound and well-established but appears to be economic only where cheap fuel, e.g brown coal or brown coal coke, is available, which cannot be gasified conveniently in other ways.

INTRODUCTION

The first large-scale Winkler generator for making power gas was put into operation at Leuna in 1926 and the first large-scale generator making water gas followed in 1930; the successful use of a "boiling" bed of fine fuel thus introduced a new process for the manufacture of power gas and water gas. Since then the process has become firmly established inside Germany and since 1936 has found considerable use in the large-scale production of hydrogen in plants manufacturing petrols, oils, etc., by the hydrogenation of brown coal and brown coal tar. For the manufacture of hydrogen the process requires large quantities of oxygen, and despite the fact that the Linde-Fränkl process, developed in the last 20 years, is a marked improvement over older processes, oxygen is still relatively expensive, so that its use, and hence the use of the Winkler process, can only be justified when it makes possible the use of a cheap fuel, which otherwise could not be satisfactorily gasified. This explains why all known Winkler generators are located near the brown coal fields of Central Europe; brown coal, as obtained by open strip mining, is very cheap, but it is difficult to get it into a form suitable for use in a conventional "make-and-blow" water-gas generator; on the other hand brown coal is an ideal fuel for a Winkler generator.

In recent years German economy has been such that it was advantageous to produce vast quantities of petrol and oil from indigenous coal. A particularly favourable process was to hydrogenate the tar obtained from the low temperature carbonisation of brown coal briquettes; this carbonisation produced several times as much brown coal coke, or "grude" coke, as it did tar, so that a use had to be found for the vast quantities of grude. The biggest use of grude was for firing the boilers of power stations, already existing in many cases and previously using raw brown coal, but it was also very convenient to use grude for making the hydrogen, required for hydrogenating the tar. Moreover since the Winkler process resulted in an appreciable fraction of the fuel being carried over as dust with the gas, it was also very convenient to be able to recover this dust and use it as boiler fuel.

Thus there has grown up in Central Germany, centred around Leipzig, a collection of large factories, all primarily based on the vast deposits of brown coal found in that region; these factories, although carrying on different processes, are largely inter-related and are often located on the same or neighbouring sites. The diagram below sets out this inter-relationship.



The diagram shows up how the power stations can be used as a sink for unwanted products and how they can be used to keep a balance.

As far as we are aware there are no Winkler generators outside the Central European area, (possibly excepting Japan), and there are no large generators operating on anything but dry brown coal or brown coal grude. It is possible to operate Winkler generators on bituminous coals, L.T. coke from bituminous coal or even anthracite; operation however is not so satisfactory and in general it appears that the Winkler process is not economic for such fuels, where the alternative processes of coke ovens - water gas generators are available. Indeed even at Leuna, in the centre of the brown coal area, according to Ref. 1 Winkler gas cost approximately the same as water gas from ordinary water gas generators, operating on hard coke, brought 275 miles from the Ruhr.

The Winkler process is not suited to making town's gas, as the calorific value is low, and its field of application appears to be limited to the large-scale production of (a) water gas, to be used for manufacture of hydrogen, methanol or Fischer-Tropsch synthesis gas, (b) producer gas, to be used as a fuel gas or power gas, and (c) ammonia synthesis gas, but in all cases based on a cheap fuel, not otherwise easily utilisable. In the light of this it is easy to see why the process has not hitherto been used in Great Britain or the U.S.A. Nevertheless it is a technically sound process and economic in a limited field of application. Brown coal occurs extensively in the U.S.A. and Australia (but not in Great Britain) and there is no reason why the process should not eventually be operated in those countries at least.

WINKLER GENERATOR INSTALLATIONS

Table I is a list of known Winkler generator installations.

TABLE I

Plant	Started up	Operating Company	Units	Approx. Output/unit M^3/hr. water gas	Remarks	Ref.
GERMANY						
Leuna 20 m W Leipzig	1926 to 1930	I.G.	4 1	60,000 30,000	75,000 on producer gas. Only one unit works on water gas and one on producer gas at one time.	1
Böhlen 10 m S Leipzig	1938	Brabag	3	20,000		2
Zeitz 20 m SSW Leipzig	1939	Brabag	3	20,000		3
Magdeburg 50 m NW Leipzig	1939?	Brabag	3	20,000		1
CZECHOSLOVAKIA						
Brüx 80 m SE Leipzig	1942	Sudetenlandische Treibstoffwerke A.G.	5 or 6	20,000		1

In addition there are small units at Oppau, nr. Mannheim, as well as at Leuna, operated by I.G. to test various coals. It is also possible that there are three generators in Japan (Ref.1).

HISTORICAL

The Winkler generator was developed by the I.G.; the development work was carried out at Oppau and large-scale plants were first erected at Leuna. The huge production of ammonia and methanol at Leuna was originally based on synthesis gases made from hard coke, brought from the Ruhr and gasified in conventional water-gas generators, operating on a make and blow cycle. The local cheap brown coal was used only for steam raising and for making producer gas, used as a power gas, but the power requirements of ammonia and methanol synthesis were so high that it paid to locate the factory on the brown-coal fields, rather than near a supply of hard coke, quite apart from any military reasons. In 1920-30 the I.G. were much concerned with the possibility of using brown coal, instead of coke, for synthesis gas manufacture. Before that time brown coal could be used for making producer gas, for power, only after submitting it to the relatively expensive process of briquetting; even so the producer gas contained up to 2% CH_4 and could not be used for ammonia synthesis, whilst the low ash m.p. and low strength of the fuel were additional obstacles; there was no satisfactory process for making water gas or producer gas from brown coal, suitable for ammonia and methanol synthesis.

Dr Fritz Winkler in 1921 (Ref.5) conceived the idea of using a "boiling" bed, i.e. using particles of fuel small enough to be almost gas-borne and hence comparatively mobile. Under such conditions the fuel bed behaves very much like a liquid; the gas passing through the fuel gives an appearance as if the bed were boiling, the bed finds its own level, as does a liquid, and circulation of particles within the bed is such as to give substantially equal temperatures throughout the bed. The first patent, DRP 437,970 was applied for on 28/9/22 and several others followed (Ref.7). The original work at Oppau was directed towards making power gas and the first Winkler producer (No.1) was put into operation at Leuna in 1926, having a capacity of 40,000 M^3/hr, equivalent to 3,300 M^3/hr/M^2 grate area. By 1929, four more producers had been added, each having a grate area of 25 M^2, double that of the first. During 1929 the whole plant often produced 200,000 to 230,000 M^3/hr power gas, and at times as much as 300,000 M^3/hr. One year afterwards, however, the slump hit Germany and requirements of power gas sank considerably, and normally only one or two producers had to be run.

After initial experiments at Oppau attempts were made at Leuna to make water gas from brown coal, coke or grude, by the "make-and-blow" method, without the use of oxygen, as described in DRP 437,970. It was expected that raw brown coal could not be used, because the presence of carbonisation products in the gases made would render them unfit for subsequent use, so grude was used. It was hoped that by blowing air alone through the boiling bed to raise its temperature and then passing steam through it, water gas could be successfully made, but the attempt failed for the following reasons. Particulate fuel, contained in a bed of fixed cross-sectional area, will "boil" satisfactorily only with gas velocities between certain fairly narrow limits; if the velocity is too low the bed ceases to boil and if it is too high entrainment occurs and the fuel is blown from the bed. A compromise had therefore to be made between air and steam rates. The steam rate had to be high enough to boil the bed, and the fuel bed deep enough so that too much undecomposed steam did not pass. The air rate had to be held below that which would cause entrainment, but it was desirable to have shallow fuel beds, so as to keep the time of contact between blow gas and fuel low enough to prevent excessive reaction between CO_2 and fuel. In practice it was found that with the highly reactive grude the CO content of blow gas was very high, and in fact blow gas approximated to producer gas, and this, coupled with the high exit temperature of blow gas, 1,000°C., gave an undesirably high ratio of producer gas/water gas, viz. about 5:1. This ratio was much bigger than the power gas/synthesis gas ratio for processes worked at Leuna and moreover water gas still contained 1% CH_4, which was still a drawback, although did not entirely prohibit its use. Theoretically the process could have been improved by preheating the air and steam with the hot waste gases, but this was not tried at that time.

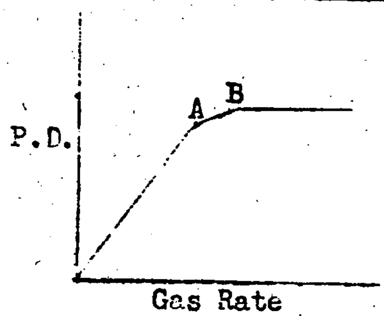
In 1929 small-scale tests were commenced at Leuna, with the object of making NH_3 synthesis gas continuously from dry brown coal or grude, by using a continuous blast of steam and oxygen-enriched air. In 1930 the original No.1 generator was producing about 10,000 M3/hr. of mixed gas for ammonia synthesis, but the CH_4 content was still an objection.

Also in 1930 Leuna began the production of nitrogen-free water gas, and profiting by previous experience, a satisfactory way was devised of using a continuous blast of pure oxygen with steam. Both grude and later dry brown coal were used as fuel, and three of the existing large Winkler producers were adapted for the purpose. In 1932-3 new Linde-Fränkl air separation plants were installed, specially to make oxygen for the Winkler generators. The introduction of part of the oxygen-steam mixture above the boiling fuel bed was useful in reducing the CH_4 content of the gas made, especially when using dry brown coal, but the content of 1 to 2% was now tolerated because of other advantages of the process and because Winkler gas provided only a part of the synthesis gas requirements.

Since 1933 as a rule one of the large Winkler producers at Leuna has continued to make 40,000 to 70,000 M3/hr power gas, and one large generator to make up to 60,000 M3/hr nitrogen-free water gas. It is to be noted that the old coke water-gas generators were still running in 1945, making several times as much gas as did the Winkler water gas generator. That a complete changeover was not made was due partly at least to the high brown coal demands of the factory as a whole on neighbouring mines (Ref 6, p.12); it is expensive to transport brown coal more than short distances, owing to its bulk, high water content and reactivity. It is also probable that Winkler water gas was not so much cheaper than coke water gas at Leuna, as to warrant the large capital expenditure required for the conversion.

In 1936 a large expansion of German synthetic petrol and oil industry was started, and Winkler generators, using oxygen to gasify grude, were chosen for manufacturing hydrogen at the BRABAG(Braunkohle-Benzin-A.G.) plants erected at Böhlen, Zeitz and Magdeburg; the plants were designed by Bamag under license from I.G., who, of course, were also involved. These were put into operation in 1938-9. After the outbreak of war a further hydrogenation plant was started at Brüx, in N.Czechoslovakia, and again the Winkler process was chosen and the plant was started up in 1942(?).

CHARACTERISTICS OF "BOILING" BEDS



The accompanying diagram illustrates a typical pressure drop-gas rate relationship of a bed of particulate fuel. At low rates the pressure drop increases almost linearly with increase in gas rate until a point A is reached, where pressure drop x area = mass of fuel. There is then a tendency for the bed to be lifted bodily like a piston, but at first the bed expands and the voidage increases; then at B the bed begins to "boil". From B onwards the pressure drop remains constant as the gas rate is increased. The particles are constantly in motion and as the voidage increases so the depth of bed increases. The bed becomes increasingly rarified as the gas rate increases, until eventually when the gas velocity reaches the free-falling speed of the particles (at least with a bed of uniformly-sized particles), the whole bed is carried away, i.e. true entrainment occurs.

The gas rates corresponding to points A and B are a function of particle size and density, moving to the right as these are increased. For the same fuel and air rate the pressure drop across the bed is proportional to the depth of bed and is in fact equal to the "hydrostatic" head, i.e. mass of fuel/unit area.

DESCRIPTION OF THE PROCESS

Whilst the principle of the use of a boiling bed remains in all plants, the details have changed considerably with the various installations. As these changes have not been made without reason, it is instructive to follow them.

The gasification chamber itself has always been a brick-lined vessel, of greater height than width, with the fuel bed contained in the lower part. It has apparently never been necessary to replace the brick lining by a water jacket, and this is understandable, because the temperatures are not too high, probably never above 1,050°C. The blast always enters through the base, but usually a portion is fed in through tuyères above the fuel bed. The hot gases are led off at the top, sometimes through waste heat boilers, and then dedusted in some manner before final cooling.

Photographs and sketches of various installations are shown in Figs. 1 to 7.

The various stages will now be considered in detail, with particular reference to the manufacture of water gas with a blast of steam and oxygen only, with no air.

OXYGEN PLANTS

These are adequately described elsewhere (Ref.8). All the plants installed since 1929 have been Linde-Fränkl units, each of capacity 2,000 to 4,000 M3/hr oxygen (97 to 99%).

FUEL SIZING AND STORAGE

Brown coal and grude are very reactive and are liable to spontaneous combustion, so that special care is necessary in handling. The fuel is milled and screened in inert atmospheres of nitrogen or CO_2, containing limited amounts of oxygen, and may be transported pneumatically by inert gases; the bunkers are likewise kept under inert gas pressure. The size range of the milled and screened fuel varies from plant to plant and a summary is given in Tables III and IV. In general it can be said that the size range is between 0.1 and 10 mms., with the bulk in the range 0.2 to 4 mms. According to Ref.11 it is very desirable to keep out material $<$ 0.5 mms, since such material is liable to be blown through the bed unchanged. On the other hand, if the fuel is too large it tends to sink down to the grate, where the heat of combustion cannot be properly exchanged with the surrounding fuel, as is the case within the bed; consequently such larger pieces become overheated and clinkering results.

At Zeitz the milled grude is stored under nitrogen in two large bunkers each 7 m. diameter and 8 m. high, plus a conical base; the total storage volume is thus about 700 M3. In addition each generator has its own intermediate storage of about 125 M3.

At Böhlen the grude is blown over pneumatically with CO_2 from the power plant; the CO_2 from the bunkers is dedusted in Beth filters and cyclones.