C

Miscellaneous Material Copied from the Files of Dr. Wm. Gumz

FUEL and LUBRICANT UNIT, F I A T.

Investigation re Powdered Coal Gasification.

Information on the points enumerated below is desired with reference to your process for gasifying powdered coal. Please assemble all available information along these lines including supporting experimental data, drawings, calculations etc.; for discussion with FIAT representatives within about one week. This material is to be incorporated in a detailed report on your process and should be amplified in any way possible to make a complete and accurate report.

1. Record of all forms of apparatus and all methods of operation which were tried, and a discussion of the results obtained in each case. Difficulties encountered as well as success achieved are important.
2. The effect of kind of coal and fineness of grinding on its behaviour in gasification unit.
3. Details of equipment for feeding powdered coal to the reactor and operating characteristics of such equipment.
4. Description and drawing of all accessories which you regard as more or less standard equipment, such as preheaters, waste heat boilers, scrubbers etc. and their operating characteristics.
5. A discussion, theoretical and practical, of the design, construction and operation of the gasification chamber itself.
6. recommended procedure for starting, running and shutting down such a unit.
7. Safety precautions and devices.
8. Difficulties likely to be encountered because of corrosion or erosion in any part of the system and preventive and remedial measures therefore.
9. Flexibility of the unit with respect to throughput and product gas composition.
10. Exact method of controlling the unit to make gas of any possible composition, particularly of high ratio of H_2 to CO.
11. Comparison of the process with other known powdered coal, gasification process including Koppers, Schmalfeldt, Didier etc.
12. Effect of coal composition and operating variables on organic sulphur content of the product gas.
13. Relationship between fluidizing of flow characteristics of the powdered coal and performance of the generator.
14. Extent of ash entrainment, under different operating conditions and any other important features of the ash handling problem.
15. Suitability of the process for operation at elevated pressures up to 20 atm or more.
16. Effect of moisture content of coal on generator performance and gas quality.
17. Operating conditions applying to heat balance examples given in paper.
18. Specific operating data for various coals and various gas compositions.
19. Possibility of energy exchange between generator and oxygen plant.

20. Effect of oxygen purity on operating characteristics of generator.

21. Methods of determining gum-forming (Harzbildung) constituents of gas and effect of operating variables on the wontent of such materials in the product gas.

22. Methods of removing gum forming constituents and other foreign materials from product gas.

23. Importance of the water gas equilibrium in determining compositions of the product gas.

24. Effect of weathering of coal on its gasification characteristics.

25. Preferable operating conditions for making different types of heating gas instead of synthesis gas.

26. Preferable operating conditions for making synthesis gas of relatively high ratio of CO to H_2.

27. Effect of recycling part of product gas or supplying extraneous gas other than oxygen and steam with the coal.

28. Operability of the process on partially or completely carbonized coal.

29. Desirability of accomplishing the gasification in stages operated under different conditions.

30. Effect of size of unit on plant cost and cost of operation.

31. Factors determining most economical size of unit.

H.V.ATWELL

11th April, 1947

Headquarters
North German Coal Control
(Production Branch)
B.A.O.R.

E S S E N

22a Villa Hügel

CC/P/ VII/12 12th April TV 75 14th April, 1947
Coke Department

Subject: Powdered Coal Gasification - FIAT investigation.

Replying to the questionnaire prepared by Mr. Atwell of Fuel and Lubricants Unit FIAT we beg to hand you herewith the following answers:

General remark: The plant in question was not a commercial plant but errected for studying and experimental purposes. The aim was to examine the process of gasification of fine grains and powdered coal by measuring gas temperatures and gas composition while running through a plant consisting mainly of two towers combined together, in order to have a fairly extended way of the gas. The plant was planned by Bergbau-Verein, errected by DEMAG and run by Ruhrgas A.G., experimental work was done by these three partners for joint account. It was errected during 1941 at the nitrogen works of Hibernia, Herne, tests were made during 1942 and 1943. Many difficulties arose even from standard equipment as well as from lack of man power. The tests are far from being complete and the plant should be rebuilt during 1944 which proved impossible because of lack of material and man power and because of difficulties by warfare.

1.) The plant is shown diagrammatically in the annexed tables. It consists of two towers of 1200 mm inner diameter, the walls clad with fire clay bricks containing 39 - 42 % Al_2O_3, delivered by Didierwerke. The lower part of the first tower is made conical. Devices are provided to blow in powdered coal, air, steam, oxygen or gas not only from below but also from the top of the first as well as the second tower. The gasifying agent (air, air-steam - and air - oxygen - steam - mixtures) could be preheated by two methods 1) by mixing with hot combustion gases 2) by tubular heater, externally heated and 3) by both methods at once. Possibilities of measuring gas temperatures and composition were provided at several points, although some difficulties arose from the high temperatures of the oxydation zone, when tubes, thermocouples would not stand and where the holes for introducing the instruments soon were clogged by melting slag and fire clay. Coal mill installation was standard equipment, delivered by Kohlenscheidungsgesellschaft (KSG) of Berlin, but not quite satisfactory because fineness of powdered coal could not be changed in any considerable range by adjusting the air sifter, which would have been of special interest.

Most of the tests, the results of which are contained in two unpublished reports - because the experiments are not yet sufficient for a definite answer to all questions placed by ourselves - were made by blowing powdered coal and air with littl or medium steam content from below, running through the two towers. Some tests were made by feeding coarser material from the top of the first tower. The fuel used was mostly fine coal from the Wilhelmine Victoria pit of the Hibernia Colliery, in some cases we used bituminous coal of the Shamrock pit of the same colliery and lignite (Rhenish brown coal).

In some cases we used mixtures of air, oxygen and steam (oxygen delivered by the Hibernia nitrogen works) but as we found that there are no difficulties to handle this gasifying agent and to make a much better gas by it we found it necessary at first and running expense lower to use air. If the process would run with air, which is the most difficult task the change to oxygen-steam mixture would make the problem easier.

Some typical results with bituminous coal are the followings:

N° of test	18 (1942) without preheating		35 (1943) with preheating	
load (coal per hr)	959 lbs/h		794 lbs/h	
Heating value of coal	12870 BTU/lb		12870 BTU/lb	
through # 65 (Tylor)	~ 90 %		~ 90 %	
gasifying agent	air + steam		air + steam	
air	88 290 cb.ft./h		51 560 cb.ft.	
steam	441 lbs/h		617 lbs/h	
temperature	140 °F		523 °F	
quantity of gas produced	100 650 cb.ft./h		66740 cb.ft./h	
gas produced per pound of coal	104,9 cbft/lb		84,1 cbft./lb	
composition of gas	8,6 % CO_2		10,1 % CO_2	
	14,5 % CO		14,4 % CO	
	7,6 % H_2		14,3 % H_2	
	69,3 % N_2		61,2 % N_2	
	100,0 %		100,0 %	
Gross heating value	75,5 BTU/cb.ft.		97,75 BTU/cb.ft.	
net heating value	71,1 "		90,1 "	
Efficiency (cooled gas)	59,2 %		55 %	
temperature, measured near the wall (not exact)	°C	°F	°C	°F
Point I	1260	2300	1310	2390
" II	1260	2300	1280	2336
" III	1360	2480	1150	2102
" IV	-	-	1080	1976
" V	1000	1832	-	-
" VI	900	1652	1010	1850

The success achieved was rather low at the beginning but it should be borne in mind that this plant was not a commercial one and was not built to realize a certain process but to study different processes and to find out the best way to solve the problem. Before errecting the plant, theoretical considerations were made which are laid down in the enclosed thesis of Dr.Gumz on "Gasification of particles in suspension" (reprinted and translated into English by BCURA, document N° C 1691, File N° 611). The first experimental work was begun by Reichskohlenrat in Berlin 1940 where powdered bituminous coal in suspension was gasified in a small scale. This experimental plant consisted of a small tube (3" Ø, 18 feet long) with external heating and was worked by Dr.Histler.

The aim of our plant, therefore, was to have a full scale test plant although calculations showed that difficulties would be less at still bigger plants, higher outputs and greater diameters.

Many difficulties arose in the first time as well from the mill and the coal distribution installation which should be regulated in a still more exact manner than in a powdered coal firing plant, as from the producer itself. As the tests showed that it was impossible to keep the temperatures below the melting point, many difficulties were caused by the narrow entrance of the conical part, which was clogged by molten slag and running down of the brick surface. Several times the plant had to be shut down and the clogging worked out by hand from below, whereby much time was lost.

The gas produced was of very low heating value but the tests showed clearly that an improvement was possible by fine grinding of fuel, by saving the volatile matter and by the use of higher temperatures. This plant would not stand to higher temperatures, therefore it had to be rebuilt to molten slag removal, better protection of the walls in the oxydising zone and greater diameters (cylindrical shape, not conical).

2.) Kind of coal is effective from the following points of view: Amount of volatile matter, reactivity of coke produced, behaviour of mineral matter, melting point and melting characteristics. In our case a coal with high melting point was selected but a plant like this should fit the different kinds of coal or economy would seriously effected.

Fineness of coal is essential. The use of unground fine coal is impossible. Loss of carbon would be too high and gas quality would not suit to technical requirements. We generally used a fineness of 90 % through # 65 (Tylor).

3.) The feeding of the powdered coal from the powdered coal bins to the producer was made by an ordinary cell feeder (rotating sliding valve) by means of air or inert gas. The equipment was standard delivered by Kohlenscheidungsgesellschaft (K.S.G.) Berlin. Air or gas pressure was up to 70 lbs/sq.in., between blower and feeder a pressure storage tank was arranged in order to have constant pressures. The feeder was driven by a variable speed gear allowing continuous variation of the output. The feeders did not operate to satisfaction lacking the demanded continuity.

4.) Other equipment of the plant are: Raw coal bin, coal mill (KSF-type centrifugal mill) with gas heated hot air stove for drying, spray cooler instead of a waste heat boiler, two-stage-gas-washer and chimney-cooler.

5.) The gasification chamber itself may be considered as a long tube with conical end in which the powdered coal is kept in suspension and travels through this tube. In order to have a sufficient long way for the gas travel two tubes or towers are errected and connected together because it was felt to be more convenient to feed the powdered coal from below and to extract the hot gas below. This was the reason for the choice of two towers. Tests have shown that with high temperatures a tower would be sufficient and that too long a run with falling temperatures may detoriate the gasquality. Thus the volume of the gasification chamber is not characteristical for the volume needed. The quality of gas produced is mainly a function of temperatures of the suspending particles and in order to afford these temperatures fine grinding and high preheating is advisable. The most advantagous shape of the chamber from structural and operating point of view is cylindrical. The walls should be protected against slagging and heat by cooling but such a device is only practicable if the diameters of the plant are large enough. Therefore the greater the throughput the better the lifetime of walls, the better the gas quality. From this point of view our experimental plant was of semi-commercial scale.

6.) Recommanded procedure of starting is to begin with air in excess and to add so much carbon until the gasquality is reached. Special feeding and regulating device is necessary and was intended to do as proved in the small experimental plant of Reichskohlenrat. The plant was run by observing the temperatures and the darkness of torch or gas flame at the outlet. Shutting down was made by taking away the powdered coal. If the plant would be connected with a gas consumer or main line, it would be switched to free gas outlet and then dealt with as before.

7.) No special safety precautions had been provided, as the plant was not connected to a gas main line and practically like an open tube. No accidents happened.

8.) The difficulty of melting down the brickwork can be cured by suitable materials and by cooling devices. In order zu examine different kinds of fire bricks 9 types were tested in the upper part of the first tower during the second experimental period. The worst results had shown a magnesite-brick which not only was dissolved to a high extent but the melting material corroded the wall beneath it. The best results showed "Korunit 90" (corundum brick delivered by Didier-Werke A.G.) the edges of which remained even unhurt. Quite good were the following types of fire bricks: "Thuringia" (good quality of fire clay, delivered by Didier Werke A.G.) "Otto 60" (same quality, delivered by Dr.Otto u. Co., Bochum) and "Mullital X" (quality of high aluminium oxide content, delivered by Didier-Werke A.G.). "Carsial O" (silicium carbide, Didier-Werke A.G.) was standing very well the wear by slag but cannot be used in an oxidising atmosphere, because it burns to SiO_2.

9.) The best results were reached by a load of about 500 kg/m^2 h= 100 lbs/sq.ft. h but time of running the plant and number of tests were unsufficient to find out the influence of load to gas quality, which may be only slight. Other factors effecting the gas quality in a more distinct manner are the composition of the gasifying agent. No special tests were made till now to make synthesis gas with a limited CO/H_2 ratio but there is not doubt that this could be done with such a plant, if necessary be using a special converting plant. In the case of synthesis gas, using steam-oxygen-mixtures as gasifying agent no other inert gases occu than CO_2 and H_2O which can be washed out easily.

11.) The tests made by the Demag-Ruhrgas-Bergbau-Verein-partnership should realise the fundamentals of a gasification of solid fuel particles in suspension and may not be called a special process of gasification on a commercial scale although the main principles of such a process could be worked out in a certain extent. From our experience it is possible to make a comparison or even a criticism of other processes. These are the Koppers-, the Wintershall-Schmalfeldt and the Winkler-process.

The main feature of the Koppers process is a high preheat up to 1200°C (= 2192 °F) in a regenerator heated by about the half of the gas produced. By this method the economical success is affected although good gas qualities are possible. Tests were made in a semi-commercial plant with different fuels, preferably with lignite, lignite coke and other high reactive fuels. We conform with the principle that a high preheat is essential for good gas quality but preheating by produced gas is too expensive, when synthesis gas is made. In this case a low grade heating gas should be used and this gas must be washed thoroughly in order to avoid clinkering trobles in the brick layers of the regenerator.

The Wintershall-Schmalfeldt-process is only used with lignite and, although used in a commercial plant, the effect was rather poor. The main disadvantage is the use of a regenerator to deliver the necessary heat of reaction to the recirculated gas, so that the maximum temperature was limited by the quality of regenerator bricks. Bituminous coal could not be used in this process.

The Winkler producers are mostly used in hydrogenation plants of middle Germany, where predried lignite or lignite coke (low temperature coke, carbonized fuel) are used as fuel. The Winkler producer runs with fine coal (not ground) keeping and gasifying the coal in suspension in a simmering fuel bed. Heavy carbon losses occur as soon as bituminous coals are used with this device, although an installation for bituminous coal is reported to run in Japan. Tests made with bituminous coal in a semi technical plant at Ludwigshafen had shown that the efficiency would be about 20 % due to excessive carbon losses. Gasification of powdered coal will be more effective, as the tests have shown.

Didier has not developed an own process but has worked together with us.

Other proposals were made by Pintsch, Berlin, using external heating and Rittershausen, Cassel, using electrical heating, no plants were errected. Electrical heating would be uneconomical at all events.

12.) Coal composition has only slight effect as the gasification in suspension is an uniflow process and all differences in coal quality or composition of the volatile matter are equalized by burning them to CO_2, SO_2 and H_2O in the oxidising zone. No tests were made with variable sulphur content. Sulphur will burn to SO_2 or H_2S depending upon the composition of the gasifying agent. At all events a purification of the gas is unevitable but the content of any disturbing components of gas will be lower than in any other process because of the decomposition of all these constituents in the oxidising zone.

13.) Flow characteristics of the powdered coal could only be changed in no sufficient range, in order to examine the effect of slight differences of grain size or size characteristic. The effect of grain size and the difficulties of homogeneousness of the air-solid-mixture have already been mentioned.

14.) As has been said before, it has been expected at first to run the plant in a dry way and to wash out the fly dust at the end of it by scrubbers. Between the two towers a device had been provided to remove solid particles and to recircle the carbon if need be. It was not possible to remove fly ash or unburnt carbon from this point but the ash accumulated here became molten.

As the trend of development is to higher temperatures it must be assumed that a part of the mineral matter will be come out in the gasification chamber and must be removed by a special device and the rest of it will be eintrained and washed out behind. The idea was to use a similar device, a rotating drum, as has been used by Mrss. Szikla and Rozinek in their semi-gas suspension furnace.

15.) The process would be realized under high pressure and the idea was to extend the experiments to pressures up to 20 atm (= 286 lbs/sq.in) or more. No special plans have been made till now because at first the problem had to be solved at normal pressures.

16.) Moisture content of coal has no effect on generator performance except the same as an equivalent moisture content of the blast. Moisture content of coal is yet important for the pulverizer and coal has to be dried before or during milling. Lignite must be predried to about the usual moisture of brown coal briquette e.g. 13 - 17 %.

17.) Complete and accurate heat balances could not be made because the exact weight of input of coal could not be measured. Part of the coal dust escaped through the separator of the milling plant. It was planned to change the powdered coal bin to a weighing bin by suspending it and using a pressure measuring device.

As can be seen from the tests made the estimated fuel efficiency was between 36 and 62 % referring to cold gas. From these figures it seems possible to get 50 - 60 % efficiency in a commercial plant and that a great deal of the wastes could be regained by using a waste heat boiler and by recircling the unburnt carbon.

18.) Tests were made with bituminous coal and in one case with lignite, the blast consisted of air-steam mixtures in some cases oxygen was added. Most of the tests were made with air-steam blast as time and possibilities for testing were rather limited. The operating data can be taken from the reports mentioned but these figures are not characteristic as far as variations of the load, the preheat a.s.o. cause respective changes.

19.) There are possibilities to exchange energy between the gas producer and the oxygen plant, as the gas will leave the producer with temperatures of 1000 to 1200°C (= 1832 to 2192 °F) so that high pressure steam may be produced. This energy - nearly 25-30 % of the heat input may be recovered with 60 to 70 % boiler efficiency and this energy may be use to drive the blowers, the coal mill and ~~it~~ the oxygen plant (or part of it). Energy balance is much improved by such a combination, the experimental plant however was not fitted with a waste heat boiler.

20.) Oxygen purity is essential in all cases where oxygen steam mixtures are use for the production of hydrogen or synthesis gas. The effect of inert constituents can be calculated. No tests were made with pure oxygen till now but the effect of purity is quite clear and needs no elucidation.

21.) Gum forming constituents and other foreign materials dangerous to the joined gas utilizers will be less in gases from such plants as was already mentioned in the answer to question 12. No special examination of this problem has been made till now.

22.) Gas produced in this plant was only burnt. No methods of removing incidental gum forming constituents have been proved. If synthesis gas will be produced the ordinary gas purification methods should be used.

23.) Water gas equilibrium as well as other gas equilibria are determining the quality of the gas produced with respect to the surface temperature of the solid particles gasified. This is not only the question in this process but may be considered as generally spoken. In all kinds of producers water gas equilibrium and equilibrium of Boudouard's reation is reached, methan formation only by 0,24. From these reasons high surface temperatures are necessary and extra long runs through gasification chamber is useless if temperature of the particles cannot be maintained high enough.

24.) Weathering of coal has no effect to its gasification characteristics. This is only the case with degasifying (production of towns gas by carbonisation).

25.) For producing heating gas, air blast or air-steam mixtures will be used as gasifying agends. Saving the volatile matter to improve the heating value, by degassing similar to Wintershall-Schmalfeldt-process, may be advisable.

26.) For producing synthesis gas pure oxygen-steam-mixtures will be used in uniflow process. H_2O, CO_2, SO_2 and H_2S may be removed by washing with water, lye a.s.o.

27.) Recycling of produced gas or supplying extraneous gas has no advantageous effect and is unnecessary, as the oxygen partial pressure would be diminished by these gases. The preheating of air by mixing with combustion gases (burning high grade extraneous gas) proved uneffective from this reason. Recycling of product gas in small proportions may be useful from other reasons e.g. as feeding agent (carrier gas) of fresh powdered coal or coke.

28.) The process is operable on partial or completely carbonized coal. Low temperature carbonizing would be more high temperature carbonizing less effective because of the difference of coke reactivity. Milling coke is very difficult, expensive and causes high wearing of the pulverizers, milling of coal, therefore is preferred and pulverized coal may be carbonized in suspension by product gas. No tests have been made with high temperature coke dust, low temperature coke has been used by Winkler, Koppers, Schmalfeldt with similar or better results than with coal itself.

29.) Proposals had been made to gasify the coal in two or more stages under different conditions of velocity, temperatures, grain size and so on, but as separating devices would be necessary behind each of these stages and separating at high temperatures is an extremely difficult problem no practical use has been made of these proposals.

30.) Effect of size of unit to plant cost and cost of operation is so high that it seems undesirable to construct commercial plants with much less than 100 tons of coal a day. No exact calculations of this question have been made till now. A special advantage of this kind of plant is the possibility to construct units of high capacity. Operating cost will be low, working cost of product gas mainly depend upon coal prices and in the cases of producing synthesis gas oxygen prices. Although effiency will be low with this kind of producer first coast of gas will be low as price difference of raw coal or slack and crushed coke is more than compensated.

This was the reason for continuing the development of these processes during the war. Price of oxygen depends upon the size of unit and power cost, from these reasons too only big units for producing synthesis gas may be considered as economical.

31.) As mentioned above factors of the most economical size of unit are: Price of coal, energy, oxygen and man power. Other limitations are of mere technical character such as diameter of gasification chamber, possibility of water cooling of the walls and so on. With too small units cooling would effect gas quality, no cooling would effect life time of walls. From these reasons commercial plants should be errected in large units only.

32.) The proposals of errection and operation the plant were planned by Bergbau-Verein (Dr.Gumz), Demag (Dr.Pistorius, Dipl.-Ing.Schneemilch) und Ruhrgas A.G. (Dir.Traenckner, Dipl.-Ing. Kukuk). The tests reported were mainly made by Dr.Nistler (German Mines Supplies Organisation) with assistance of Mr.Kukuk (Ruhrgas) and Mr.Lilienfeld (Demag). No publications have been made till now because the experimental work is not yet complete. A continuation of the work is desirable. Although the plant is not damaged by war events, it is in a very bad state and partly dismantled after a standstill of 4 years.

We hope that the above answers to your questions will cover the whole field, more details, drawings or further material beyond the reports mentioned are not available.

GERMAN MINES SUPPLIES ORGANISATION