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NEW METHODS OF LEAN GAS PRODUCTION FROM BITUMINOUS COAL

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The rising economic importance of pipe-line gas, synthesis gas, and lean gas resulted in the increasing gasification of solid fuels which demanded a widening of the fuel basis. The former Union of Mining Concerns in Essen and the Ruhrgas A. G. occupied themselves with the question for several years before the last war, and constructed with the DEMAG A. G. an experimental installation for powdered coal gasification at the ammonia plant of the Hibernia A. G. in Herne. This experimental unit was completed in 1943, but tests were not conducted to successful conclusion because of the war. The special development section of the Ruhrgas A. G. resumed this study in 1949. It resulted in some new processes, and its development of the lean gas production from coal dust by the Vortex method (Wirbelkammer) is being reported here as having reached the industrial stage.

Powdered coal gasification methods are of particular interest because they make the process independent of the nature and grade of fuel, since almost any fuel can be ground and gasified in suspension without reference to its baking properties, tar content, or other factors. The large surface of the coal particles results in a rapid reaction which promises a high efficiency in the generator unit and low operation and installation costs. It must further be taken into consideration that with the progress of mechanization of today, dust and fine powders are produced in ever-increasing amounts.

The production of lean gas is of importance in the Ruhr region, because a large number of coking plants use coke-oven gas to supply their own firing needs, although these needs could be covered with lean gas. With no blast-furnace gas available, the lean gas could only be produced from coke fines in rotating-grate generators. In spite of the relatively low installation

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and operating costs and an efficiency which can hardly be further improved, this process does not furnish cheap substitute gas because of the high coke cost.

Figure 1 shows that the cost of powdered fuel gasification is similar to that of generator, with similar low capital and operating costs, and like the gasification of tailings, the economic advantages of coal-dust gasification against coke generators is based principally upon the lower fuel costs.

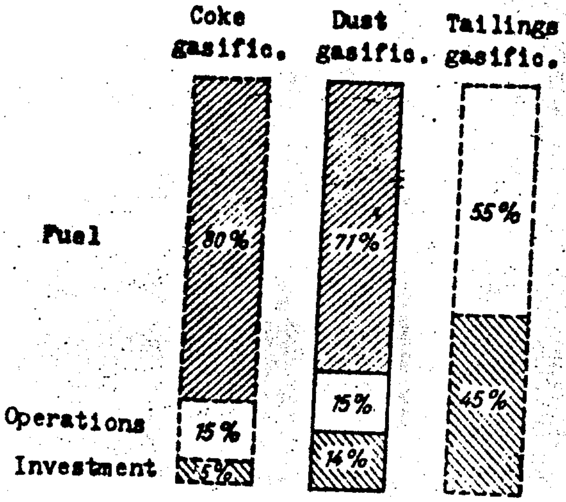

Figure 1. - Composition of production costs in gasification of coke, dust, and tailings.

Figure 2 shows the effect of gasification efficiency and fuel cost of the fuel upon the price of the gas. The cost of coke amounts to almost 7 DM. per 10^6 kcal., and the production cannot result in a cost of the replacement gas below 10 DM. per 10^6 kcal. Brown coal and brown-coal briquettes cannot be considered in the Ruhr region because of transportation costs. Only the cheapest grades of bituminous coal per kcal., that is, dust, coal fines, sludge coal, etc., can be considered. The slope of the curves permits one to conclude, however, on the possibility to gasify these high-ash grades of coal with as good efficiency as in the rotating-grate generators.

The operating procedure developed by the Ruhrgas A. G. consists essentially in causing powdered coal to react with much less air than necessary for complete combustion. The gasification process may be considered similar to powdered coal combustion operated with great air deficiency.

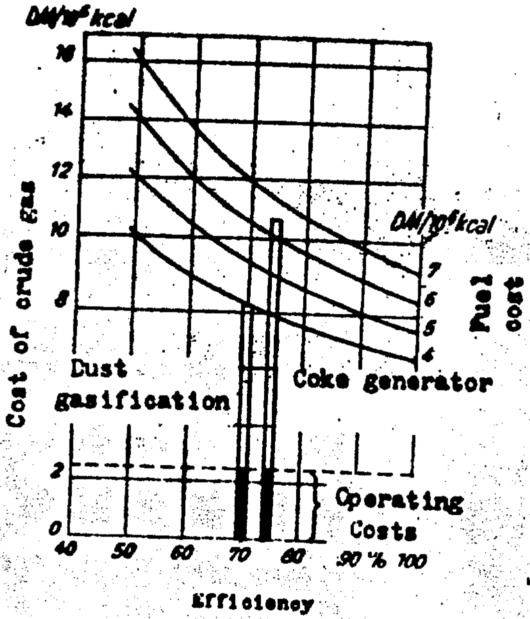

Figure 2. - Raw gas costs in relation to efficiency and to the P.t.u. costs of the fuel.

Figure 3 shows temperature changes in this type of powdered fuel flame. Temperatures rise at first steeply with the consumption

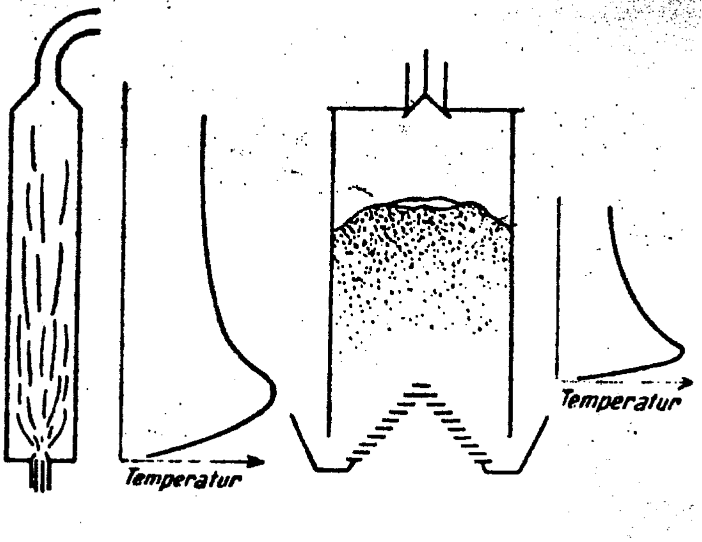

Figure 3. - Temperature changes in powdered fuel gasifier and in a gas generator.

of oxygen present in the gasification air. The temperature drops then and the drop becomes more gradual towards the end of the process and approaches the final state asymptotically. This temperature drop is the result of the endothermic gasification reactions, and is, to a certain extent, analogous to the temperature changes in the fuel bed of the generator, in which one may also distinguish between a rising temperature in the oxidation zone and a drop in temperature in the reduction zone.

Difficulties of powdered fuel gasification result, however, from several differences between the two processes which are not obvious but are nevertheless important. In the first place, there is a great difference between the two processes in the concentration of the reaction components: When proceeding in the direction of the gas flow in the generator, the oxygen concentration drops rapidly to zero and the reduction of the CO_2 and H_2O gases begins immediately where oxygen disappears, while its maximum reaches gradually near the end of the process. The carbon concentration increases, however, steadily during the whole process. In powdered fuel gasification, the concentration changes of the gaseous reaction component proceed entirely analogously, except that the changes in the carbon concentration become continuously smaller towards the end of the process, because the carbon, moving in the same direction with the gases, is consumed by the gasification reactions; the splitting of CO_2 and steam also consumes carbon, and can therefore proceed only as long as sufficient carbon is available.

Intensive stirring of the gas stream is of advantage to promote heat and material exchange; the necessity of a certain excess of dust towards the end of the process cannot, however, be avoided, because carbon dioxide and steam splitting cannot be brought about without the presence of free carbon, even with the strongest relative motion between the gasification means and the suspended fuel.

An excess of fuel cannot be avoided and this ungasified residual fuel must be separated from the gas stream behind the gas producer.

This excess may then be put to some other use, for instance, for powdered fuel burner, or else it may be returned into the process. Supplying the residual dust to some other process leads, however, to a combination of dust gasification with some other installations, which is the less readily realizable because relatively high-ash powders are used in the gasification, and the residual fuel is still higher in ash, even after losing only its volatile constituents on its path through the gas producer. The advantages to other users from this excess dust with an increased ash content are therefore very slight, and it appears desirable to return that dust to the gasifier.

Different paths may be followed in returning the excess fuel to the gasifier, as shown schematically in figure 4. It may be introduced here together with fresh coal dust from the coal bin into the gas producer, or else it may be used in a reaction with a gasification air before introducing the make-up coal dust. The second method is more attractive because it will cause the high-ash, de-gased residual fuel to be acted upon by the full oxygen concentration of the gasifying means, but from the standpoint of installation the single-stage process is considerably simpler. This method was therefore selected and was found in numerous tests to permit complete consumption of the fuel even in a single-stage process.

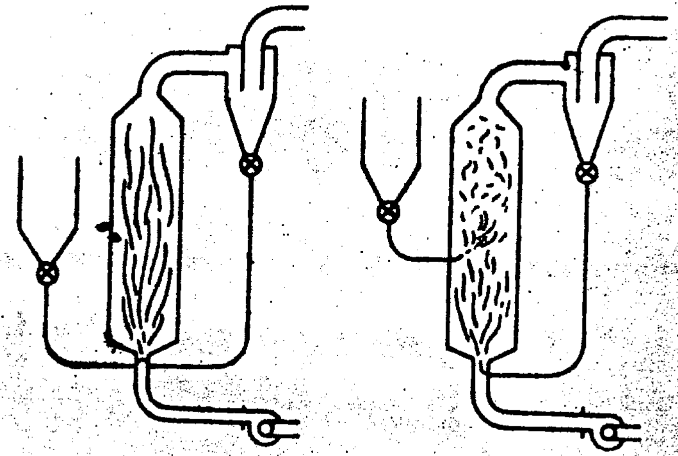

Figure 4. - Single-stage and two-stage powdered fuel gasification.

The problem of slag removal requires once more a comparison of the temperature changes inside a generator with a stationary layer of fuel and a powdered fuel burner operated with an excess fuel. In both cases, a distinct temperature maximum at the end of the oxidation zone is obtained. The principal difference consists, however, in the composition of the fuel at the highest temperatures. With generators with stationary fuel layer, or more accurately, with the fuel layer slowly moving countercurrently to the gasifying means, fuel is at that time available which may have lost about half of its carbon content, but which still consists mostly of carbon and remains solid at the 1,400° C. temperature at that place.

No such high temperature exists, however, where most of the carbon is consumed. This necessary fuel movement permits, therefore, exceeding the melting point of the ash.

Conditions are different in the dust process in which the fuel moves concurrently with the gasification means and where the differences in size of the fuel particles are much greater than in a mixture of lump fuel, even when the latter is very poorly sized. Unavoidably, a large number of dust particles are completely ashed at the point of the highest temperature, and even 1,400° C. would result in the liquefaction of some of the ash. Were this fusion or softening of the ash to be definitely avoided, the temperatures must remain appreciably lower during dust gasification than in generators.

There was no lack of proposals of this kind, and in particular, exceeding the ash melting point was to be avoided by the introduction of the gasification means at different points. It would, however, be doubtlessly very difficult to reach in this way a satisfactory solution, because a great lowering of the temperature would result in a lowering of efficiency. It appeared therefore preferable to use a different method and raise the process temperature high enough by preheating of air to completely liquefy the ash. A cyclone-like shaping of the gas producer will help in the separation of the ash and provides, moreover, a high relative velocity of the dust particles against the gasification means, causing the process to proceed in surprisingly small volumes. Such concentration of heat production in a small space again favors the ash fusion, resulting in very greatly increased fuel conversion per unit volume of the gasifier proper, and in the separation of a liquid ash.

The accuracy of these conclusions were tested in about 200 tests in an experimental installation with a daily throughput of around 5 tonnes. The fuel study embraced all grades of bituminous coal, brown coal and peat. The fineness of grinding varied between 20 percent on about 175-mesh screen to 82 percent. The size of the coal was found to have surprisingly little effect. The slag in this experimental installation was removed discontinuously by tapping. The coal used contained up to 30 percent ash. Tests have shown that even coals with the highest slag-melting point could be used successfully, and a complete experimental plant, with coal grinding and final purification of the gases and a continuous slag removal was put in operation with a daily throughput of 14 tonnes.

The calorific value of the gases corresponded to a blast-furnace gas. The gas flame coal with 24.4 percent ash, 1.8 percent moisture, and 30.2 percent volatile matter gave, for instance, a lean gas of the following composition:

5.3 percent CO_2
22.1 do. CO
12.6 do. H_2
60 do. N_2

The gross calorific value was therefore about 1,051 kcal./nm.^{3} and net 991 kcal./nm.^{3}. Only traces of methane were found. Heat-flow diagram of the experimental unit, figure 5, gives an idea on the heat economies of the process discussed. Sixty-three percent of the total calorific value of the fuel were obtained in the lean gas as combined heat. Part of the heat was re-introduced into the process with the excess dust. The sensible heat of the gas produced was recovered in a heat exchanger for the preheating of the gasification air, returning thus a considerable part of the heat to the process; the residual excess heat was used for steam production in a waste-heat boiler, so that the total heat utilization of the experimental plant amounted to 72 percent. Losses in heat conduction and radiation are rather considerable, being 17 percent, and also the dust losses during the return of the residual dust. Both sources of loss will be reduced in a large-scale unit with a daily throughput of 100 tonnes, permitting a gasification efficiency of 70 percent and a total heat utilization of 84 percent when utilizing the steam produced.

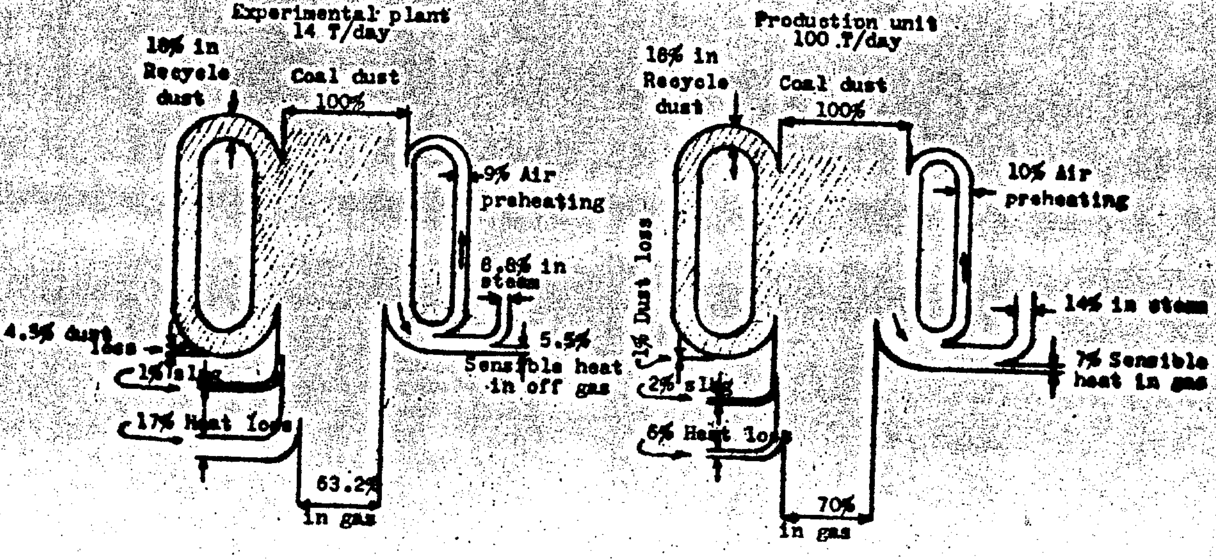

Figure 5. - Heat balance in the powdered fuel gasification.

Figure 6 is a sketch of a design of a large installation which makes use of the method of operation discussed: The strongly preheated air and fuel dust enter a cyclone-shaped chamber through tangentially arranged orifices. The liquid slag is continuously removed centrifugally from the Vortex drains through an opening in the bottom, and is granulated in a water bath. The dust-containing gases are freed from most of their dust in the cyclone, and passed through a preheater and a waste-heat boiler. A fine purification of the gas adjoins it through a multiclone, and is followed by a washer and electrostatic filter as a final stage.

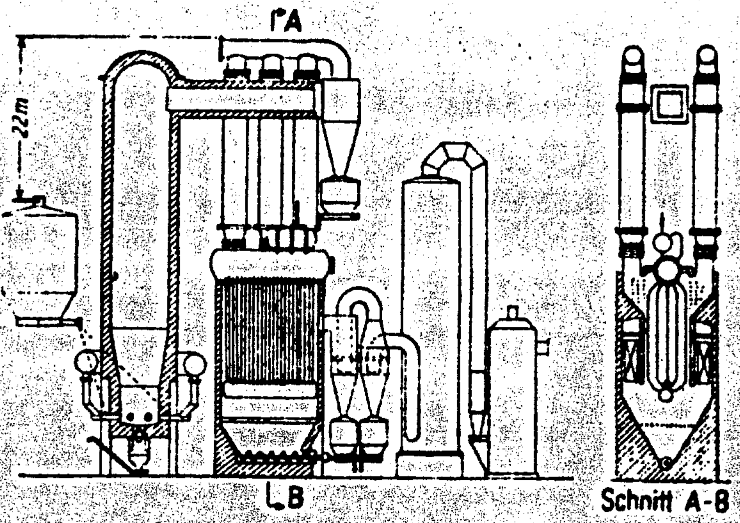

Figure 6. - Lean gas producer for 100 tonnes coal dust per day.

The present tests were largely limited to our most urgent problem of lean gas production by gasification with air, but it may be safely expected that when steam-oxygen mixture is used it can also be applied to a synthesis-gas production. It may even be assumed that in many respects the process will be easier to carry out, because in this case effects can be brought about by changing the oxygen concentration of the gasification means. The gasification efficiency can also be increased against gasification with air, because the elimination of nitrogen will reduce heat losses.

In addition, a few remarks on the costs of the gas: The installation and operating costs of the new process will certainly be no higher than in a rotating-grate generator. The efficiency will be practically the same. Reduction in the fuel costs will therefore certainly result in lowering the cost of the gas.