THE MANUFACTURE OF METALLURGICAL FORMED COKE ACCORDING TO THE BFL-HOT BRIQUETTING PROCESS

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For the making of metallurgical coke, quite a number of continuous formed coke making processes have become known in the past years. It was the aim of these processes to produce lumpy coke suitable for blast-furnaces, above all from weakly or not caking coals. From a world-wide viewpoint, such coals are much more available than the prime coking coals from which conventional coke has been produced so far in slot-type recovery coke ovens.

Since 1962, Bergbau-Forschung GmbH., Essen, and the Lurgi Mineralöltechnik GmbH., Frankfort, developed the so-called BFL-process which uses the hot briquetting of mixtures of coal and char in order to make formed coke. For the development of such a process for the thermal refining of hard coal, several years of testing and trial are indispensable. Subject of such a phase of trial are the process as such as well as the products made according to this process.

As for the trial and the process itself, the question arises first of all about the technical feasibility of the process. When this feasibility has been principally proven, questions of a suitable selection and set-up of machines and apparatus gained in importance, while the optimization of the overall process concludes the development. The necessary tests can be carried out in small-scale testing or trial plants or with physically similar models. Both methods of development are suitable and complement each other meaningfully. In this connexion, the question of the transferability of the results, first from small-scale plants to large-scale plants, and then, in case of model tests from the model to the large-scale realization, has an essential importance.

It is the objective of a testing and trial of the products to prove that the new product is at least equivalent to those hitherto used. A two-way procedure offers itself also for this stage of trial: on the one hand, trials can be run in small-scale plants as are available, e.g., to the West European metallurgical industry in the trial blast-furnace Ougrée, or, on the other hand, prediction about the behaviour of the product in practice can be made from the chemical, physical and technological properties obtained from the laboratory tests. It is a matter of course that - in order to establish the evidence of the formed coke for its suitability - a long-term trial in a practical blast-furnace for at least one month will be necessary. Without such a long-term trial nobody will risk to establish a commercial plant according to a new process, as the investments required therefor would be too high.

The BFL-process[1)2)] has already passed a considerable part of the lead time up to the unlimited application of the process in practice. For better understanding of the following expositions, however, the principle of the BFL-process will be described once more below.

Description of the process

As shown in Figure 1, hot and finely grained char with a temperature of about 75o °C is mixed with finely grained binder coal in a mechanical double screw mixer. The binder coal should be available in a size $<$1 mm. The ratio between binder coal and char is about 3o:7o. On account of this ratio and the temperature of the hot char, the temperature of the mixture is in the range of softening of the binder coal. The double screw mixer has the function to mix rapidly and intensively the char and the binder coal in order to attain a balance of temperature between the two flows at the end of the mixer. Thus, the binder coal has been heated up to a temperature of 45o °C and has become plastic. The mixture then gets into a pug mill from where it is conveyed to the double-roll press, This press gives the briquettes their shape. The briquettes leaving the press at a temperature of about 45o °C must be subjected to a careful cooling and are then eligible for use in the blast-furnace.

As Figure 2 shows, there are two methods for producing the necessary char. The more simple process and also that requiring less investments is the fluidized-bed carbonizer. Here, the fine coal fed into the reactor at a temperature of about 75o °C is carbonized in the fluidized bed. Part of the necessary heat can be supplied with the fluidizing gases, another part by the burning of char in the fluidized bed. The oxygen necessary for combustion is contained in the fluidizing gases. The waste gas consists of a mixture of degasification gas and the fluidizing gases. Due to its high nitrogen contents, however, it has still only a low calorific value in the range of 1000 to 2000 kcal/m_n^3.

The more expensive process circulating a heat carrier according to Lurgi-Ruhrgas, briefly called "the LR process", provides a separation of the heating-up process and of the degasification process with the result that a rich gas is obtained as a by-product. Circulating char at a temperature of about 750 °C and fine coal, in a ratio of 10:1, are supplied to a mechanical double-screw mixer. This mixture is then brought, with a temperature of 650 to 700 °C, into a subsequent degasifier from which the product gas on the one hand can be withdrawn and, on the other, the excess fine char. The excess fine char is supplied to the hot briquetting section, while most of the char remains in the circulation and is supplied to an airlift. In this airlift the char now used as a heat carrier is re-heated up to 750 °C either by partial combustion or by a bottom firing with fuel gas. In the collecting bin, the char is separated from the carrier gases and re-enters the process, while the flue gas, with its content of sensible heat, can be used for pre-heating the combustion air for the airlift and the drying of coal. The selection of the process for the production of a finely grained char is not without influence on the properties of the product.

The LR-process yields, as a whole, a denser char and, thus, also denser hot briquettes. Generally, all hard coals, from the anthracite to the long-flame coal, are suitable for char making. The binder coal, however, must fulfill certain requirements, viz. concerning the coking and the softening properties. Recent investigations in the laboratory and in our semi-technical plant showed that not only well-caking coal but also medium and weakly caking coal with a Swelling Index of ca. 3 can be used successfully as binder coal, provided part of the tar obtained during low-temperature carbonization and hot briquetting is admixed to the hot briquetting mixture. By adding about 6 to 9 % of tar to this mixture, the binding capacity of the coal is improved to such an extent that hot briquetting strengths are reached as with the sole use of a well caking coal as binder component.

Testing and trial of the process

The process has, so far, been tested and tried in four stages. Parallel to the investigations in the testing plants, individual problems of the development of the process were solved in a number of model tests. After reaching the next higher stage, however, the smaller-scale testing plants did not usually become superfluous as the duty to investigate several times new coals necessitated each time tests and trials in the smaller-scale apparatus. Besides, the process itself is being further developed and improved continuously, as, e.g., now weakly or medium caking coals can be used as binder coal with the addition of tar or other binding agents to the hot briquetting mixture.

The smallest-scale plant, as shown in Figure 3, is a laboratory apparatus. This is, in fact, a discontinuously operated briquetting plant working with a small piston press. This press yields briquettes with a weight of about 12 g. From density and strength investigations a first statement can be made about this suitability of the used coals as well as about the presumably best operating conditions. In small coking ovens, the behaviour of these green briquettes during the subsequent heating-up can be investigated.

The next stage involves semi-technical plants with a throughput of loo to 6oo kg/h. These plants are working continuously with a double-roll press. For the production of char, an LR-plant as well as a fluidized-bed carbonizer are available. Figure 4 shows the building accommodating these plants. But even testing plants of this size do not yet permit to produce the quantities required for blast-furnace tests. This became possible only by a plant with a throughput of 5 t/h of hot briquettes shown in Figure 5. In this plant, quantities could be produced for blast-furnace tests with throughputs up to 7ooo tons per test.

The presently last step of development are the large-scale testing plants. Messrs. Still of Recklinghausen established, by order of the Ruhrkohle AG, during 1973 and 1974 a 12.5 t/h hot briquetting plant on the area of the coke oven plant Prosper in Bottrop. This plant is operated by the "Arbeitsgemeinschaft Formkoks" formed by experts of Ruhrkohle AG and of Bergwerksverband GmbH., a subsidiary of the Bergbau-Forschung GmbH. Figure 6 will give you an impression of this plant which, compared with conventional coke oven plants, has been built much more to the height.

A further large-scale testing plant according to the BFL-process with an throughput per hour of 27 tons of hot briquettes is being built at present, by order of the British Steel Corporation, by the Lurgi Mineralöltechnik GmbH. in England.

These large-scale testing plants are to fulfil three duties:

1. Testing of the BFL-technology in a larger scale.
2. Making sufficient quantities of hot briquettes available for long-term blast-furnace tests.
3. Drawing-up of reliable material and heat balances to serve as a basis for economy calculations.

The flowsheet of the large-scale testing plant Prosper and its individual stages: drying, LR-low-temperature carbonization, hot briquetting, the cooling of briquettes and the purification of gases, can be seen from Figure 7.

The coals delivered by rail are stored separately, according to coal for char making and binder coal and are then dried after withdrawing through vibrating chutes into two parallel flash driers (1). The about 7oo °C hot waste gases of the LR plant are used for drying. Afterwards, the moisture content of the coal is < 1 %.

The dried binder coal is crushed in an impact mill (2) to < 1 mm. As for the coal for char making, the sizes > 3 mm separated in a pneumatic deduster can also be subjected to crushing (2). According to our experience, however, crushing can be resigned on because of a sufficient crushing of the charring coal particles during the shock type heating-up during carbonization. The dried coal is bunkered for a while in the plant. The char is produced according to the LR-process. For this process, the coal for char making is proportioned, in a ratio of 1:1o, to the circulating char, via a belt scale, in the double-screw mixer. By the following admixture of fresh coal, the temperature of the mixture decreases to about 7oo °C. After a short residence in the degasifier shaft, the mixture is proportioned to the airlift to which the heat necessary for low-temperature carbonization is supplied, either by the combustion of char or the combustion of gas. In the ascension pipe, the char is heated up to 75o °C and conveyed into the collecting bin. The bulk of the char is returned to the circuit and, thus, into the mixer, while the excess char flows into the hot briquetting.

The waste gases of the airlift are passed, via a cyclone system (4), into a secondary combustion chamber where the residual coke dust and the combustible gases are burnt. The heat of the waste gases is utilized for the pre-heating of the air to the airlift and in the driers.

For hot briquetting, the binder coal is proportioned, via a belt scale, to the double-screw briquetting mixer (5) and is there intensively mixed with the hot char. In the subsequent pug mill (6) the final homogenization and degasification of the briquetting material take place which flows to the roll press by gravity (7).

The used briquetting rolls have a diameter of 1.4 m and a maximum contact pressure of 3.5 t/cm. Briquette sizes of 2o to 3oo cm^3 can be produced.

Directly below the press, the grooves are separated from the briquettes by a fixed grate and are returned into the LR-plant.

The hot briquettes are cooled in a shaft cooler (8) by circulating gases, these gases being cooled themselves in a warm water cooler in order to avoid a condensing of water. At the end, the briquettes pass a water bath where the residual heat is discharged.

The carbonization gases from the LR-plant and the hot briquetting are subjected for purification to a several-stage condensing process where tar, oil and gas liquor from the carbonization are obtained, in addition to the gas.

As concerns environmental protection, the hot briquetting process can be considered as "non-polluting". All stages, from drying up to the cooling of the products, take place in closed containers and apparatus. Contrary to the presses in conventional briquetting processes, the hot briquetting press, too, is totally encased. This, however, hinders the attendance and the operating of the press by no means.

The dedusting of the waste gases from the drier and the collecting bin of the LR-plant takes place in an electrostatic precipitator down to a value - prescribed by the Mines Inspectorates - of 15o mg/m^3, after the residual CO and H_2 have been burnt in a combustion chamber.

Desulphurized carbonization gas can be used for bottom firing of the LR-plant with the result that the dust gases, too, are free of sulphur.

All gases and water flows containing any contaminations are fully under control. As regards measuring and control, the entire plant has been conceived such as to be controlled from a central control room. No personnel needs to be present in the station, except for repair and attendance work. Thus, the demands placed on a modern hygiene at the working point have been realized to a wide extent.

The taking into operation of the demonstration plant Prosper began in May 1974 and has not yet been completed up today. Figure 8 containing schematically the individual sections with the ancillary plants, shows (in a dark colour) which components of the plant have been taken into operation so far.

A number of technical disturbances and standstills - not unusual for commissioning such a demonstration plant - caused considerable delays in the originally planned time schedule. Deficiencies in the conventional equipments formed a frequent source of defects and failures. E.g., the drying and re-heating phase of the refractory material required a much longer time as unexpected conditions of the Inspectorates with regard to the safety in operation had to be observed.

At the time when this report was written, the LR-cycling had been taken into operation and was well under control. The time schedule provides as a next step the taking into operation of the gas purification, which will be followed by the commissioning of the hot briquetting stage.

Testing of and trials with the products

A first indication on the suitability of different formed cokes for use in blast-furnaces is obtained from the data of analyses. The interesting properties are: size and shape, strength, density, reactivity and contents of volatile matter. These factors are much influenced by the control of the process, while other factors, such as the ash and sulphur contents, depend essentially on the type of input coals.

The size and shape of the briquettes can be freely selected during the briquetting process, the shape being subjected to a more stringent limitation than the size. In the 5 t/h plant, hot briquettes have been produced up to a maximum of 300 cm^3. This large briquette, however, was not used in blast-furnaces, but in cupolas. Thorough model investigations about the flow resistance of formed coke led to new perceptions[3]. Of decisive influence on the strength of burdens of formed coke is the purling of the burden into the void space of the formed coke.

For the lower part of the blast-furnace, e.g., the zone where the iron has been molten yet, a formed coke as lumpy as possible, is desirable in order to attain a low flow resistance. On the other hand, a lumpy coke can be disadvantageous before the tuyeres as well as in the shaft of the blast-furnace. In front of the tuyeres, the surface offered can be so low that the turn-over slows down with the blast. In the upper part of the blast-furnace, the finely grained sinter can purl into the void space to such an extent that the pressure loss will be higher than with small sizes of coke. Thus, there is an optimum size which always depends on the type of burden used. Generally, the optimum size is smaller when pellets are used than with the use of finely grained sinter. This know-how obtained first in model tests could be much confirmed in actual blast-furnace trials.

The strength of the formed coke plays an important part during trials in the blast-furnace. In order to be able to draw a comparison with the conventional coke, the drum test offers itself, as the crushing strength usual for briquettes cannot be applied to a conventional coke, because of the irregularity of the coke lumps. Figure 9 shows - besides other properties - some comparison strengths according to MICUM as well as according to IRSID. Attention must be paid, however, that the abrasion $<$ lo mm developing from formed coke is finer as when conventional coke is subjected to drum tests.

After the trials by Ledent[4] in the Ougrée blast-furnace, the attention has been directed to the coke density and the porosity connected therewith. According to Ledent, formed coke should have, if possible, a similarly high porosity as conventional coke. An extremely dense coke is not suitable for use in a blast-furnace.

The reactivity of formed coke is, as a rule, higher than that of conventional coke. However, it is still within a range where it is without much influence on the operation of the blast-furnace.

Important in connexion with the behaviour of the hot briquettes in the blast-furnace was the question whether the burn-up of the green briquettes takes place from the outside or through the pore system in the inside of the green briquettes. In the latter case, the burn-up in the blast-furnace could have caused a decisive weakening of the green briquettes with the result that they could fall to pieces in the bottom part of the blast-furnace. Samples drawn from the tuyeres during blast-furnace tests showed, however, that the burn-up takes place wellnigh exclusively via the outside surface of the briquette and that the structure in the rest of the briquette remains nearly unchanged.

When using uncoked hot briquettes in the blast-furnace, a much higher content of volatile matter must be reckoned with as in the case of conventional coke, as is to be seen from Figure 9. As far as these volatile matters emit from the briquettes in form of gas, they will not interfere with the operation of the blast-furnace. The blast-furnace gas willbe enriched thereby in its calorific value what was not even unwelcome in many of the works. The volatile matter must not contain any traces of tar, as otherwise operational defects could be caused by its condensation in the equipment subsequent to the blast-furnace. Tests run so far, however, gave not reason to such fears.

That this must not be expected from longer-lasting tests has been shown by comparable tests where steam coal nuts (with 17.5 % Vol.Matter waf) were added to the coke (to the extent of 6:8 %) in operating blast-furnaces of the Youngstown Sheet and Tube Company[5]; even after an operation of one year no depositions could be found in the subsequent pipelines.

Figure lo gives a review of the blast-furnace tests and trials carried out in the meantime with BFL-formed coke. Green as well as calcined briquettes were tried, the hot briquettes being charged to the extent of loo %, i.e. without admixing conventional coke. The strength of the hot briquettes proved to be sufficient for the transport processes outside the blast-furnace as well as for the mechanical stresses inside the blast-furnace. No breaking of the briquettes could hardly be observed. Dust development in the transport cars in front of the blast-furnace remained low. In the blast-furnace gas as well, the dust contents increased only a little, compared with the operation with conventional coke.

The tests and trials covered the period 1967 to 1973. They were run in Belgium, the Federal Republic of Germany[6] and in England[7]. The diameters of the hearth-casing of a blast-furnace reached from 1.4 m to 9.5 m, and the period of testing from one day to seven days. After the demonstration plant Prosper has been successfully taken into operation, it is provided to prove the definite suitability of the new fuel in blast-furnaces in long-term trials.

To close with, the advantages of the BFL-process will be summarized once more:

The process permits the use of coals otherwise not suitable for coking, thus enlarging essentially the coal basis for making coke.

The process can be considered to be "non-polluting", as the coking process takes place in closed apparatus from which the developing flows of waste gas can be got hold of fully and can be purified by conventional methods.

The entire plant can be started and stopped quickly. Thus, the process is most flexible and can be easily adjusted, if necessary, to a varying market for coke.

Thanks to the free selection in size and shape, the hot briquettes can be adjusted to different types of burdens with a view to a good permeability across the blast-furnace.

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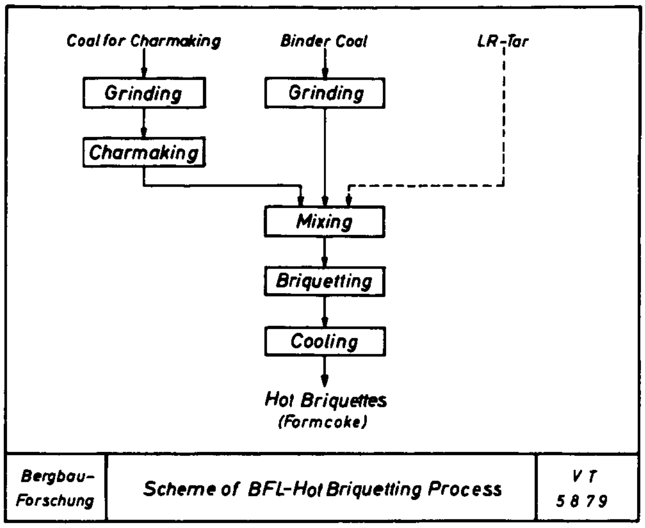


Figure 1

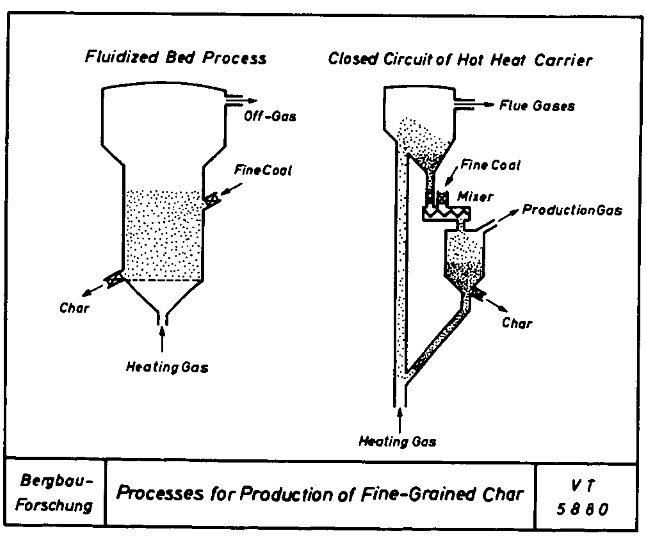
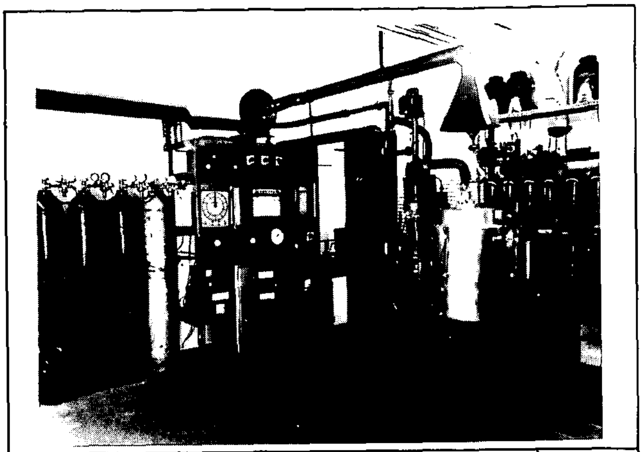
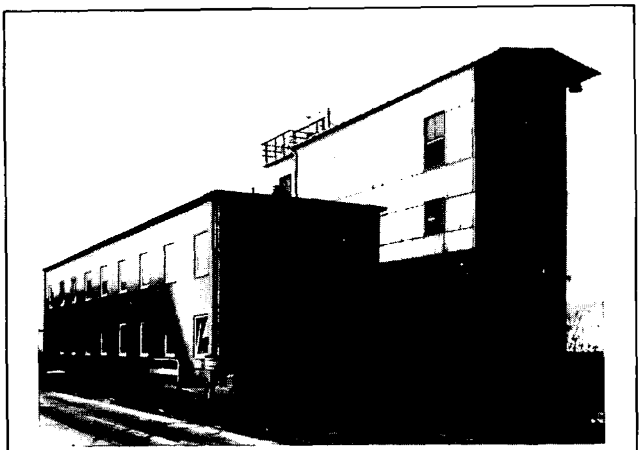


Figure 2



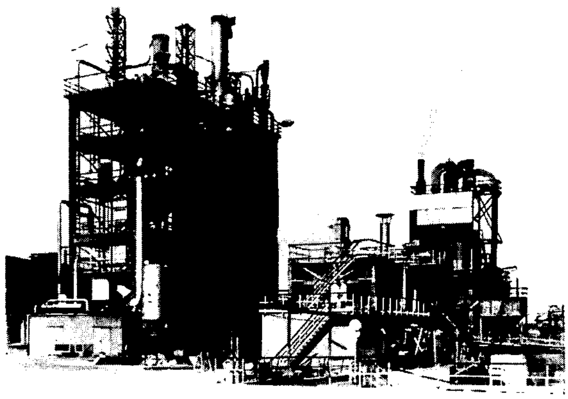
Bergbau-Forschung	Laboratory Hot Briquetting Equipment	VT 5881

Figure 3



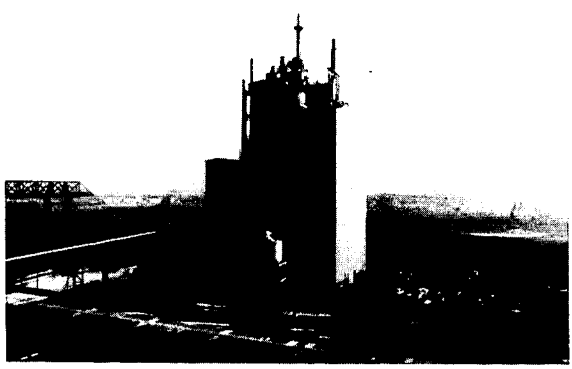
Bergbau-Forschung	Semi-Technical Plants	VT 5882

Figure 4



Bergbau- Forschung	5t/h Pilot Plants for Continuous Production of Formcoke	VT 5883

Figure 5



Bergbau- Forschung	Demonstration Plant Prosper	VT 5884

Figure 6

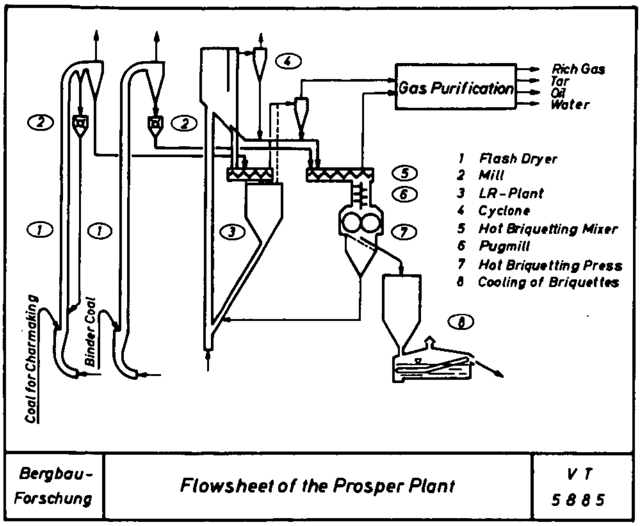


Figure 7

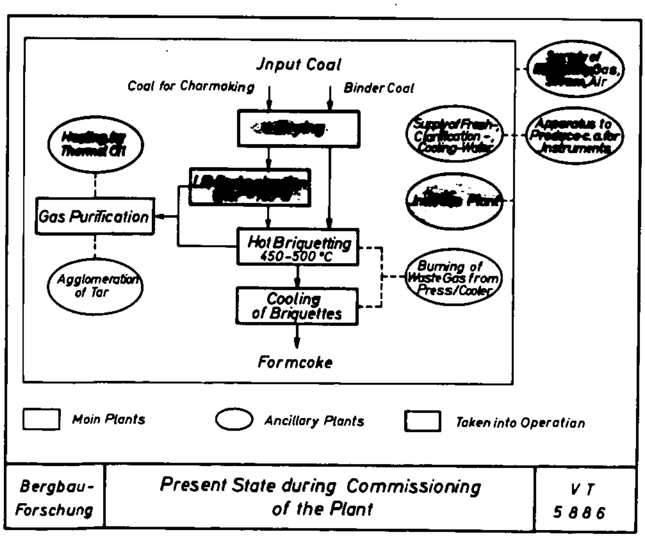


Figure 8

	BFL-HOT BRIQUETTES		BF COKE III
Weight per Piece........g	101	48	–
Porosity....................%	39	49	50
Vol. Matter.................%	10,1	7,1	‹ 1
Ash ....%	6,8	7,0	8,6
Sulphur.....................%	0,91	0,83	0,86
Bulk-Density............Kg/m³	561	508	437
STRENGTH			
MICUM [DIN 51717]			
M_{40}........................%	92,6	91,7	81,2
M_{10}........................%	6,7	7,8	6,5
IRSID			
I_{20} ....%	79,0		80
I_{10}...........................%	20,8		18
BF 1975	PROPERTIES OF BFL-HOT BRIQUETTES AND CONVENTIONAL COKE		5887

Figure 9

TEST	1	2	3	4	5	6
Year	1967	1969	1970	1970	1971	1973
Country	BEL	BRD	BRD	BRD	GB	BRD
Dia of Hearth-Casing..m	1,4	9,5	6,8	6,8	5,5	6,8
Tonnage...................t	500	1350	2700	7000	2650	1150
PROPERTIES OF BRIQUETTES						
Weight.....................g	21	45	48	44	53	98
Volume....................cm³	26	49	55	51	58	106
ABRASION M 10						
[DIN 51717]..............%	6,7	7,0	7,8	7,1	12	10,4
Porosity...................%	57	54	49	59	43	45
Bulk-Density............Kg/m³	415	558	508	495	507	495
Vol.-Matter...............%	2,5	1,9	7,1	1,7	6,0	9,2
BF 1975	BLAST FURNACE TESTS WITH HOT BRIQUETTES					5888

Figure 10