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The Lurgi - Huboven For Carbonization And Gasification Of High-Ash-Fuels

Oil shales and other high-ash-fuels like Cannel-coals and lower grade products of coal-mining are characterized as solid fuels of a low content of fixed carbon and a sometimes extremely high ratio of ash to carbon. An industrial utilization of such fuels naturally has to combine carbonization with gasification or combustion of the fixed carbon, because otherwise the latter could not be utilized, and the process of carbonization would require an additional fuel resulting in additional production costs. Due to the unfavorable relation of ash to carbon the combustion or the gasification of the carbon by air or oxygen generally becomes very difficult, unless the ash has an extremely high melting point.

For this reason gasification of oil shales has been tried in so many pilot-plants in spite of the many failures, which had been experienced before. Only in one case a limited success has been reached by the normal method of introducing air continuously into a fuel bed from below. In this case the ash contains so much chalk, that its melting point is extremely high. (Estonian Oil shale).

In general heavy clinkering could not be avoided in gasifying fuels of a high ash content. The cause of these difficulties lies in the fact that a small quantity of air is extremely superheated by passing a relatively very great quantity of hot ash before it meets the fixed carbon for combustion. Usually applied agents suitable for reduction of clinkering as steaming or a very reduced combustion rate have proved too expensive. Another disadvantage in utilizing the simple method of carbonizing by a direct heating with the gases which are formed by the combustion of the fixed carbon of the fuel is that the quantity of these gases is too small to carry sufficient heat from the combustion or gasifying zone into the carbonizing zone. Cracking of hydrocarbons or their condensation and oxidation within the fuel bed is the result of this method.

In winter time, or if carbonizing a moist fuel, the condensation within the fuel bed may be so heavy that even combustion of the fixed carbon can be seriously hampered. By preheating the material and recircling gases into the fuel bed between the combustion and the carbonizing zones, these difficulties can be reduced.

The experience gained from the condensation of water and oils within the upper zones of the fuel bed have encouraged inventors to reverse the normal flow of the gases as employed by the NTU Retort and the Lurgi-Schweitzer-System. In this case condensation of liquids is reduced and a reflux of liquids into the combustion zone is prevented. But such a process can only be realized by an intermittent working process, because it is impossible to move the fuel in a shaft from the bottom to its top.

This experience shows clearly that for the treatment of bituminious high-ash material a continuous gasification process is desirable which works with a gas flow from top to bottom and in which a continuous discharge of a clinkering ash can be realized. Preheating or drying of the material, if possible, should be helpful to control carbonization and gasification. The gas should have a calorific value of more than 600 calories/m^3 as its combustion cannot be avoided (H_2S content).

The Lurgi-Huboven is a device which is suitable for the above mentioned requirement. Details of the process and of its machinery have been successfully employed in many carbonization plants or in large scale experiments for the carbonization of low grade Lias oil shale of Wuerttemberg.

The process is shown on a schematic drawing No. 1 and works as follows:

The oil shale, crushed to maximum size of 4 inches, is carried to the bunker which in its lower part is provided with grates and roofs for circulating hot gases through the fuel. When leaving the bunker the fuel is dry and can be preheated to 200° centigrade. It descends through a narrow shaft into an inclined chamber which is open at the top and closed at the sides by parallel walls. An inclined grate consisting of groups of parallel iron girders such as I or rails are arranged as a support for the fuel at the bottom of the chamber. The grate can be partly moved by means of a gear. A gas collecting chamber is provided underneath the grate. The chamber is connected at its lower end with a fixed grate and is open at the end in order to discharge the ash. A separate gas collecting chamber for hot gas is arranged underneath the non-movable grate. Chambers can be provided to both sides of the bunker. A steady movement of the fuel bed is accomplished and controlled by moving part of the grate up and down for one or two inches

Drying, carbonization and gasification of the fuel is performed by burning its fixed carbon with air and recovery of the heat which is accumulated by the hot ash. The heat transmission is carried out by circulating gases through the fuel bed. Air for combustion is sucked into the fuel by a slight vacuum which is maintained underneath the grate by the exhaust fan for the carbonization gas and at the lower end by the exhaust fan of the drying zone. This fan sucks combustion gas from the lower gas chamber into the drying zone and circulates the gas with a controlled temperature through the hopper. The surplus leaves through the stack.

The oxygen content and the temperature of the gas in the lower gas chamber can be regulated by an introduction of additional air or combustible gas by a burner which is fixed to this chamber. This burner is also used for the start of the plant. In order to avoid combustion of oil at the entrance of the dried fuel into the chamber hot gas free from oxygen is used for carbonizing the uppermost layer of the fuel bed. For this purpose part of the clean gas is reconducted after being heated to 500° centigrade in a heater which is heated by the hot gases flowing to the dryer. In order to increase the heat transmission from the combustion zone to the carbonizing zone if a low-grade oil shale with less than 8% of fixed carbon is carbonized oil free gas can also be recircled into the middle section of the chamber.

The residue of gasification is discharged directly into iron cars for further transport to a dump by a locomotive. The gas which is sucked from the grate by the exhaust fan is conducted by an electrical precipitator to a cooler and to a scrubber where tar oils and light oils are extracted from the gas. Part of the gas returns to the plant and the rest is available for heating purposes or for the production of electric energy.

From an economical standpoint some principles are of greatest importance for the success of an oil shale industry.

1. Cost of mechanical treatment as crushing, screening, must be reduced to a minimum.

2. A waste of fines, which cannot be used for oil production should be avoided.

3. Manpower required for the handling of material and operation of the plant must be kept at a minimum.

The grade of crushing and the necessity of fractionating of the raw material in general depends on the load or the throughput per square meter, whith which the furnace shall be operated. This concerns an equal carbonization as well as the gasification with respect to clinkering and gas quality.

More than any other industry the carbonization of oil shale needs units of great capacity but with a relatively small throughput per square meter.

In this respect the Huboven seems to meet highest demands. Handling of shale and residue is very simple and needs no complicated machinery.

With one chamber on both sides of the dryer and a width of the chamber of 6 meters a working surface of the grate of 120 square meters can easily be constructed and operated in one unit. With the low gasification velocity of 0.15 m per hour, which has proved satisfactory for relatively lumpy clinkering shale, the capacity of such a unit reaches

$$120 \times 0.15 \times 24 = 432 \text{ tons per day.}$$

It can be increased considerably if the fusion point of the ash and the physical structure of the shale are favorable and if the crushing to a maximum size of 60 - 80 mm is not too expensive.

An experimental furnace with a daily capacity of 50 - 70 tons was erected in 1944 in Wuerttemberg (photographs # 2 and 3). It was operated for nearly one year with Lias oil shale. The chamber of this furnace is 2.3 m wide and 6 m long, with a depth of the fuel bed of only 1.3 m. It was also operated during one week with a moist oil shale from Brunswick. This shale was extremely crumbled by weathering and repeated handling with a shovel. Both shales have an extremely low content of organic substance and carbon and both are inclined to clinker. The experiments were hindered by the facts, that crushed material never could be delivered to the plant and the operation was frequently interrupted for several hours by air raids, lack of electric energy or cooling water. Therefore, the operating of this plant was more or less a study of details of the process and of the mechanical device. The plant was operated during 10 or 12 months and showed that the principles of the process and the design of the furnace were entirely correct:

a. A constant ignition of the shale and an undisturbed firebed could be maintained even with unscreened leafy crumbled shale of 30% moisture and 0 to 30 mm size. In both cases the fixed carbon was less than 5% calculated on dry shale.

b. The movement of the layer of the material through the chamber was absolutely uniform and steady and without any movement within the layer in the vertical direction.

c. The movement of the material could be perfectly controlled and the discharging offered no difficulty even with a highly clinkered residue.

d. The quantity of solid material and dust passing through the grate was very low even with straight vertical outlets (15 mm wide) for the gas. This first unit had no gas recirculation and the dried and preheated shale was immediately ignited by sucking in cold air. Under such unfavorable conditions the recovery of oils and the quality of the gas could not be expected to be very good. The amount of recovered oils was only 40 to 50% as compared with the Fischer Assay. Nevertheless, the results of operation have clearly proven that with a sufficiently crushed material and recirculating of some gas a good thermal and chemical control of the process can be reached even with such a low carbon content. A good oil recovery, as well as combustible gas for industrial use, can be expected.

Extended experimenting, which has been carried out in cylindrical furnaces of 1 to 3 m of diameter with various oil shales and residues from coal mining, has clearly shown that with less than 4% fixed carbon the formation of such a gasification zone as is required for a good yield of oil and gas is very difficult. Otherwise, 90 to 100% of oils and a calorific value of the gas of 800 to 1200 kcal/m^3 have easily been reached with oil shales of more than 10% oil content.

With an oil shale of 10% oil content and the corresponding organic matter, which is more than twice as high as that of the oil shales which were tried in the pilot plant, a recovery of 80% of the oil present in the shale and a calorific value of the gas of at least 800 kcal per Nm^3 (90 B.T.U. per cft) can doubtless be expected for a first commercial furnace. In the stationary cylindric retort 90 - 100% recovery was normally obtained. Such a commercial unit of 400 - 500 tons capacity contains as a central part the bunker and preheater of 5 to 7 m cross section which are made out of concrete or steel. The gear for the movement of the grate and 2 exhaust fans for the dryer are placed on a platform underneath the dryer. Another exhaust fan for the carbonization gases is placed underneath this platform. Both the chambers for carbonization and gasification are connected with the long sides of the dryer. They are mounted on steel pillars. The grates are subdivided into 3 sections of 2 x 10 m and one non-movable grate at the lower end which is 6 x 2 m large. The lower part of the grate is cooled by water. The gas collecting chambers are made of sheet iron. They are lined with bricks in the lower part only. The thickness of the fuel bed is provided with 1.80 to 2.20 m according to the physical structure and the size of the shale.

The apparatus for the treatment of the gas is placed beside the furnace ~~and~~ a central gas purification plant for several units may be provided as practiced in many big carbonization plants. The standard outfit of such plants, which consists ~~of~~ electrical precipitators, indirect working gas coolers and oil scrubbers, can be used.

Belt conveyors are provided for the transport of the shale. Wagons or lorries, as usual in the mining industry, can be used for dumping the ash into the pit or into a natural valley.

A plant for treating 4,000 tons of shale per day consisting of 10 units comprises the following items and costs of erection (costs are based on conditions and prices of Germany 1938 to 1943).

A. Investment Costs	RM
a. Ditch Storage for shale (Grabenbunker)	450,000
b. Machinery for loading and transport	300,000
c. Crusher plant (3 units 100 tons per hour, 60 ton crusher	400,000
d. Belt conveyors for shale	170,000
	1,320,000

	RM
	1,320,000
e. 10 Carbonizers	1,800,000
f. Condensation plant	2,300,000
g. Wash oil Distillation plant 150 cbm per hour	900,000
h. Storage tanks, Capacity 12,000 tons	300,000
i. Distribution system for energy, steam and water incl. motors	800,000
k. Recooling system	400,000
l. Boiler house (gas fired) and Power Station 100 atmosphere 2 x 5000 kw turbines	2,000,000
m. Roads and tracks	250,000
n. Laboratory, office and social buildings	400,000
	10,470,000
Miscellaneous	530,000
	11,000,000
Operating Capital	1,000,000
TOTAL	12,000,000

The investments for mining and dumping of residues are not included.

B. Operating figures for 340 working days per year.

	Germany RM	USA $
1. Total investment cost	11,000,000	6,000,000
Operating Capital	1,000,000	500,000

2. Oil Shale (long tons)

340 x 4,000 = 1,360,000 tons/year

3. Fresh water 250 x 8,600 2,150,000 cbm per year

4. Laborers and employees

Shale storage	3	men
Conveyors	2	"
Crusher plant	3	"
Carbonizers	20	"
Condensation plant	8	"
Wash oil plant	2	"
Tanks and Loading	2	"
Power station	3	"
Electrician, Repair	3	"
Guards	2	"
	48	per shift
3 shifts	144	
1 shift		
Repair shop	10	men
Outside work, cleaning . .	10	"
Laboratory	4	"
Office and drivers	10	"
~~Social rooms~~	~~6~~	"
	184	men
10% for vacation	18	
Total Laborers	202	

Officers: 4 foremen
3 engineers
1 manager.

5. Production of oils (12% oil content of shale)

1,350,000 x 0.12 x 0.8	130,500 tons
90% tar oils	117,450 tons
10% light oils	13,050 tons.

C. Production costs

Oil shale (including dumping of ash)	Germany RM	USA $
1,360,000 tons @ 1.50 RM	2,040,000	
1,360,000 tons @ 75 ¢		1,020,000
	2,040,000	1,020,000

	RM	$
	2,040,000	1,020,000
Water		
2,150,000 cbm @ 0.05 RM	107,500	
2,150,000 cbm @ 3 ¢		64,500
Wages		
Laborers 202 @ RM 3,000	606,000	
" 202 @ $ 2,000		404,000
Engineers	60,000	30,000
Repair and material for operation		
2.5% of RM 11,000,000	275,000	
2.5% of $ 6,000,000		150,000
Amortization Cost		
8% of RM 11,000,000	880,000	
8% of $ 6,000,000		480,000
Interest		
3% of RM 12,000,000	360,000	
3% of $ 6,500,000		195,000
Taxes and Administration	400,000	200,000
Total Costs per year	4,728,500	2,543,500

Production cost per ton of oil

$\frac{4,728,500}{130,500}$ RM 36.20

$\frac{2,543,500}{130,500}$ $ 19.50

The heating value of the surplus gas at least 300,000 Cal per ton of shale is available for production of power or for sale. It is not accounted for.

Operating Costs per ton of oil shale

$$\frac{4,728,500 - 2,040,000}{1,360,000} = \qquad \text{RM } 1.98$$

or

$$\frac{2,543,500 - 1,020,000}{1,360,000} = \qquad \$ \; 1.12\tfrac{1}{2}$$

Operating costs

per ton of oils

$$\frac{1}{0.096} \times 1.98 = \qquad \text{RM } 20.60$$

$$\frac{1}{0.096} \times 1.125 \qquad \$ \; 11.70$$

Cost of oil shale per ton of oils

$$\frac{2,040,000}{130,500} = \qquad \text{RM } 15.60 \qquad \$ \; 7.80$$

The above figures shall give but a rough estimate on the relative influence of the mining costs, the operating costs, and the loss of oil due to the necessity of the waste of fines or due to an inadequate efficiency of the process.

Figures corresponding to a 95% efficiency of oil recovery or to an increased oil content (14.3% instead of 12%) are as follows:

Operating costs per ton of oils

$$\frac{80}{95} \times 11.70 = \qquad \$ \; 9.86$$

Cost of oil shale per ton of oils

$$\frac{80}{95} \times 7.80 = \qquad \$ \; 6.57$$

Production costs per ton of oils $16.43 per ton

With an oil content of 14.3% and 95% recovery the production costs are further reduced to $16.43 \times \frac{80}{95} = \$ \; 13,84$

1. A waste of the "fines" which cannot be treated, influence the cost of the raw material only.

2. Higher costs of operation (capital and labor) is of a relatively higher influence on the total production costs.

3. A higher efficiency would reduce the cost of the raw material and the cost of operation.

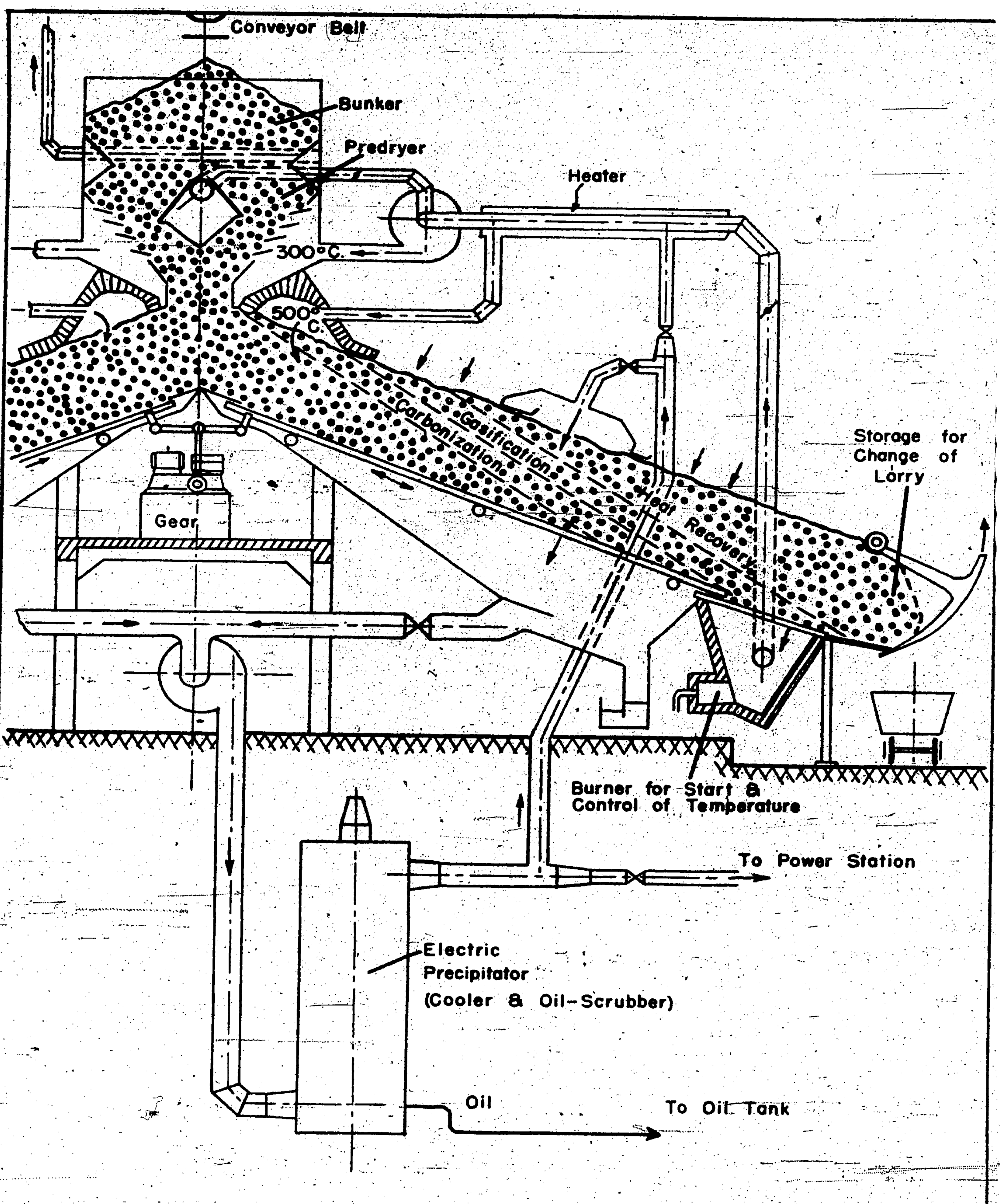
In case of treating higher grade shales with an oil-content of 20% which probably need underground mining, the cost of the shale might be increased to $ 3 per ton.

With 95% efficiency $\frac{1}{0.95 \times 0.2}$ = 5.3 tons of shale are required for the production of one ton of oil.

The production costs are as follows:

a. For shale 5.3 x 3.00 =	$ 15.90
For operating 5.3 x 1.125 =	$ 5.90
Total production cost per ton of oil	$ 21.80 per ton.

These figures show that in case of underground mining the production costs of oils are so much increased, that they become higher than those of a low grade shale which is mined by open cut mining and operated with a low efficiency of the oil extraction.



PLAN OF A HUBOVEN
For Gasification of Highash Fuels