### METHOD OF CONTROLLING PRESSURE.

Pressure in the cracking system is maintained by controlling the discharge of the gases formed by the decomposition of the hydrocarbons fed into the tube. In the operation of the process at the development plant a laborer is employed for each unit of five tubes in order to regulate the pressure. Regulation is accomplished by opening a valve and permitting the gases to escape into a gas main or header until the pressure in the individual tube has been sufficiently lowered to keep it at the point required. For a furnace of 10 tubes, two men are employed to control pressure conditions.

There is no reason why in new subsequent installations the services of these men can not be dispensed with by using automatic valves which can be set to release at the desired pressure. It was undesirable to do this in the course of the operations described in this bulletin for the reason that absolute control of operations could be better attained by hand regulation. It will be realized that in the first stages of the development of any process, labor costs are always high until after procedure has been so far simplified as to permit the substitution of mechanical control for manual labor. There seems to be no reason why a substantial reduction in operating expenses can not be effected by mechanical regulation of the pressure.

At the outset of the experiments it was considered desirable to obtain as large quantities of benzene as possible. Therefore, a uniform pressure of 250 pounds per square inch, which had been shown to give the best yields, was adopted. After a considerable period of time it became of more consequence to increase the percentage of toluene formed, for which a lower pressure is more favorable; consequently a number of experiments were conducted which established the fact that for the distillate oil a uniform pressure of 150 pounds per square inch is the most satisfactory from a commercial standpoint. A reasonable degree of conversion is obtained at this pressure which, coupled with the improvement along mechanical lines, makes 150 pounds the most favorable pressure when toluene is the chief product desired.

### CARBON FORMATION.

As was stated in the discussion of temperature, carbon difficulties increase when heat is not uniformly regulated. The experiments again indicated the already well-known fact that the percentage of carbon formed increases with temperature.

Although the temperatures (600° to 750° C.) favorable for formation of low-boiling aromatic hydrocarbons are sufficiently high to make unavoidable the formation of a considerable percentage of carbon, the amount of carbon formed is also dependent to a large



extent on the character of the original oil. The Oklahoma crude oil, which was used in the first runs formed on the average 1 to 1½ pounds of carbon per gallon of oil. The distillate which was substituted formed one-fourth to one-half pound per gallon. With both types of oil, when temperatures and rate of feed are in proper relationship, the carbon is soft and flaky in character and of fine texture, or else is in the form of a tar. The soft carbon resembles lampblack to some extent, and is a useful by-product. When the carbon is in this condition, the use of stirring rods will efficiently prevent incrustation of carbon on the walls of the tube.

It is only when the heat becomes excessive that a layer of coke accumulates on the inner wall of the tube. When dense, hard, coke forms, it is difficult to remove. As has been previously suggested, the use of heavier chains than those employed on the stirring rods in the experiments reported in this bulletin might noticeably increase efficiency in removing carbon.

The nature of the carbon formed when excessive heats are permitted is shown in Plate VI, *B*. It will be noted in the illustration that the carbon is built up on the stirring rod to the full diameter of the tube, completely choking it and preventing the passage of gases generated in the upper part of the chamber. Considerable difficulty was experienced with this type of coke, or carbon, in the early stages of the experimental work. Its formation was due to three causes: First, to the higher temperatures, which were used in order to obtain the maximum conversion possible in a single operation; second, to the inexperience of the heaters, which resulted in excessive heats; and third, to the greater carbon deposition incident to the use of Oklahoma crude oil as original material.

With the change in the character of the oil used, and a somewhat improved heating control, practically no dense coke has been formed on the walls of the tube, and the carbon has been removed either in the form of a tar, or else in the form of the soft flaky carbon previously mentioned. More recently (December, 1915) the carbon has been removed from the carbon pots in the form of a heavy oil, which has been mixed with the product from the condensers. This fact alone will indicate to what extent the carbon difficulties have been overcome.

The presence of carbon in the reaction chamber is a disadvantage from the mechanical side alone. From various references in the appended bibliography it can be discovered that carbon is one of the best catalysts for the formation of benzene and toluene. The mechanical difficulties from the deposition of coke arise not alone from the fact that it chokes the passage of the gases, but also hinders heat conductivity. The formation of coke on the inner wall of the