

Oct. 11, 1960

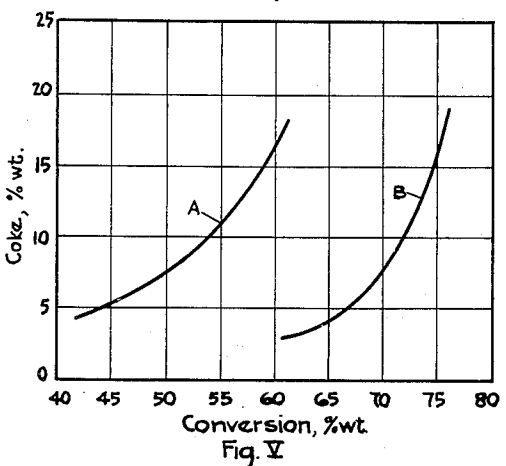
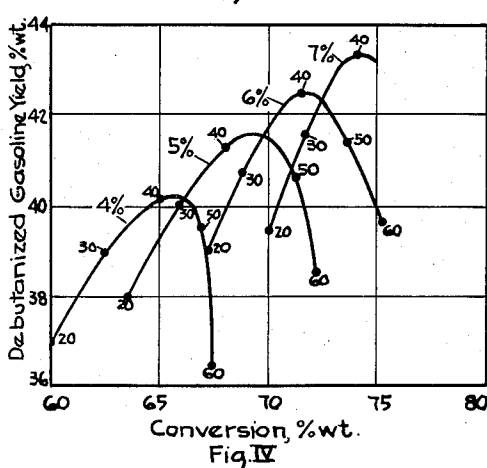
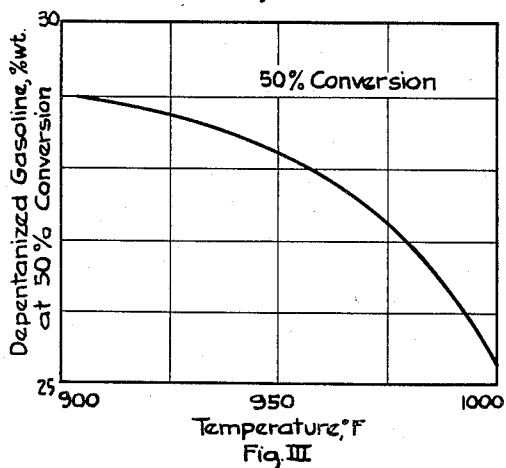
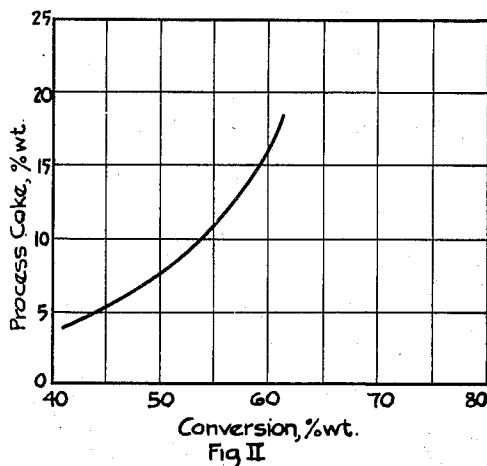
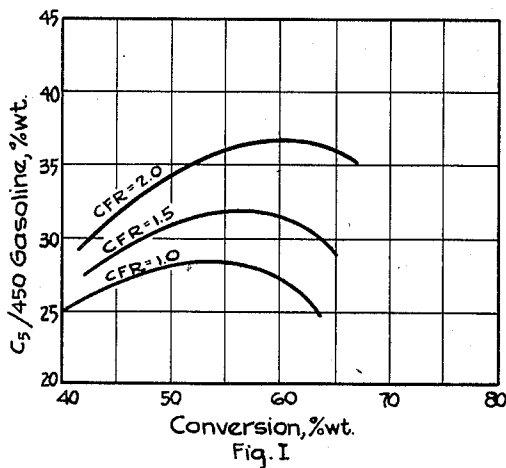
J. A. MARSHALL ET AL

2,956,003

TWO-STAGE CATALYTIC CRACKING PROCESS

Filed May 20, 1959

3 Sheets-Sheet 1



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Oct. 11, 1960

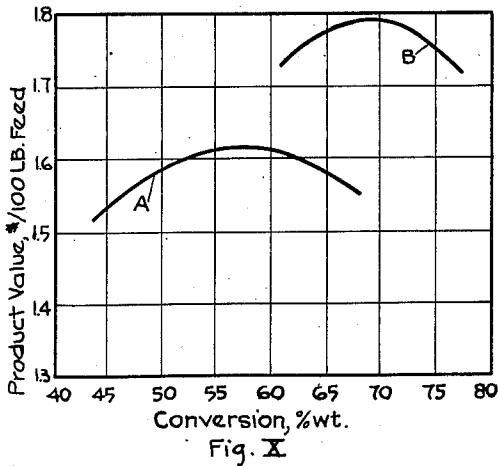
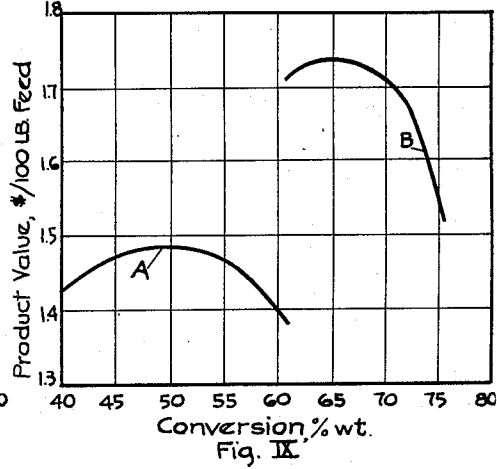
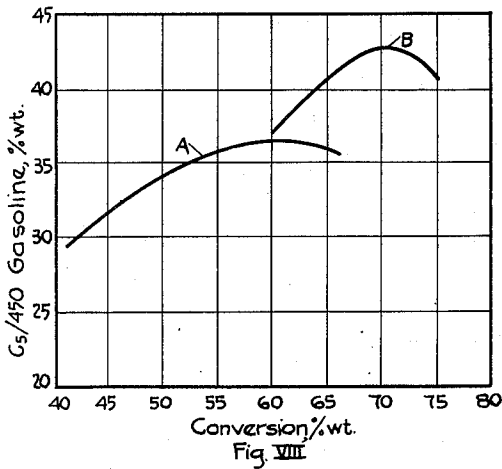
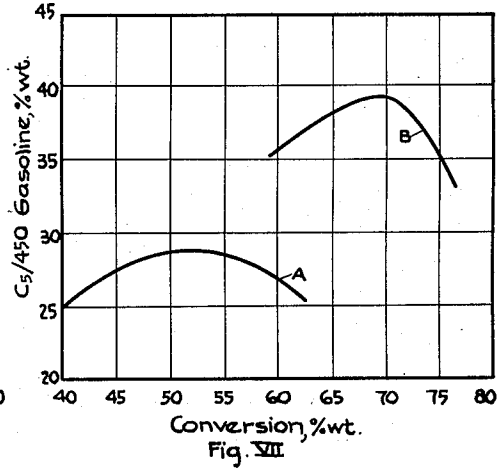
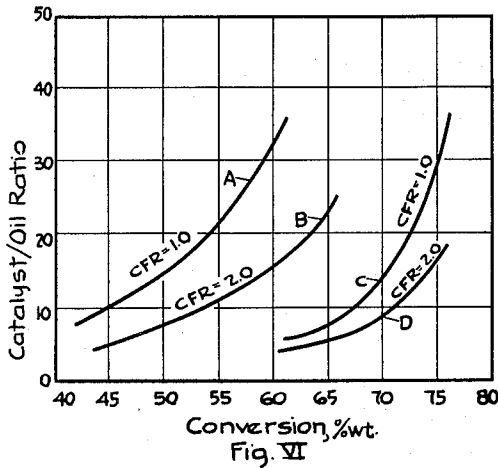
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TWO-STAGE CATALYTIC CRACKING PROCESS

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3 Sheets-Sheet 2



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TWO-STAGE CATALYTIC CRACKING PROCESS

Filed May 20, 1959

3 Sheets-Sheet 3

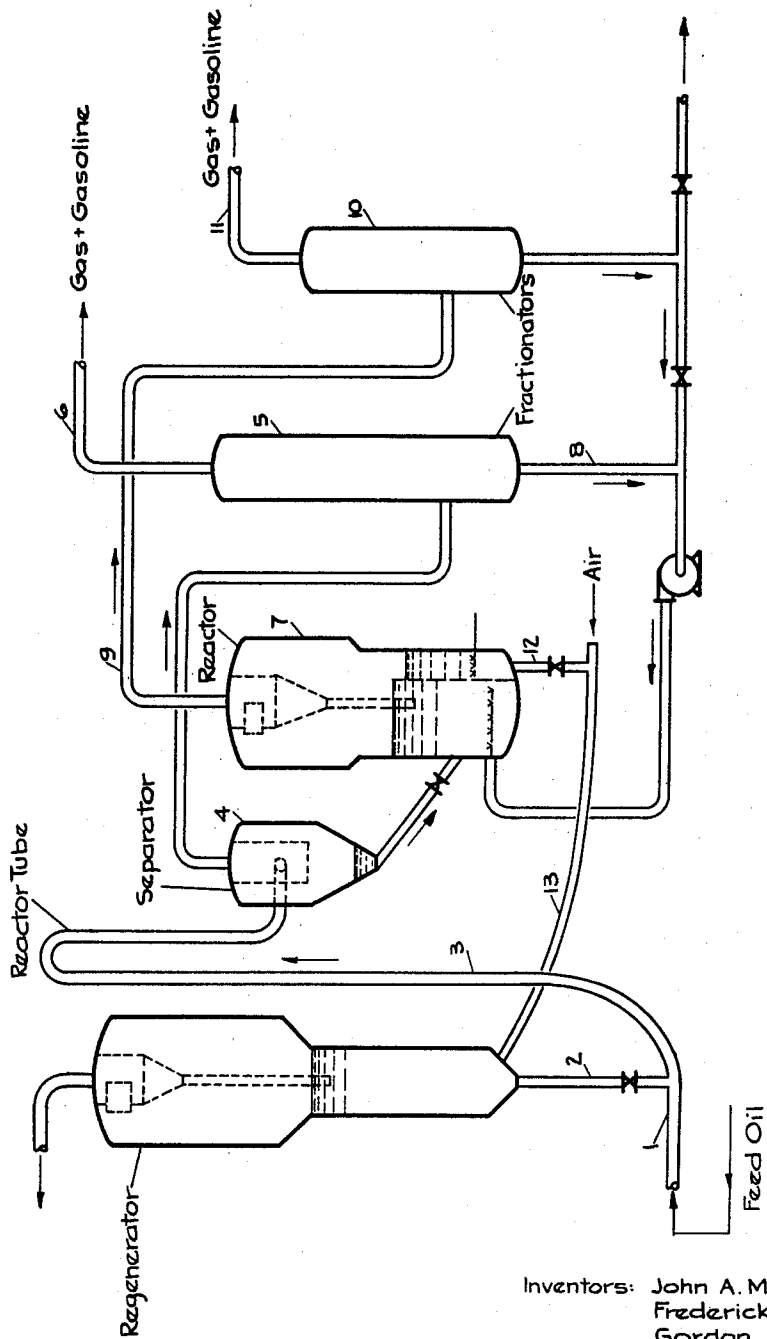


Fig. XI

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2,956,003

TWO-STAGE CATALYTIC CRACKING PROCESS

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Filed May 20, 1959, Ser. No. 814,643

5 Claims. (Cl. 208—74)

This invention relates to the production of gasoline from higher boiling oils by controlled cracking using finely divided catalyst. More particularly, the invention relates to a combination of particular arrangements and conditions in such a process whereby conversions considerably higher than those economically possible by the hitherto known processes may be obtained. Also, there are obtained considerably increased yields of gasoline and significantly decreased yields of coke.

Since the primary purpose of the process known as catalytic cracking is to produce gasoline from heavier hydrocarbon oils, it has been the aim to operate the process in a manner and under conditions calculated to maximize the gasoline production. A large body of experimental data, and practical experience, led to the establishment of a narrow range of conditions wherein this desired maximum economical gasoline yield is thought to be achieved and such conditions are invariably used in commercial practice.

The depth of conversion of the oil during the cracking operation depends upon the so-called severity factor which in any given system with a given catalyst is primarily a function of the temperature and space velocity and secondarily a function of the activity of the catalyst. The conversion is defined as 100 minus the percentage of recovered oil boiling above 450° F. Numerous investigations, and experience in practice, have shown that the practical temperature range in fluid catalytic cracking lies somewhat under 1000° F., e.g., 900–950° F. Using such temperatures, the space velocity is adjusted to give a conversion corresponding to the optimum gasoline yield. As the depth of conversion is increased from a low conversion the gasoline yield rises, passes through a rather flat maximum, and then begins to fall. The coke production on the other hand, rises slowly at first and then more steeply as the depth of conversion is increased. While the optimum point on the relatively flat gasoline yield curve varies somewhat with different feeds, it is found to lie close to 55% and a depth of cracking around this figure is commonly used in commercial practice.

If it is desired to crack more deeply than around 55%, it is the practice to do so by recycling the catalytic gas oil rather than by increasing the severity of the conditions. By using a combined feed ratio as high as 2.0, a total conversion based on the fresh feed of around 60% is usually possible. This operation is not uncommon although its profitability is marginal due to the fact that cycle oil backs out virgin feed.

Figures I and II

In order that the above mentioned facts may be clearly understood, they are reproduced in graphical form in Figures I and II of the accompanying drawing. In Figure I there are shown the conversion vs. gasoline yields for conventional fluid catalytic cracking of a typical flashed distillate feed (ex West Texas crude) and for combined feed ratios of 1.5 and 2.0. The curves for other combined feed ratios between 1.0 and 2.0 are not shown but

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have a similar shape and fall between the curves shown. The flat maxima are easily seen. It is seen that maximum gasoline may be obtained at a maximum conversion of 60% at a combined feed ratio of 2.0. This increased conversion to gasoline at a combined feed ratio of 2.0 is obtained at the expense of cutting the throughput capacity of the plant approximately in half.

Figure II shows the total process coke in percent by weight vs. the conversion for ordinary catalytic cracking (combined feed ratio=1.0) of the same feed and may be correlated with the data in Figure I.

While the described process is overall the most efficient of the known processes and is for that reason the process used in industry, it has for some time been recognized that the same gasoline production can be achieved using several variations of the processing technique. For instance, it is known that certain oils and certain fractions of a given oil are sometimes best treated under somewhat different processing conditions to achieve the mentioned optimum conversion. Various suggested methods have been proposed where different stocks or fractions thereof are separately cracked. This suggestion, which is practical in certain cases has been extended in numerous patents to the separate cracking of the cycle stock under relatively more drastic conditions. It has also been suggested to effect the catalytic cracking with various modified methods of handling the powdered catalyst and oil to be cracked. These suggested variations sometimes offer advantages in lower operating costs, the production of gasoline of slightly better octane number, and the like improvements, but no such process has been described which shifts the maximum gasoline yield and product value appreciably into the region of higher conversions.

In the past it has been possible to achieve higher conversions than the optimum described above but only at the disadvantage of a decrease in selectivity to gasoline production and considerably increased coke yields. This greatly decreases the efficiency of the operation and greatly increases the plant and operating costs. The process of the present invention provides a great improvement over the prior known and suggested methods since, by the particular method of handling in combination with the special processing conditions, the point of maximum gasoline yield is shifted to much higher conversion levels. This in itself would represent a major improvement. The gasoline yield is increased over the maximum hitherto though optimum and this allows a very much greater gasoline production. In addition to this, however, the present process affords two other advantages which are important. The first is that the recycle may be employed with less loss in throughput capacity. Furthermore, due to the increased selectivity and, contrary to all previously recognized practice, operation at the greater depths of conversion in the present process actually produces less coke than conventional operation at lower conversion and lower gasoline yields.

In the present process, extensive work has shown that a combination of the following conditions is essential:

(1) The oil to be cracked must be subjected to at least two separate vapor phase catalytic cracking operations which will hereinafter be referred to as first and second stage cracking.

(2) The oil must be cracked at a high temperature of at least about 1000° F. in the first stage.

(3) The oil must be cracked at a lower temperature, preferably about 100° F. lower in the second stage.

(4) The oil must be cracked in the first stage with freshly regenerated catalyst and not partially spent catalyst from some previous operation.

(5) The residence time of the catalyst in the first stage cracking operation must be very short, not more than about 12 seconds, and in this stage a so-called dense

catalyst phase (pseudo liquid phase) must be avoided. These conditions require that the first stage cracking be carried out in a tubular reactor of essentially uniform diameter at fairly high linear velocities above the critical velocity. The critical velocity is the superficial gas velocity above which the solid will not tend to separate into a pseudo liquid phase. It depends upon the nature of the catalyst and the properties of the gas phase. It is to be pointed out that the well known "upflow type" reactor does not meet these specifications.

(6) The residence time of the catalyst in the second stage cracking zone must be considerably longer than in the first stage, and is in general at least two minutes, e.g., six minutes.

(7) The conditions of temperature and space velocity must be adjusted such that the major conversion (at least 40% conversion) takes place in the first cracking stage.

(8) The conditions of temperature and space velocity must be adjusted such that the conversion in the second stage cracking step is less than that in the first stage. It ranges according to circumstances between about 10% and about 40% depending on the feed.

(9) The gasoline produced in the first stage cracking operation must be separated before the oil heavier than gasoline passes to the second stage cracking operation.

Aside from these conditions, which are necessary, and some of which are not individually novel, the process is not critically dependent upon the manner of operation. Thus, the process may be advantageously used to crack the usual run of cracking stocks. It may be applied for the cracking of reduced crude petroleum but is preferably used for the cracking of cleaner stocks such as distillate or deasphaltized stocks. The process is particularly suited for the treating of gas oils of wide boiling range such, for instance, as distillates obtained by two-stage flashing of reduced crude, or made up of flashed distillate and deasphaltized flasher residue. It is to be understood however that the process is also advantageous for the cracking of narrow range stocks such as light straight-run gas oil, heavy straight-run gas oil, coker distillate and the like, previously used as catalytic cracking feed stocks.

Any of the solid cracking catalysts suitable for the so-called fluidized catalyst catalytic cracking process may be used. Although there are numerous other applicable catalysts, those coming primarily into consideration today are the so-called natural or clay catalysts such as the various grades of Filtrol catalyst, synthetic silica-alumina composite cracking catalysts, and synthetic silica-magnesia composite cracking catalysts. The catalyst may be in the form of powder, e.g., passing for the most part a 100-mesh U.S. standard sieve, or in the form of small spheroidal particles such as produced by spray drying techniques. The only prerequisite as to size and form is that the catalyst be suitable for handling by the so-called fluidized catalyst technique.

As previously pointed out, the conditions required in the first stage cracking step impose severe limitations as to the type of equipment and method of handling in that step. The second step, on the other hand, is relatively free of such limitations and various conventional types of reactors may be employed. The only essential limitation is that the second stage reactor must be capable of allowing the depth of conversion to be controlled in the conversion range and at the temperature levels indicated.

The remaining parts of the process, e.g., the catalyst regeneration, catalyst stripping, method of producing the static heads required for catalyst circulation, and the like, may follow the conventional practices.

Figure III

As pointed out above, it is important in the present process that the temperature be higher in the first or dispersed phase cracking step than in the second or dense phase cracking step. It is well known that in ordinary

catalytic cracking the yield of gasoline at any given conversion decreases with increasing temperature. This is illustrated in the graph shown in Figure III, wherein the gasoline yields obtainable from a typical flashed distillate feed stock by conventional dense phase catalytic cracking at different cracking temperatures are shown at constant conversion near the optimum. It will be seen that the yields decline as the temperature is increased. It is for this reason that temperatures in the range of 850° F. to 950° F. and usually about 900° F. are chosen for commercial operation.

It is found unexpectedly that the above correlation does not hold when the cracking is effected with the catalyst entirely in the dispersed phase, i.e., no pseudo liquid phase is present. In this case, it is found that the gasoline yield at constant conversion is independent of the cracking temperature.

The two facts described and illustrated above would indicate that the cracking steps could be equally well carried out at a low temperature, e.g., 900° F. However, such operation does not afford the advantageous results of the present process. As pointed out above, it is essential in the present process that the temperature in the first cracking step be above that in the second cracking step. Thus, the temperature in the first cracking step is preferably at least 1000° F., whereas the temperature in the second cracking step is preferably considerably lower, e.g., about 900° F. Part of the heat required to attain the reaction temperatures may be imparted by preheating the feed. The remaining heat is supplied by the catalyst heated during regeneration thereof. The reason for the necessity of the low temperature in the second cracking step will be apparent from the above. The high temperature in the first cracking step is necessary to obtain the necessary conversions with the short contact time dispersed phase conditions in this first cracking step, for, as pointed out above, an essential feature of the process is that the major conversion (at least 40% conversion) be effected in the dispersed phase cracking step. The importance of this condition will be evident from the data present in the following figures of the drawing.

Figure IV

The graph given in Figure IV of the drawing shows the effects of varying the conversion in the first or dispersed phase cracking step at different levels of constant coke make. The data refer to the catalytic cracking of a typical West Texas flashed distillate feed according to the method of the invention where the temperature in the first cracking step was 1000° F. and that in the second cracking step was 900° F. The total conversions, i.e., the combined conversions of the dispersed phase and dense phase cracking steps, based on the fresh feed, are plotted on the abscissa and the C₅+ gasoline yields are plotted on the ordinate in weight percent of the feed. As indicated by suitable labels, the individual curves of the family shown are for constant total coke makes of 4, 5, 6, and 7%, respectively. The small numbers opposite the points represent the conversions in the dispersed phase cracking step. Referring to Figure IV, it is seen that, with this particular feed and these particular temperatures, the maximum gasoline yields are obtained at about 65, 68, 72, and 74% conversions for total coke makes of 4, 5, 6 and 7%, respectively, and that, in each case, the optimum gasoline yield is dependent upon the degree of conversion obtained in the dispersed phase cracking step. In all cases the yield drops off considerably if the conversion in the first cracking step is below or above a critical figure, which in this case is slightly above 40%. With other feeds and variations in the cracking temperatures in the respective steps, the optimum first stage cracking conversion is equally sharp, although it may be higher. Thus, in other typical cases, the gasoline yields all peak at about 45% and 55% conversion in the dispersed phase step. In all cases, the first

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stage conversion is appreciably greater than the second stage conversion at optimum gasoline yields, being at least 40%, whereas the total conversions in the region of practical coke makes it between about 65 to 75%. These maximum gasoline yields, it will be noted, are much higher and obtained at much higher total conversions than obtainable with conventional catalytic cracking and are even higher than obtainable with dense phase catalytic cracking, using a recycle operation with a combined feed ratio as high as 2.0.

In order to obtain the indicated high conversion in the dispersed phase cracking step where the contact time is short and the catalyst density is low, it is necessary that the catalyst used in this step be freshly regenerated catalyst and not a catalyst partially carbonized in a previous cracking step.

Figure V

As pointed out above, the present process not only allows maximum and much higher gasoline yields to be obtained at much higher conversion levels, but it also affords a considerable reduction in coke make despite the higher conversions. This may be seen from the data presented in the graph shown in Figure V wherein the total coke makes vs. total conversions are plotted for conventional catalytic cracking of West Texas flashed distillate (curve A), and for the process of the invention in the case where the dispersed phase cracking step is carried to a conversion of 45% (curve B). There was no recycle in either case. Referring to Figure I, it will be seen that the maximum gasoline yield for conventional catalytic cracking of this stock is at about 53% conversion. Referring to Figure V, it is seen that the total coke make at this conversion with conventional catalytic cracking is about 9%. It is also seen that at all conversions up to 71.5%, the coke make by the present process is lower than at the maximum gasoline yield in conventional catalytic cracking. Thus, according to the present process, without recycle, a conversion of 69% may be obtained with less coke than obtained in conventional catalytic cracking of the same feed stock under optimum conditions at a conversion of only 50%. This feature in itself is a most substantial and unexpected advance in the art of catalytic cracking and would warrant application of the process, even in the absence of the other larger advantages pointed out.

Part of the reason for the considerably lower coke make at any given total conversion obtained by the present process lies in the fact that, as a consequence of the particular conditions and sequence used, the catalyst-to-oil ratios required are lower than required in the processes used heretofore. This will be understood from the data shown in Figure VI now to be described.

Figure VI

It has been found that the so-called coke make in catalytic cracking is dependent, not solely, but to a considerable degree, upon the so-called catalyst-to-oil ratio which is the ratio of the weights of catalysts and oil charged to the reactor. The coke make increases as this ratio increases. This is probably due largely to the effect of impurities which invariably contaminate the catalyst during use. Considerable evidence has been found that these contaminants catalyze the formation of coke at a slower rate than that at which the cracking takes place. In the present process, where the residence time of the catalyst in the first reaction zone is maintained very short, these contaminants are not given enough time to exert their full effect and, since the major conversion is effected in this first zone a good part of the job is completed before much coke is produced. Furthermore, as the amount of coke produced is decreased, the amount of catalyst that must be circulated to maintain the plant in heat balance is decreased. In the particular method of operation, according to the invention, these two factors pyramid or multiply so that, as a re-

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sult, much lower coke makes are obtained at lower catalyst-to-oil ratios per degree of conversion. This is illustrated in Figure VI wherein there are plotted again for the same West Texas feed stock the catalyst-to-oil ratios required for heat balance vs. the total conversion for conventional catalytic cracking, both with and without recycle (curves A and B), and for the operation of the invention with and without the same recycle ratio in the second cracking stage only (curves C and D). Referring to Figure VI, it will be seen that for conventional catalytic cracking of this typical feed to an optimum conversion of 50%, a catalyst-to-oil ratio of about 15 to 1 is required, whereas in the operation according to the invention a catalyst-to-oil ratio of 15 to 1 affords a conversion of about 70.5%.

Figures VII and VIII

Having shown the effects of various individual factors through comparative experimental data, the overall effects of the factors forming a part of the process will now be shown. Figure VII of the accompanying drawing shows graphically the gasoline yield in weight percent vs. the conversion in weight percent in cracking the same West Texas flashed distillate in a conventional dense phase system (curve A) and, according to the method of the invention for the particular case in which the conversion in the dispersed phase step was maintained at 45% by weight (curve B), both operations without recycle. The improvement is apparent and very great. Thus, whereas in conventional dense phase cracking under optimum conditions the conversion is about 53.5% by weight with a yield of C_5-450° F. gasoline of about 28.5% by weight, the optimum conversion by the process of the invention is about 69% by weight with a yield of C_5-450° F. gasoline of about 39.5% by weight. The above comparison shown in Figure VII is for the case where no recycle is employed.

As pointed out above the gasoline yield can be increased (at the cost of decreased plant capacity) by recycling at least part of the catalytically cracked gas oil. In the conventional operation at a combined feed ratio of 2.0, the plant throughput is approximately halved. The comparison in the recycle case is shown in the graph given in Figure VIII. To take the extreme case, the comparison is made at a combined feed ratio of 2.0. In the case of the present process the dispersed phase cracking step is again maintained at a conversion of 45% by weight. Referring to Figure VIII, it is seen that in the case of dense phase catalytic cracking (curve A), a maximum gasoline yield of about 36.7% by weight is obtained at a conversion of about 60%. In the process of the invention (curve B) a maximum gasoline yield of about 43.5% is obtained at a conversion of about 71.5%. It is to be pointed out that the advantage of the process of the invention is much greater than would appear at first glance from these figures since in the case of conventional fluidized cracking with recycle a combined feed ratio of 2.0 cuts the plant capacity approximately in half, whereas in the process of the invention where the recycle is only in the second cracking step, the plant capacity is reduced by such recycling only by about half this amount.

Figures IX and X

In the above, the comparisons have all been made on the basis of gasoline yields whereas in practice a certain minor amount of valuable by-products, chiefly gaseous olefins, is obtained. It is therefore proper, if not preferable, to base the comparison on the total value of the products obtained rather than on the gasoline alone, although this is by far the most important item. Such a comparison is given, based upon comparative pilot plant data, in the graphs shown in Figures IX and X. Figure IX shows the product values obtained under optimum and near optimum conditions for conventional dense

phase cracking (curve A) and for the process of the invention (curve B)—again at 45% dispersed phase conversion. In this case, since product values are considered, the depths of conversion are important only in showing the effects of the total conversion in a given case upon the product values obtained. Referring to Figure IX, it is seen that for the case without recycle the optimum dollar value of the products obtained from 100 pounds of feed in the conventional dense phase cracking is about 1.49, whereas in the process of the invention the optimum value is about 1.75.

The corresponding case for recycle operation to a combined feed ratio of 2.0 is shown in Figure X in which the optimum product values are about 1.61 and 1.80, respectively. These figures translated into plant operations, e.g., a plant of 35,000 barrels per day input, mean an increased product value of about \$25,000 per day for the non-recycle case. In the recycle case the increased product value is about \$19,000 per day at equal throughput rates, but, as pointed out above, recycle operation cuts down the throughput in the conventional operation approximately twice as much as in the process of the invention and, therefore, the increase in product values actually obtainable is somewhat greater than in the non-recycle case.

All of the experimental data shown in the above were obtained using a commercial equilibrium silica-alumina cracking catalyst.

Figure XI

The process of the invention will be described more particularly with respect to a specific and preferred operation. In this description, reference will be had to the accompanying drawing, Figure XI, which diagrammatically illustrates the more important vessels and flow lines of a catalytic cracking plant suitable for operation in accordance with the invention. Referring to the Figure XI, the feed stock entering by line 1 and at a temperature of about 810° F. is mixed with hot regenerated catalyst from the regenerator standpipe 2 and the mixture is passed up through the tubular reactor 2 which is the first stage reactor. The feed in this specific case is a mixture of flashed distillate produced by vacuum flashing a West Texas straight-run residue, and heavy deasphaltized oil produced by propane deasphalting the residue from the said flashing operation. The catalyst is a so-called equilibrium synthetic silica-alumina composite cracking catalyst in the form of a power passing a 100 mesh standard sieve and having an available surface of about 100 square meters per gram. The reactor tube 3 is approximately 2.5 feet in diameter and 109 feet long. The linear velocity of the vapors in the reaction tube is about 42 feet/second under which conditions the catalyst is carried concurrently as a dispersed suspension in the oil vapor with little slippage and a residence time about 4 seconds. The hot regenerated catalyst introduced from the regenerator standpipe 2 has a temperature of about 1110° F. The temperature of the mixture in the reaction tube is about 1015° F. near the inlet and about 1005° F. near the outlet. The space velocity is adjusted to give a conversion of 52%.

Since it is important that the residence time of the catalyst with the oil in the first stage cracking step be kept very short, it is essential that efficient means be provided for rapidly separating the catalyst from the oil in the mixture issuing from the first stage reactor. This rapid separation is effected in a cyclone type separator 4. Any efficient separator may be used.

As pointed out, it is essential that the gasoline produced in the first stage cracking step be separated before contacting the oil in the second cracking stage. Thus, the total product vapors from the cyclone separator 4 are passed to a fractionator 5 wherein they are quenched and fractionated to separate the gasoline as an overhead vapor fraction from the remaining oil which is recovered as a

lower liquid fraction. The gasoline+gas fraction is withdrawn by line 6.

The catalyst collected in the cyclone separator 4 has been in contact with oil for only a very short time. This catalyst is passed from the cyclone separator to the second stage reactor 7. The second stage reactor illustrated is a so-called downflow fluidized catalyst reactor of substantially conventional design. The reaction takes place in a dense or pseudo liquid bed of the catalyst therein and no substantial amount of the catalyst is carried out of the top of the reactor with the effluent vapors. The residence time of the catalyst in the reactor 7 is about 5 minutes and the temperature is about 910° F. The oil from the fractionator 5 is withdrawn by line 8 and pumped into the second stage reactor. The space velocity (adjusted by adjusting the bed level in the reactor) is adjusted such that the conversion is limited to 21%. This, when added to the 52% conversion in the first stage cracking zone, gives a total conversion of 73%.

The vapors from the second stage cracking reactor are also passed to a fractionator to separate the gasoline from unconverted oil. Thus in a preferred embodiment these vapors are passed by line 9 to fractionator 10 wherein gas and gasoline are separated as an overhead product and withdrawn by line 11. The bottoms from fractionator 10 are in part passed along with the bottoms from fractionator 5 to reactor 7 and the remainder is withdrawn from the system. In an alternative embodiment fractionator 5 is eliminated and the vapors from both reactors 3 and 7 are passed directly to fractionator 10. The coke production is 4.8% based on the feed.

Catalyst is withdrawn from the second stage reactor by line 12 and passed to the regenerator with air by line 13.

It is emphasized that, while the cracking is effected in two or more stages in the present process, and this is essential, the main importance is in the particular conditions and sequence of conditions giving the controlled cracking in the stages. The results noted are not obtained merely by effecting the cracking in a number of stages.

In the above, the process of the invention has been described in the form of the two-step process extensively studied and developed to a commercial process. It is to be pointed out that the same, or even somewhat greater advantages, may be obtained but at a considerably increased cost of the plant by employing three steps instead of two, provided that the added step has the effect of splitting the described first step into two parts with fractionation of the product after each step. In this case, the conversion in each of the two dispersed phase cracking steps may be less than 40% but their sum is at least 40%, and preferably at least 50%. Both dispersed phase operations are effected at a high temperature.

Various attempts to increase the yield of gasoline in catalytic cracking have generally resulted in producing gasoline of inferior anti-knock properties. The gasoline produced by the present process has an unblended octane number at least equal to that produced at similar conversions in conventional cracking. However, the blending octane number of the gasoline produced by the present process is in all cases higher when the gasoline is evaluated in the presence of appreciable concentration of saturates which more nearly corresponds to its condition in finished blended gasoline.

Also the gasoline produced by the present process has a higher average molecular weight and therefore a lower vapor pressure than gasoline produced from the same feed by conventional cracking. If the yield comparisons are made on the usual basis of 10 pound RVP the yield advantages are therefore even more pronounced.

This application is a continuation-in-part of copending application Serial Number 436,004, filed June 11, 1954, now abandoned.

We claim as our invention:

1. Process for the production of gasoline and related products by the catalytic cracking of hydrocarbon oils

boiling essentially above gasoline which comprises passing the oil to be cracked through a first reaction zone in the vapor phase, passing simultaneously through said first reaction zone in contact with said oil a freshly regenerated finely divided solid cracking catalyst, said passage of catalyst through said reaction zone being at such a rate that the residence time of the catalyst in said zone is not above 12 seconds, the horizontal cross-section of said first reaction zone being such that the linear velocity is above that at which the solid catalyst will separate into a pseudo liquid phase, the temperature in said reaction zone being at least about 1000° F., said oil being passed at a space velocity adjusted to provide a conversion of at least 40% removing hydrocarbon oil vapors substantially free of catalyst from said reaction zone and cooling and distilling them to separate an intermediate oil boiling essentially above gasoline therefrom, passing catalyst from said first reaction zone after a residence time therein of less than 12 seconds to a second reaction zone of such size that the residence time therein is considerably longer than in said first reaction zone, maintaining said second reaction zone at a temperature below the said first reaction zone and between about 850° F. and 975° F., passing the above said intermediate oil through said second reaction zone in contact with the partially used catalyst therein at a space velocity adjusted such that the conversion therein is between about 10% and about 40%, removing hydrocarbon oil vapors from said second reaction zone and cooling and separately distilling the same to separate the gasoline produced.

2. Process for the production of gasoline and related products by the catalytic cracking of hydrocarbon oils boiling essentially above gasoline which comprises passing the oil to be cracked through a first reaction zone in the vapor phase, passing simultaneously through said first reaction zone in contact with said oil a freshly regenerated finely divided solid cracking catalyst, said passage of catalyst through said reaction zone being at such a rate that the residence time of the catalyst in said zone is not above about 12 seconds, the horizontal cross-section of said first reaction zone being such that the linear velocity is above that at which the solid catalyst will separate into a pseudo liquid phase, the temperature in said reaction zone being at least about 1000° F., said oil being passed at a space velocity adjusted to provide a conversion of at least 40%, removing hydrocarbon oil vapors substantially free of catalyst from said reaction zone and cooling and distilling them to separate an intermediate oil boiling essentially above gasoline therefrom, passing catalyst from said first reaction zone after a residence time therein of less than 12 seconds to a second reaction zone of such size that the residence time therein is considerably longer than in said first reaction zone, maintaining said second reaction zone at a temperature below the said first reaction zone and between about 850° F. and 975° F., passing the above said intermediate oil through said second reaction zone in contact with the partially used catalyst therein at a space velocity adjusted such that the conversion therein is between about 10% and about 40%, removing hydrocarbon oil vapors from said second reaction zone and cooling and separately distilling the same to separate the gasoline produced from a cycle oil boiling essentially above gasoline, cycling a part of said oil with said intermediate oil to said second reaction zone.

3. The process of catalytically cracking higher hydrocarbon oils in the vapor phase with a continuously regenerated and recycled finely divided catalyst comprising a combination of steps having the following ten features: (1) the oil to be cracked is subjected to at least two separate vapor phase catalytic cracking operations referred to hereinafter as first and second stage cracking; (2) the oil is cracked at a high temperature of at least 1000° F. in the first stage; (3) the oil is cracked at a lower temperature between 850° F. and 975° F. in the

second stage; (4) the oil is cracked in the first stage with hot freshly regenerated catalyst; (5) the residence time of the catalyst in the first stage cracking zone is very short and not more than 12 seconds, and the catalyst is maintained entirely in the dispersed phase as contrasted to a so-called dense or pseudo liquid catalyst phase; (6) the residence time of the catalyst in the second stage cracking zone is considerably longer than in the first stage cracking zone; (7) the conditions of temperature and space velocity in the first stage cracking zone are adjusted such that the major conversion, and at least 40% conversion, takes place in the first cracking stage; (8) the conditions of temperature and space velocity are adjusted such that the conversion in the second cracking stage is less than that in the first cracking stage and lies between about 10% and about 40%; (9) the gasoline produced in the first stage cracking operation is separated before the oil is passed to the second stage cracking operation; (10) the products from the two stages of cracking are separately fractionated to recover the gasoline therefrom.

4. Process for the production of gasoline and related products by the catalytic cracking of hydrocarbon oils boiling essentially above gasoline which comprises passing the oil to be cracked through a first reaction zone in the vapor phase, passing simultaneously through said first reaction zone in contact with said oil a freshly regenerated finely divided solid cracking catalyst, said passage of catalyst through said reaction zone being at such a rate that the residence time of the catalyst in said zone is not above about 12 seconds, the horizontal cross-section of said first reaction zone being such that the linear velocity is above that at which the solid catalyst will separate into a pseudo liquid phase, the temperature in said reaction zone being at least about 1000° F., said oil being passed at a space velocity adjusted to provide a conversion of at least 40%, removing hydrocarbon oil vapors substantially free of catalyst from said reaction zone and cooling and distilling them to separate an intermediate oil boiling essentially above gasoline therefrom, passing catalyst from said first reaction zone after a residence time therein of less than 12 seconds to a second reaction zone of such size that the residence time therein is considerably longer than in said first reaction zone, maintaining said second reaction zone at a temperature below the first reaction zone and between about 850° F. and 975° F., passing the above said intermediate oil through said second reaction zone in contact with the partially used catalyst therein at a space velocity adjusted such that the conversion therein is between about 10% and about 40%, removing hydrocarbon oil vapors from said second reaction zone and cooling and distilling the same to separate the gasoline produced from a cycle oil, cycling a part of said cycle oil with said intermediate oil to said second reaction zone.

5. Process for the production of gasoline and related products by the catalytic cracking of hydrocarbon oils boiling essentially above gasoline which comprises passing the oil to be cracked through a first reaction zone in the vapor phase, passing simultaneously through said first reaction zone in contact with said oil a freshly regenerated finely divided solid cracking catalyst, said passage of catalyst through said reaction zone being at such a rate that the residence time of the catalyst in said zone is not above about 12 seconds, the horizontal cross-section of said first reaction zone being such that the linear velocity is above that at which the solid catalyst will separate into a pseudo liquid phase, the temperature in said reaction zone being at least about 1000° F., said oil being passed at a space velocity adjusted to provide a conversion of at least 40%, removing hydrocarbon oil vapors substantially free of catalyst from said reaction zone and cooling and distilling them to separate an intermediate oil boiling essentially above gasoline there-

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from, passing catalyst from said first reaction zone after a residence time therein of less than 12 seconds to a second reaction zone of such size that the residence time therein is considerably longer than in said first reaction zone, maintaining said second reaction zone at a temperature below the first reaction zone and between about 850° F. and 975° F., passing the above said intermediate oil through said second reaction zone in contact with the partially used catalyst therein at a space velocity adjusted such that the conversion therein is between about 5 10

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10% and about 40%, removing hydrocarbon oil vapors from said second reaction zone and cooling and distilling the same to separate the gasoline produced.

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