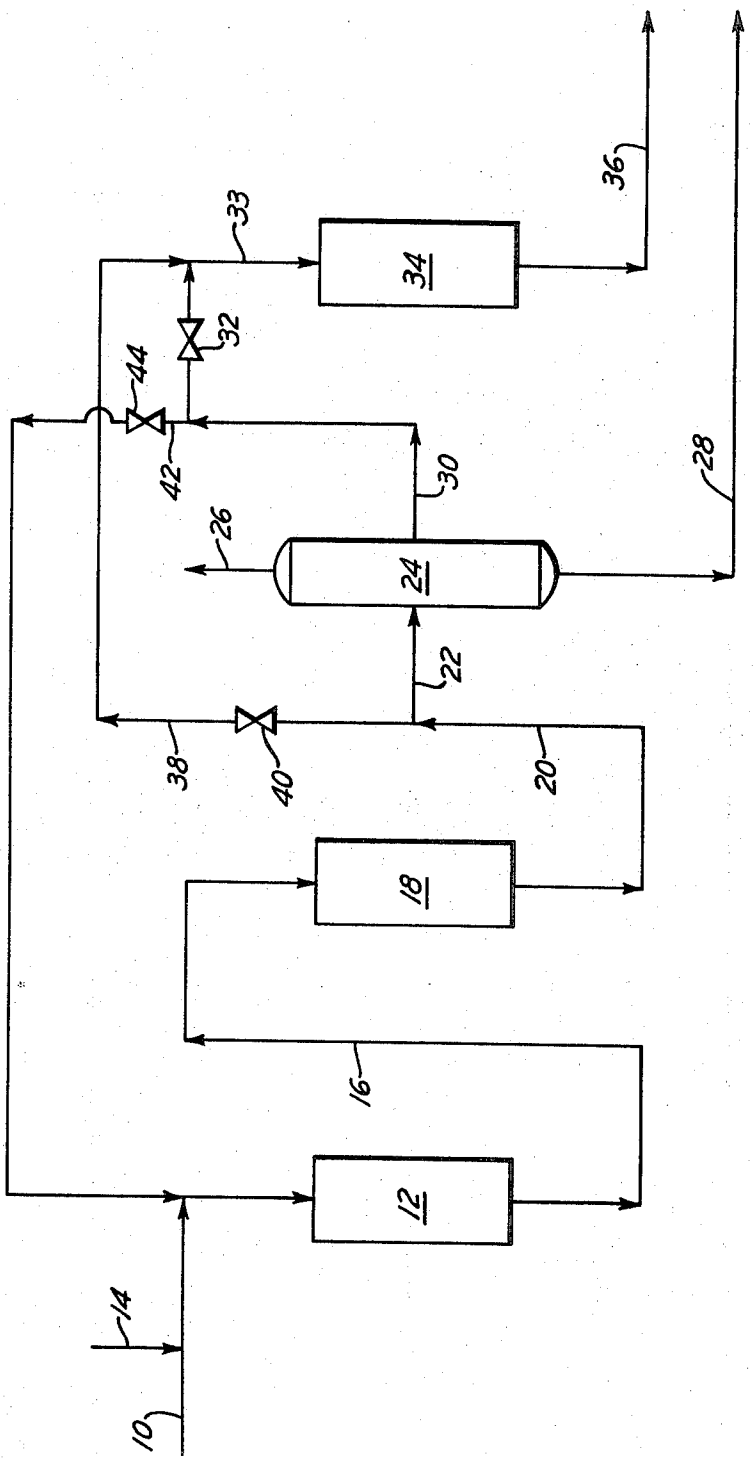
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LUBE OIL HYDROTREATING PROCESS

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ABSTRACT OF THE DISCLOSURE

A process for producing lubricating oils with an improved yield and viscosity-viscosity index distribution from a wide boiling range crude lubricating oil by subjecting the crude lubricating oil to a hydrotreatment in a series of reaction zones. A portion of the effluent from the earlier zones in the series is removed for the recovery of heavier lubricating oil stock therefrom while the balance of the effluent is passed to the remaining reaction zones in the series for the production of lighter lubricating oil stocks.

Our invention relates to the production of lubricating oils from a wide boiling range crude lubricating oil stock by hydrotreating. More particularly, our invention relates to the production of lubricating oils by subjecting such crude lubricating oil to hydrotreating in a series of reaction zones wherein a portion of the effluent from an intermediate reaction zone is withdrawn for the recovery of heavier lubricating oil product, while the balance of the effluent is passed for further treatment in subsequent reaction zones for the production of lighter lubricating oil product.

It has previously been suggested in the art to subject hydrocarbon fractions boiling in the lubricating oil range to various treatments with hydrogen in order to provide lubricating oil base stocks meeting desired specifications, such as, for example, viscosity, viscosity index (VI), pour point and acceptable contaminant levels. These hydrogen treatment techniques are designated by a variety of terms whose definitions tend to overlap depending upon the individual employing such terms. Regardless of the inadequacy of nomenclature in this area, these hydrogen treatment processes can be categorized into four different groups. We chose to term these categories as hydrocracking, hydrotreating, hydrogenation and hydrofinishing.

As employed herein the term "hydrocracking" is meant to describe an extremely severe hydrogen treatment, usually conducted at comparatively high temperatures and requiring the employment of a catalyst having substantial cracking activity, e.g., an activity index (AI) greater than 40 and generally greater than 60. This type of process is conducted to effect extensive and somewhat random severing of carbon to carbon bonds resulting in a substantial overall reduction in molecular weight and boiling point of treated material. Thus, for example, hydrocracking processes are generally employed to effect an extremely high conversion, e.g., 90% by volume, to materials boiling below the boiling range of the feed stock or below a designated boiling point. Usually a hydrocracking process is employed to produce a product boiling predominantly, if not completely, below about 600° to 650° F. Most frequently this type of process is employed to convert higher boiling hydrocarbons into products boiling in the furnace oil and naphtha range. When applied in connection with lubricating oils, hydrocracking processes produce only a minor quantity of materials boiling in the lubricating oil range, i.e., 625° to 650° F.+, to the extent that, at times, the production of a lubricating oil is merely incidental to the production of naphtha and furnace oil. Hydrocracking is the most severe of the four types of processes mentioned above.

On the other end of the spectrum, "hydrofinishing" is an extremely mild hydrogen treatment process employing a catalyst having substantially no cracking activity. This process effects removal of contaminants such as color forming bodies and a reduction of minor quantities of sulfur, oxygen and nitrogen compounds, but effects substantially no saturation of unsaturated compounds such as aromatics. This process, of course, effects no cracking. As a general rule, hydrofinishing is employed in lieu of the older techniques of acid and clay contacting.

A third type of hydrogen treatment process is "hydrogenation" which, as employed herein, describes another comparatively mild process. Hydrogenation, although being comparatively mild, is more severe than hydrofinishing and generally effects saturation of unsaturated materials such as aromatics. A hydrogenation process is also capable of removing somewhat larger quantities of contaminants such as sulfur. A hydrogenation process is conducted with a catalyst having substantially no cracking activity and accordingly does not produce any significant reduction in boiling point of the material treated over and above that which might be effected from contaminant removal alone. Accordingly, therefore, a hydrogenation process is employed, albeit infrequently, in the area of lubricating oil production in order to effect saturation of aromatics and removal of contaminants from a charge stock already boiling within the lubricating oil range without the production of any lower boiling materials.

As distinguished from hydrocracking, hydrofinishing and hydrogenation, the term "hydrotreating" is employed heerin to describe a processing technique significantly more severe than hydrogenation although substantially less severe than hydrocracking. The catalyst required in a hydrotreating process must possess cracking activity and generally possess a particular type of activity termed "ring scission activity." Thus, a hydrotreating process effects a substantial molecular rearrangement as compared to hydrogenation or hydrofinishing but does not effect the extensive and somewhat random breakdown of molecules effected in hydrocracking. Accordingly, this type process effects substantially complete saturation of aromatics and the reactions are believed to follow the course of converting condensed aromatics to condensed naphthenes followed by selective cracking of the condensed naphthenes to form single ring alkyl-naphthenes. Thus, polynuclear cyclic compounds are attacked and the rings are opened, while mononuclear cyclic compounds are not substantially affected. The alkyl side chains formed by opening the rings are not further reacted to sever the alkyl side chains. Hydrotreating processes are also effective for the isomerization of paraffins. As with the less severe hydrogenation process and the more severe hydrocracking process, hydrotreating is also effective to remove contaminants such as sulfur, nitrogen and oxygen. Thus, a hydrotreating process removes contaminants, reduces the quantity of aromatics and polynuclear cyclic compounds and increases the quantity of paraffins, thereby enhancing the quality of the material treated, reducing its iodine number and increasing its VI.

A hydrotreating process can also be identified by the fact that the particular combination of operating conditions and catalyst selected to accomplish the above-mentioned results produces a product wherein there is a general decrease in VI from the highest viscosity fraction to the lowest viscosity fraction of the lubricating oil. While at times the rate of decrease in VI with decreasing viscosity may be extremely slight, or even non-existent among extremely high viscosity fractions, the rate of decrease in VI tends to become greater as the viscosity of the lubricating oil fraction decreases. Usually this decrease in VI with decreasing viscosity is particularly pronounced

among the lighter lubricating oils having the lowest viscosities, such as, for example, materials whose viscosity is usually measured in Saybolt Universal Seconds (SUS) at 100° F. Additionally, this phenomenon is evidenced quite drastically in hydrotreated lubricating oil products having viscosities of less than about 300 SUS at 100° F. and obtained from distillate charge stocks. This is not to say, however, that the decrease in VI with decreasing viscosity cannot be seen quite clearly in the hydrotreated products of residual stocks whose viscosities, at times, are more conveniently measured in SUS at 210° F.

The particular operation involved in the process of our invention is hydrotreating as distinguished from hydrofinishing, hydrogenation and hydrocracking. The material normally charged to a hydrotreating operation can be termed a "crude lubricating oil stock" and is generally obtained from crude petroleum by distillation so as to provide a material boiling at least above about 600° F. and preferably above about 625° to 650° F. Depending upon the crude petroleum from which the crude lubricating oil stock is obtained, such material may be subjected to a pretreatment such as solvent extraction prior to being charged to a hydrotreating operation. Within the overall boiling range of crude lubricating oils, we term materials boiling up to about 950° or 1000° F. as "distillates" or "distillate crude lubricating oil stocks," while we term the portions boiling above about 950° or 1000° F. "residuals" or "residual crude lubricating oil stocks." In connection with residual crude lubricating oils, it may be desirable, depending upon the source of the crude, to subject such material to deasphalting such as, for example, propane deasphalting, prior to charging it to a hydrotreating process. The products from hydrotreating operations can be fractionated and blended with each other to produce desired lubricating oil products and in some instances, depending upon specific end uses of the lubricating oils, such materials can be subjected to finishing operations, such as acid and clay contacting or the hydrofinishing treatment described previously.

Generally, an individual lubricating oil base stock fraction, i.e., the product of hydrotreating, and the corresponding individual crude lubricating oil fraction, i.e., the charge to hydrotreating, boil over a nominal range of about 100° F. At times the actual spread from initial boiling point (IBP) to end point (EP) of the fraction may be somewhat greater or lesser than the nominal 100° F. but the spread from 10% point to 90% point rarely exceeds 100° F. and is usually well within the 100° F. range, e.g., about 80° F. The present invention, however, is directed to hydrotreating wide boiling range crude lubricating oils which usually boil over a range of at least 150° F. and frequently boil over a range of at least 200° F. Such wide boiling range crude lubricating oils also have a spread between 10% points and 90% points of at least about 125° F. and usually at least about 175° F.

Generally, when hydrotreating a wide boiling range crude lubricating oil, the operating conditions selected must be sufficiently severe to effect adequate enhancement of the VI of any product fraction to meet the minimum base oil specification for such fraction. Usually, this requires the employment of operating conditions severe enough to meet the VI specification for the lowest viscosity fraction. Since, as mentioned previously, the VI of the product tends to increase with increasing viscosity, such technique results in the production of higher viscosity product fractions having needlessly high VI's. This is termed "VI giveaway."

Additionally, the treatment of the heavier, higher viscosity fractions, e.g., the residual or heavy distillate fractions, at the severity required to meet VI specifications for the lower viscosity products results in an undesirable conversion of the heavier materials into excessive quantities of low viscosity base oils or extremely light products boiling below the lubricating oil range. Thus, such technique results in an overall loss in the volume of product obtained.

Further, the loss in overall product is obtained at the expense of the heavier fractions and particularly bright stock. This is especially important from the viewpoint of economics of operation and flexibility in the slate of products obtainable, due to the fact that bright stock or heavy distillate can be blended with low viscosity lubricating oils to provide products of intermediate viscosity or reprocessed to provide additional quantities of lower viscosity lubricating oils. On the other hand, however, blending will not produce a product of increased viscosity and once a heavier material has been converted to a lighter material it cannot readily be reprocessed to return it to a heavier form. In effect then, the quantity of higher viscosity material produced, particularly in the case of bright stock, is probably the paramount factor in determining the flexibility available in the process and the economic feasibility of operating the process.

Thus, for example, if it were desired to produce a light neutral oil having a VI in the range from about 100 to 105 from a wide range crude lubricating oil containing about 20% residual components employing a typical single pass hydrotreating technique, it would be necessary to employ operating conditions of a severity sufficient that the higher viscosity products would have VI's ranging from 105 to 112. Inasmuch as bright stocks are normally required to have a VI in the range of about 95 to 100, there is substantial VI giveaway. Furthermore, the yield of bright stock from such an operation would be substantially reduced. Frequently, it will be less than 10% by volume and probably would be closer to about 5% by volume or even lower.

Our invention provides a process for producing lubricating oils with an improved yield and viscosity-VI distribution. In accordance with our invention a wide boiling range crude lubricating oil, preferably a residual containing crude lubricating oil, is subjected to hydrotreating in a series of reaction zones. At an intermediate point in the series, i.e., subsequent to the first reaction zone and prior to the final reaction zone, a portion of the hydrotreated effluent from a reaction zone is removed and a comparatively heavy, high viscosity base oil, e.g., bright stock or heavy distillate, is recovered therefrom as product. Another portion, preferably the balance, of the hydrotreated effluent is passed to the remaining reaction zones in the series including the final reaction zone. Comparatively lighter distillate lubricating base oil is recovered as product from the effluent of the final reaction zone.

If desired, the portion of the hydrotreated effluent removed at the intermediate point can be fractionated so as to separate the heavier product from a lower boiling distillate fraction and the distillate fraction can then be returned to a reaction zone upstream of the intermediate point, e.g., the first reaction zone.

While the process of our invention is operable with any processing scheme employing two or more reaction zones, we prefer to utilize processing schemes employing three or more reaction zones. Futher, we prefer to employ operating schemes utilizing separate reactors for each of the reaction zones. In a typical embodiment of our invention, a three reactor system can be employed and an aliquot portion of the effluent from the second reactor can be removed for the recovery of the heavier product while the balance of the effluent from the second reactor is passed to the third reactor for the production of lighter distillate lubricating oil product. Alternatively, the total effluent at the intermediate point, e.g., the effluent from the second stage of a three stage system, can be fractionated so as to separate it into a lighter distillate fraction and a heavier fraction. The heavier fraction is recovered as product and the lighter distillate fraction is passed for further treatment in the remaining zones or stages in the series, e.g., the third and final stage of a three stage system.

As indicated previously, the feed stock to our process can be any wide boiling range crude lubricating oil boiling above about 600° F. and preferably above about 650° F. Thus, the feed stock can be comprised completely of distillate components or can be a wide boiling range crude lubricating oil which contains a significant quantity of residual components, i.e., at least about 10% by volume of residual components and preferably at least about 25% by volume of residual components. Particularly advantageous results can be achieved when employing a feed stock composed predominantly of the residual components. If desired, the process of our invention is suitable for a treatment of a feed stock composed entirely of residual components. Due to the nature of our invention, however, we more typically would employ a feed stock containing both residual and distillate components with the distillate components comprising at least about 25% by volume of the fresh feed.

The catalyst employed in the process of our invention is a dual functional catalyst comprised of a hydrogenating component on a cracking carrier. Suitable catalyst includue metalliferous hydrogenating components selected from the group consisting of Group VI and Group VIII metals, their oxides and sulfides supported on a carrier having cracking activity. Suitable carriers include those having an AI of at least about 15. Carriers having an AI which is comparatively high, e.g., greater than about 60, are also quite satisfactory. Conversely, we have found that in some employments carriers having an AI of less than about 20 and even less than about 18 can be utilized satisfactorily. Illustrative of these catalysts are those containing a plurality of hydrogenating components such as combinations of nickel, cobalt and molybdenum; nickel and tungsten; cobalt and molybdenum, etc. supported on refractory metal oxide carriers. Suitable carriers can be comprised of a single oxide or a plurality of such oxides, e.g., alumina, silica-alumina, silica-magnesia, silica-zirconia, silica-alumina-magnesia, etc. We have found a catalyst comprised of nickel and tungsten hydrogenating components supported on a silica-alumina carrier to be quite satisfactory. Additionally, all of these catalyst can be promoted by the addition thereto of a small quantity of halogen in the range from about 0.1 to about 10% by weight based on the total catalyst, and preferably from about 1 to about 4% by weight based upon the total catalyst. We prefer to employ a catalyst containing from about 1 to 3% by weight based on the total catalyst of fluorine.

The operating conditions employed in the hydrotreating operation in accordance with our process include a temperature in the range from about 650° to about 900° F., preferably from about 700° to 850° F. and particularly from about 725° to about 825° F.; a pressure (hydrogen partial pressure) in the range from about 2,000 to about 10,000 p.s.i.g. and preferably in the range from about 2,500 to about 5,000 p.s.i.g.; a liquid hourly space velocity (LHSV) in the range from about 0.1 to about 10 and preferably from about 0.5 to about 5.0 volumes of crude lubricating oil feed stock per volume of catalyst per hour, and a hyrogen feed rate in the range from about 2,000 to about 10,000 standard cubic feet per barrel (s.c.f./b.) and preferably in the range from about 3,000 to about 6,000 s.c.f./b. It is not necessary to employ pure hydrogen gas in this operation but it is desirable to maintain a hydrogen purity of at least 50% by volume. Thus, impure hydrogen streams of the type generally found in a refinery such as, for example, reformer off-gas, containing from 70 to 90% by volume hydrogen are quite satisfactory.

Additionally, the process of our invention can be operated employing different operating conditions in the different reaction zones. Thus, for example, at times we find it desirable to employ less severe operating conditions in the reaction zones in the series preceding the intermediate point than in the reaction zones subsequent to the intermediate point. This mode of operation can be employed regardless of whether an aliquot portion of the effluent is removed at the intermediate point or whether the effluent is fractionated at the intermediate point to separate and remove residual boiling range material. This type of operation provides particularly advantageous results when the effluent is fractionated at the intermediate point so as to remove all residual materials from the system and wherein all distillate components fractionated at the intermediate point are passed to the remaining reaction zones in the series for further treatment. At other times, however, more severe conditions can be employed in the reaction zones in the series preceding the intermediate point or conditions of equal severity can be employed in all reaction zones depending upon the nature of the charge stock employed and/or the slate of products desired.

The maintenance of operating conditions of different severity in the different reaction zones can be accomplished quite readily. Thus, for example, after fractionation of the effluent at the intermediate point, the distillate fraction can be treated in a subsequent reaction zone at a temperature somewhat higher, e.g., at least about 10° to 15° F., than employed in reaction zones preceding the intermediate point thereby effecting separate hydrotreating of the distillate fraction at more severe conditions than employed when treating the wide boiling range charge stock. Alternatively, the average operating temperature of all zones in the series can be maintained at the same temperature with the catalyst inventory equally distributed among all reaction zones. Due to the removal of material at the intermediate point, either an aliquot portion of the effluent or a residual fraction, the space velocity in the reaction zones in the series subsequent to the intermediate point will be lower than in the reaction zones preceding the intermediate point thereby resulting in more severe treatment in the subsequent zones.

Further, we prefer to employ operating conditions in our hydrotreating operations selected from the above-described ranges so as to obtain a yield of at least 50% by volume based upon total charge stock of 625° F.+ material. Accordingly, the operating conditions are selected so that the 625° F.+ material comprises at least 22 mol percent of the reactor effluent which is normally in the liquid state at 60° F. and one atmosphere. Furthermore, operating conditions are selected so that the actual hydrogen consumption (measured as standard cubic feet per barrel of fresh feed) is less than the product of 30 multiplied by the volume percent (measured at 60° F. and one atmosphere) of 625° F.+ material in the total C_5^+ reactor effluent.

In order to describe our invention in greater detail, reference is made to the attached sheet of drawing comprising a schematic diagram of a flow scheme showing an embodiment of our invention.

In the drawing a wide boiling range crude lubricating oil fraction comprised of both distillate components and a deasphalted residual component is passed by means of line **10** to a first hydrotreating reactor **12** containing therein a fixed bed of a suitable catalyst such as, for example, nickel-tungsten-fluorine on silica alumina. Prior to introduction into reactor **12**, the crude lubricating oil of line **10** is admixed with hydrogen introduced by means of line **14**. The effluent from reactor **12** is removed therefrom by means of line **16** and passed to a second hydrotreating reactor **18** wherein it is again contacted with a fixed bed of a suitable catalyst such as employed in reactor **12**. The effluent from reactor **18** is removed therefrom by means of line **20** and passed by means of line **22** to fractionator **24** wherein it is separated into a furnace oil and lower boiling fraction (less than 650° F.), a distillate fraction (650°–950° F.) and a residual fraction (950° F.+).

The furnace oil and lower boiling fraction is removed overhead from fractionator **24** and the system by means of line **26**, while the residual fraction is removed from fractionator **24** by means of line **28** and passed to bright stock product recovery means (not shown). The distil-

late fraction is removed from fractionator **24** by means of line **30** and passed through valve **32** and line **33** into a third hydrotreating reactor **34** where it is contacted with a fixed bed of a suitable catalyst, such as employed in reactors **12** and **18**. The effluent from reactor **34** is removed therefrom by means of line **36** and passed to distillate lubricating oil product recovery means (not shown).

In this operation, it is necessary that the valves indicated by reference numerals **40** and **44** be maintained in a closed position while valve **32** is maintained in an open position.

Alternatively, valve **40** can be maintained in the open position thereby dividing the stream of line **20** into two streams which flow by means of lines **22** and **38**. As described previously, the material flowing through line **22** is passed to fractionator **24** wherein it is separated into a furnace oil and lower boiling fraction, a distillate fraction and a residual fraction. Also, as described previously, the furnace oil and lower boiling fraction is removed from fractionator **24** and the system by means of line **26**, while the residual fraction is removed by means of line **28** and passed to bright stock product recovery means (not shown). In this alternative mode of operation, however, the distillate fraction removed from fractionator **24** by means of line **30** is not introduced into reactor **34**, but, rather, valve **32** is maintained in a closed position while valve **44** is maintained in an open position thereby permitting the distillate fraction in line **30** to pass via line **42** whereby it is combined with the fresh feed of line **10** prior to introduction thereof into the first reactor **12**. Further, in accordance with this mode of operation, the stream of line **38** is passed by means of line **33** into reactor **34**. The effluent from reactor **34** is removed therefrom by means of line **32** and passed to distillate lubricating oil product recovery means (not shown).

In either of the two modes of operation described above, it will be realized that the severity of treatment effected in each of the reactors **12**, **18** and **34** can be varied by varying the operating conditions employed in each of these reactors. Similarly, the space velocity through reactor **34** can be varied substantially by the quantity of catalyst employed in reactor **34** versus the quantity of catalyst employed in reactors **12** and **18**. This variation in space velocity by varying the proportion of catalyst distribution through the reactors is compounded by the fact that in either of the above-described modes of operation, a lesser quantity of hydrocarbon stock is passed through reactor **34** than is passed through either reactors **12** or **18**.

The following examples are illustrative of specific operations in accordance with our invention.

EXAMPLE 1

In this example, the feed stock employed was a wide boiling range aliquot blend of a deasphalted oil and heavy distillate fraction having the properties set forth in Table I below:

TABLE I

Gravity ° API	19.6
Vis, SUS:	
at 150° F.	477
at 210° F.	125.4
VI	65
Distillation ASTM D-1160° F.:	
10%	905
30%	949
50%	989
70%	1035
90%	1085

To portions of this feed stock were separately subjected to hydrotreating in a three reactor system. The percent of total catalyst volume in each of the reactors was 20, 30 and 50%, respectively. The catalyst comprised nickel, tungsten and fluorine on an alumina carrier having an activity index of about 18. In one run, the entire portion of the feed stock was passed serially through each of the three reactors, i.e., the effluent from the first reactor constituted charge to the second reactor, etc. In this run, the average temperature in each of the reactors was maintained at 750° F. and the overall space velocity for the operation was about 1.0 volumes of crude lubricating oil per volume of catalyst per hour. The yield of hydrotreated material boiling above 625° F. based upon the crude lubricating oil feed stock was 73% by volume. At the outlet conditions of the third reactor, the 625° F.+ material in the effluent comprised 50 mol percent of the effluent which is normally liquid at 60° F. and one atmosphere. The hydrogen consumption was 1644 s.c.f./b. of 625° F.+ hydrotreated product.

The second portion of the crude lubricating oil was subjected to hydrotreating in a separate run wherein the effluent from the second reactor was fractionated so as to separate distillate materials boiling below 950° F. from materials boiling above 950° F. The heavier material was recovered as bright stock product and the distillate material (furnace oil-free) boiling below 950° F. was charged to the third reactor for further treatment. In this run, the average temperature maintained in each of the first two reactors was 750° F. Due, however, to the fact that a portion of the effluent from the second reactor was removed from the reaction system, the liquid hourly space velocity in the first two reactors was 2.0 while the space velocity in the third reactor was 1.3 and the temperature was 740° F. The yield of hydrotreated material boiling above 625° F. from the second reactor based upon crude lubricating oil feed stock was 94.8% by volume, while the yield of hydrotreated material boiling above 625° F. from the third reactor based upon charge to the third reactor was 81.4% by volume. The hydrotreated material boiling above 625° F. comprised 85 mol percent of the normally liquid material at the outlet conditions of the second reactor and comprised 57 mol percent of the normally liquid material at the outlet conditions of the third reactor. The hydrogen consumption in the first two reactors was 818 s.c.f./b. of 625° F.+ hydrotreated effluent from the second reactor and the hydrogen consumption in the third reactor was 473 s.c.f./b. of 625° F.+ hydrotreated effluent from the third reactor.

In both of the above-described runs, the charge rate of crude lubricating oil to the first reactor was the same and the pressure was maintained in both runs at a level 2400 p.s.i.g., 2000 p.s.i. hydrogen partial pressure. Similarly, in both runs the hydrogen feed rate was maintained at 5000 standard cubic feet per barrel of crude lubricating oil.

The following Table II shows inspection data for certain lubricating oil base stock fractions obtained as products from the above runs.

TABLE II

	Prior art technique	Operation of this invention
Bright stock:		
Yield, percent by volume on charge	7.2	24.5
Vis, SUS at 21 ° F	150	150
VI	110	98
Distillate base oil:		
Vis, SUS at 100° F	225	240
VI	105	105

From the above data, it will be noted that when operating in accordance with the prior art technique, the 150 bright stock product has a VI of 110 which is substantially in excess of that normally required for such bright stock, i.e., 95 to 100. This represents a substantial VI giveaway. Furthermore, it will be noted that the 150 bright stock product obtained in accordance with the operation of our invention not only has a VI of 98, falling within the desired 95 to 100 range, but is also obtained at a yield of 24.5% which is more than 3 times

greater than the yield obtained in accordance with the prior art technique. Simultaneously, the process of this invention produces distillate base oil of identical quality to that obtained by the prior art techniques.

It will be seen, therefore, that operation in accordance with the process of our invention provides several advantages including the production of bright stock in substantially increased quantities. Obtaining the most critical product fraction in increased yields permits greater flexibility in operation. Furthermore, any excess bright stock not required for the product demand slate can be reprocessed at conditions favoring the production of lighter products. Another important advantage to operation in accordance with our invention, is that, if it is not desired to produce excess quantities of bright stock, the option is now open to the refiner to charge a smaller quantity of deasphalted residual to the hydrotreating operation, inasmuch as he can obtain an increased yield of bright stock, thereby permitting a decrease in the size and, accordingly, a decrease in the investment and operating costs of a deasphalting unit.

EXAMPLE 2

In this example, the feed stock employed was a wide boiling range aliquot blend of medium and heavy distillate fractions having the properties set forth in Table III below:

TABLE III

Gravity ° API	19.2
Vis, SUS at 210° F.	72.0
VI	≈55
Distillation ASTM D-1160° F.:	
10%	804
30%	852
50%	880
70%	934
90%	1012

Two portions of this feed stock were separately subjected to hydrotreating in a three reactor system. The percent of total catalyst volume in each of the reactors was 20, 30 and 50%, respectively. The catalyst comprised nickel, tungsten and fluorine on a silica-alumina carrier having an activity index of about 75. In one run, the entire portion of the feed stock was passed serially through each of the three reactors, i.e., the effluent from the first reactor constituted charge to the second reactor, etc. In this run, the average temperature in each of the reactors was maintained at 755° F. and the overall space velocity for the operation was about 1.0 volumes of crude lubricating oil per volume of catalyst per hour. The yield of hydrotreated material boiling above 625° F. based upon the crude lubricating oil feed stock was 72.5% by volume. At the outlet conditions of the third reactor, the 625° F.+ material in the effluent comprised 44.5 mol percent of the effluent which is normally liquid at 60° F. and one atmosphere. The hydrogen consumption was 1520 s.c.f./b. of 625° F.+ hydrotreated product.

The second portion of the crude lubricating oil was subjected to hydrotreating in a separate run wherein the effluent from the second reactor was fractionated so as to separate distillate materials boiling below 950° F. from heavier materials boiling above 950° F. The heavier material was recovered as bright stock product and the distillate material (furnace oil-free) boiling below 950° F. was charged to the third reactor for further treatment. In this run, the average temperature maintained in each of the first two reactors was 755° F. Due, however, to the fact that a portion of the effluent from the second reactor was removed from the reaction system, the liquid hourly space velocity in the first two reactors was 2.0 while the space velocity in the third reactor was 1.46 and the temperature was 745° F. The yield of hydrotreated material boiling above 625° F. from the second reactor based upon crude lubricating oil feed stock was 95.0% by volume, while the yield of hydrotreated material boiling above 625° F. from the third reactor based upon charge to the third reactor was 83.6% by volume. The hydrotreated material boiling above 625° F. comprised 80 mol percent of the normally liquid material at the outlet conditions of the second reactor and comprised 59.5 mol percent of the normally liquid material at the outlet conditions of the third reactor. The hydrogen consumption in the first two reactors was 736 s.c.f./b. of 625° F.+ hydrotreated effluent from the second reactor and the hydrogen consumption in the third reactor was 239 s.c.f./b. of 625° F.+ hydrotreated effluent from the third reactor.

In both of the above-described runs, the charge rate of crude lubricating oil to the first reactor was the same and the pressure was maintained in both runs at a level 3000 p.s.i.g., 2000 p.s.i. hydrogen partial pressure. Similarly, in both runs the hydrogen feed rate was maintained at 5000 standard cubic feet per barrel of crude lubricating oil.

The following Table IV shows inspection data for certain lubricating oil base stock fractions obtained as products from the above runs.

TABLE IV

	Prior art technique	Operation of this invention
Heavy neutral:		
Yield, percent by volume on charge	7.8	21.8
Vis, SUS at 100° F	500	500
VI	110	100
Light neutral:		
Vis, SUS at 100° F	180	180
VI	104	104

From the above data, it will be noted that when operating in accordance with the prior art technique, the 500 heavy neutral product has a VI of 110 which is substantially in excess of that normally required for such stocks, i.e., about 100. This represents a substantial VI giveaway. Furthermore, it will be noted that the 500 heavy neutral product obtained in accordance with the operation of our invention not only has the desired VI of 100, but is also obtained at a yield of 21.8% which is about 3 times greater than the yield obtained in accordance with the prior art technique. Simultaneously, the process of this invention produces light neutral base oil of identical quality to that obtained by the prior art techniques.

From the data of this example, it will be seen that the process of our invention provides a substantially greater yield of heavy neutral base oil as compared to that obtained in a more conventional procedure. Additionally, the process of our invention avoids the undesired "VI giveaway" inherent in the prior art technique. Finally, it will be noted that this increase in yield of heavier product without "VI giveaway" is accomplished with no loss in quality of the lighter product.

We claim:

1. An improved process for producing lubricating oils from a wide boiling range crude lubricating oil which comprises subjecting the crude lubricating oil to hydrotreating at a temperature in the range from about 650° to about 900° F. in a series of reaction zones, removing a portion of hydrotreated crude lubricating oil at an intermediate point subsequent to the first reaction zone and prior to the final reaction zone, passing the balance of the hydrotreated crude lubricating oil to the remaining reaction zones of the series including the final reaction zone, recovering heavier lubricating oil as product from the removed portion and recovering lighter, lower boiling lubricating oil as product from the material subjected to hydrotreating in the final reaction zone.

2. The process of claim 1 wherein the removed portion is fractionated so as to separate a heavier lubricating oil product fraction from a lower boiling distillate

fraction and the distillate fraction is recycled to the first reaction zone.

3. The process of claim 1 wherein the removal of the portion of the hydrotreated crude lubricating oil at the intermediate point is effected by fractionating the total of said oil so as to separate it into a lower boiling fraction and a heavier fraction and removing the heavier fraction and wherein the lower boiling fraction constitutes the balance passed to the remaining reaction zones.

4. The process of claim 1 wherein the operating conditions employed in the remaining reaction zones are more severe than the operating conditions employed in the other reaction zones of the series.

5. The process of claim 1 wherein the operating conditions are selected so as to maintain a yield from each reaction zone of at least about 50 percent by volume of hydrotreated material boiling above about 625° F. based upon charge to the reaction zone, to maintain at least about 22 mol percent of the normally liquid hydrotreated material in the form of materials boiling above about 625° F. and to maintain a hydrogen consumption, measured as standard cubic feet per barrel of charge stock, in each reaction zone at less than about the product of 30 multiplied by the volume percent of 625° F.+ material in the normally liquid product.

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