

in a RHU. Nonetheless, economic processes to achieve high hydrocarbon conversions and sulfur removal are desired.

SUMMARY

[0004] In one aspect, embodiments disclosed herein relate to a process for upgrading residuum hydrocarbons. The process may include the following steps: contacting a residuum hydrocarbon fraction and hydrogen with a first hydroconversion catalyst in a first ebullated bed hydroconversion reactor system; recovering a first effluent from the first ebullated bed hydroconversion reactor system; solvent deasphalting a vacuum residuum fraction to produce a deasphalted oil fraction and an asphalt fraction; contacting the deasphalted oil fraction and hydrogen with a second hydroconversion catalyst in a second hydroconversion reactor system; recovering a second effluent from the second hydroconversion reactor system; ~~and~~ fractionating the first effluent from the first ebullated bed hydroconversion reactor system and the second effluent from the second hydroconversion reactor system to recover one or more hydrocarbon fractions and the vacuum residuum fraction in a common fractionation system; contacting the asphalt fraction and hydrogen with a third hydroconversion catalyst in a third ebullated bed hydroconversion reactor system; recovering a third effluent from the third ebullated bed hydroconversion reactor system; and fractionating the third effluent from the third ebullated bed hydroconversion reactor system to recover one or more hydrocarbon fractions.

In another aspect, embodiments disclosed herein relate to a process for upgrading residuum hydrocarbons, the process comprising: contacting a residuum hydrocarbon fraction and hydrogen with a first hydroconversion catalyst in a first ebullated bed hydroconversion reactor system; recovering a first effluent from the first ebullated bed hydroconversion reactor system; solvent deasphalting a vacuum residuum fraction to produce a deasphalted oil fraction and an asphalt fraction; contacting the deasphalted oil fraction and hydrogen with a second hydroconversion catalyst in a second hydroconversion reactor system; recovering a second effluent from the second hydroconversion reactor system; and combining the first effluent and the second effluent in a separator to produce a vapor fraction and a liquid fraction; fractionating the liquid fraction to recover the vacuum

residuum fraction in a first fractionation system; contacting the vapor fraction with a third hydroconversion catalyst in a third hydroconversion reactor system; recovering a third effluent from the third hydroconversion reactor system; fractionating the third effluent to recover one or more hydrocarbon fractions in a second fractionation system.

[0005] In another aspect, embodiments disclosed herein relate to a system for upgrading residuum hydrocarbons. The system may include the following: a first ebullated bed hydroconversion reactor system for contacting a residuum hydrocarbon fraction and hydrogen with a first hydroconversion catalyst to produce a first effluent; a solvent deasphalting unit to solvent deasphalt a vacuum residuum fraction to produce a deasphalted oil fraction and an asphalt fraction; a second hydroconversion reactor system for contacting the deasphalted oil fraction and hydrogen with a second hydroconversion catalyst to produce a second effluent; ~~and~~ a fractionation unit to fractionate the first effluent and the second effluent to recover one or more hydrocarbon fractions and the vacuum residuum fraction; a third ebullated bed hydroconversion reactor system for contacting the asphalt fraction and hydrogen to produce third effluent; and a fractionation unit to fractionate the third effluent to recover one or more hydrocarbon fractions.

[0006] In another aspect, embodiments disclosed herein relate to a system for upgrading residuum hydrocarbons. The system may include the following: a first ebullated bed hydroconversion reactor system for contacting a residuum hydrocarbon fraction and hydrogen with a first hydroconversion catalyst to produce a first effluent; a solvent

deasphalting unit to solvent deasphalt a vacuum residuum fraction to produce a deasphalted oil fraction and an asphalt fraction; a second hydroconversion reactor system for contacting the deasphalted oil fraction and hydrogen with a second hydroconversion catalyst to produce a second effluent; and a separator to separate a combined fraction of the first effluent and the second effluent to recover a liquid fraction and a vapor fraction; a fractionation unit to fractionate the liquid to recover the vacuum residuum fraction; a third hydroconversion reactor system for contacting the vapor fraction with a third hydroconversion catalyst to produce a third effluent; and a fractionation unit to fractionate the third effluent to recover one or more hydrocarbon fractions.

[0007] In another aspect, embodiments disclosed herein relate to a system for upgrading residuum hydrocarbons. The system may include the following: a first ebullated bed hydroconversion reactor system for contacting a residuum hydrocarbon fraction and hydrogen with a first hydroconversion catalyst to produce a first effluent; a solvent deasphalting unit to solvent deasphalt a vacuum residuum fraction to produce a deasphalted oil fraction and an asphalt fraction; a second hydroconversion reactor system for contacting the deasphalted oil fraction and hydrogen with a second hydroconversion catalyst to produce a second effluent; and a first fractionation unit to fractionate the first effluent and the second effluent to recover one or more hydrocarbon fractions and the vacuum residuum fraction; a third ebullated bed hydroconversion reactor system for contacting the asphalt fraction and hydrogen to produce third effluent; a separator to separate the third effluent and recover a liquid fraction and a vapor fraction; a second fractionation unit to fractionate the liquid to recover the vacuum residuum fraction; a fourth hydroconversion reactor system for contacting the vapor fraction with a fourth hydroconversion catalyst to produce a fourth effluent; and a third fractionation unit to fractionate the fourth effluent to recover one or more hydrocarbon fractions.

[0008] Other ~~aspects-embodiments~~ and advantages will be apparent from the following description and the appended claims.

CLAIMS

What is claimed:

1. A process for upgrading residuum hydrocarbons, the process comprising:

contacting a residuum hydrocarbon fraction and hydrogen with a first hydroconversion catalyst in a first ebullated bed hydroconversion reactor system;

recovering a first effluent from the first ebullated bed hydroconversion reactor system;

solvent deasphalting a vacuum residuum fraction to produce a deasphalted oil fraction and an asphalt fraction;

contacting the deasphalted oil fraction and hydrogen with a second hydroconversion catalyst in a second hydroconversion reactor system;

recovering a second effluent from the second hydroconversion reactor system;
and

fractionating the first effluent from the first ebullated bed hydroconversion reactor system and the second effluent from the second hydroconversion reactor system to recover one or more hydrocarbon fractions and the vacuum residuum fraction in a common fractionation system;

- ~~2. The process of claim 1, further comprising:~~

contacting the asphalt fraction and hydrogen with a third hydroconversion catalyst in a third ebullated bed hydroconversion reactor system;

recovering a third effluent from the third ebullated bed hydroconversion reactor system; and

fractionating the third effluent from the third ebullated bed hydroconversion reactor system to recover one or more hydrocarbon fractions.

- ~~3. 2. The process of claim 21, further comprising:~~

mixing the asphalt fraction with a diluent prior to contacting with hydrogen.

- ~~4.3.~~ The process of claim ~~32~~, wherein the diluent comprises at least one of a second portion of a residuum hydrocarbon fraction, FCC cycle oils, slurry oils, aromatics extracts, and straight run vacuum gas oils.
- ~~5.4.~~ The process of claim 1, wherein the second hydroconversion reactor system includes a second ebullated bed hydroconversion reactor system comprising one or more ebullated bed reactors.
- ~~6.5.~~ The process of claim ~~54~~, wherein the deasphalted oil fraction has a metals content of greater than about 80 wppm and a Conradson Carbon Residue content of greater than about 10 wt%.
- ~~7.6.~~ The process of claim ~~21~~, further comprising recycling the vacuum residuum hydrocarbon fraction to at least one of the solvent deasphalting, a vacuum distillation system, the first ebullated bed hydroconversion reactor system, the second hydroconversion reactor system, and the third ebullated bed hydroconversion reactor system.
- ~~8.7.~~ The process of claim 1, wherein the residuum hydrocarbon fraction comprises at least one of petroleum atmospheric or vacuum residua, deasphalted oils, deasphalter pitch, hydrocracked atmospheric tower or vacuum tower bottom, straight run vacuum gas oil, hydrocracked vacuum gas oil, fluid catalytically cracked (FCC) slurry oils, vacuum gas oil from an ebullated bed process, shale-derived oils, coal-derived oils, bioderived crude oils, tar sands bitumen, tall oils, black oils.
- ~~9.8.~~ The process of claim 1, wherein contacting in the first ebullated bed hydroconversion reactor system results in a hydrocarbon conversion in the range from about 30 wt% to about 75 wt%, sulfur removal is in the range from about 40 wt% to about 65 wt%, metals removal is in the range from about 40 wt% to about 65 wt% and Conradson Carbon Residue removal is in the range from about 30 wt% to about 60 wt%.
- ~~10.9.~~ The process of claim 1, wherein contacting in the first ebullated bed hydroconversion reactor system is at a reaction severity of about 105,000 °F-Bara-hr to about 446,000 °F-Bara-hr.
- ~~11.10.~~ The process of claim ~~43~~, wherein contacting in the second ebullated bed hydroconversion reactor system is at a reaction severity of about 255,000 °F-Bara-hr to about 880,000 °F-Bara-hr.

~~12.11.~~ The process of claim 1, wherein contacting in the third ebullated bed hydroconversion reactor system is at a reaction severity of about 215,000 °F-Bara-hr to about 755,000 °F-Bara-hr.

~~13.12.~~ The process of claim ~~21~~, wherein a fuel oil produced via the fractionating the third ebullated bed hydroconversion reactor system effluent has a sulfur content of 1.5 wt% or less.

~~14.13.~~ The process of claim ~~21~~, wherein an overall conversion of the residuum hydrocarbon fraction is in the range from about 75 wt% to about 90 wt%.

~~15.14.~~ The process of claim ~~21~~, wherein the ratio of the asphalt fraction feed processed in the third ebullated-bed hydroconversion system to that in the first ebullated-bed hydroconversion system is in the range from about 0.1/1 to about 10/1.

~~16.15.~~ The process of claim 1, wherein a solvent used in the solvent deasphalting unit is a light hydrocarbon containing from 3 to 7 carbon atoms.

~~17.16.~~ The process of claim 1, wherein a solvent used in the solvent deasphalting unit is at least one of an aromatic solvent, a mixture of gas oils, and a light naphtha from the fractionated first, second, or third effluent or imported.

~~18.17.~~ The process of claim 1, wherein fractionating the third effluent comprises~~further comprising:~~

~~contacting the asphalt fraction and hydrogen with a third hydroconversion catalyst in a third ebullated bed hydroconversion reactor system;~~

~~recovering a third effluent from the third ebullated bed hydroconversion reactor system; and~~

separating the third effluent in a separator to produce a vapor fraction and a liquid fraction;

fractionating the liquid fraction to recover the vacuum residuum fraction in a first fractionation system;

contacting the vapor fraction with a fourth hydroconversion catalyst in a fourth hydroconversion reactor system;

recovering a fourth effluent from the fourth hydroconversion reactor system;

fractionating the fourth effluent to recover one or more hydrocarbon fractions in a second fractionation system.

~~19.~~18. A system for upgrading residuum hydrocarbons, the system comprising:

- a first ebullated bed hydroconversion reactor system for contacting a residuum hydrocarbon fraction and hydrogen with a first hydroconversion catalyst to produce a first effluent;
- a solvent deasphalting unit to solvent deasphalt a vacuum residuum fraction to produce a deasphalted oil fraction and an asphalt fraction;
- a second hydroconversion reactor system for contacting the deasphalted oil fraction and hydrogen with a second hydroconversion catalyst to produce a second effluent; and
- a fractionation unit to fractionate the first effluent and the second effluent to recover one or more hydrocarbon fractions and the vacuum residuum fraction;

~~20.~~ The system of claim ~~19~~, further comprising:

- a third ebullated bed hydroconversion reactor system for contacting the asphalt fraction and hydrogen to produce third effluent; and
- a fractionation unit to fractionate the third effluent to recover one or more hydrocarbon fractions.

~~21.~~19. The system of claim ~~19~~18, wherein the second hydroconversion reactor system includes a second ebullated bed hydroconversion reactor system comprising one or more ebullated bed reactors.

~~22.~~20. The system of claim ~~20~~18, further comprising recycling the vacuum residuum hydrocarbon fraction to at least one of the solvent deasphalting, a vacuum distillation system, the first ebullated bed hydroconversion reactor system, the second hydroconversion reactor system, and the third ebullated bed hydroconversion reactor system.

~~23.~~21. A process for upgrading residuum hydrocarbons, the process comprising:

- contacting a residuum hydrocarbon fraction and hydrogen with a first hydroconversion catalyst in a first ebullated bed hydroconversion reactor system;
- recovering a first effluent from the first ebullated bed hydroconversion reactor system;

solvent deasphalting a vacuum residuum fraction to produce a deasphalted oil fraction and an asphalt fraction;
 contacting the deasphalted oil fraction and hydrogen with a second hydroconversion catalyst in a second hydroconversion reactor system;
 recovering a second effluent from the second hydroconversion reactor system; and
 combining the first effluent and the second effluent in a separator to produce a vapor fraction and a liquid fraction;
 fractionating the liquid fraction to recover the vacuum residuum fraction in a first fractionation system;
 contacting the vapor fraction with a third hydroconversion catalyst in a third hydroconversion reactor system;
 recovering a third effluent from the third hydroconversion reactor system;
 fractionating the third effluent to recover one or more hydrocarbon fractions in a second fractionation system.

24.22. A system for upgrading residuum hydrocarbons, the system comprising:
 a first ebullated bed hydroconversion reactor system for contacting a residuum hydrocarbon fraction and hydrogen with a first hydroconversion catalyst to produce a first effluent;
 a solvent deasphalting unit to solvent deasphalt a vacuum residuum fraction to produce a deasphalted oil fraction and an asphalt fraction;
 a second hydroconversion reactor system for contacting the deasphalted oil fraction and hydrogen with a second hydroconversion catalyst to produce a second effluent; and
 a separator to separate a combined fraction of the first effluent and the second effluent to recover a liquid fraction and a vapor fraction;
 a fractionation unit to fractionate the liquid to recover the vacuum residuum fraction;
 a third hydroconversion reactor system for contacting the vapor fraction with a third hydroconversion catalyst to produce a third effluent; and

a fractionation unit to fractionate the third effluent to recover one or more hydrocarbon fractions.

25.23. A system for upgrading residuum hydrocarbons, the system comprising:

- a first ebullated bed hydroconversion reactor system for contacting a residuum hydrocarbon fraction and hydrogen with a first hydroconversion catalyst to produce a first effluent;
- a solvent deasphalting unit to solvent deasphalt a vacuum residuum fraction to produce a deasphalted oil fraction and an asphalt fraction;
- a second hydroconversion reactor system for contacting the deasphalted oil fraction and hydrogen with a second hydroconversion catalyst to produce a second effluent; and
- a first fractionation unit to fractionate the first effluent and the second effluent to recover one or more hydrocarbon fractions and the vacuum residuum fraction.
- a third ebullated bed hydroconversion reactor system for contacting the asphalt fraction and hydrogen to produce third effluent;
- a separator to separate the third effluent and recover a liquid fraction and a vapor fraction;
- a second fractionation unit to fractionate the liquid to recover the vacuum residuum fraction;
- a fourth hydroconversion reactor system for contacting the vapor fraction with a fourth hydroconversion catalyst to produce a fourth effluent; and
- a third fractionation unit to fractionate the fourth effluent to recover one or more hydrocarbon fractions.