CLAIMS

1. A method of processing a hydrocarbon feed to remove undesired organosulfur compounds comprising:

a. flashing the hydrocarbon feedstock to provide a low boiling temperature fraction that contains a reduced level of organosulfur compounds and a high boiling temperature fraction having refractory organosulfur compounds;

b. subjecting the low boiling temperature fraction to a hydrodesulfurizing process to produce a hydrotreated effluent;

c. contacting the high boiling temperature fraction with a gaseous oxidizing agent and an oxidizing catalyst having a formula $Cu_xZn_{1-x}Al_2O_4$ wherein x ranges from 0 to 1 to convert refractory organosulfur compounds into sulfur-free hydrocarbons and SO_x by breaking the C-S bonds;

d. removing the by-product SO_x in a separation zone from the sulfur-free hydrocarbons; and

e. recovering an ultra-low sulfur level hydrocarbon product.

2. The method of claim 1, wherein the oxidizing catalyst comprises copper oxide in an amount ranging from 10 weight percent (wt%) to 50 wt%, zinc oxide in an amount ranging from 5 wt% to less than 20 wt%, and aluminum oxide in an amount ranging from 20 wt% to 70 wt%, wherein said catalytic composition has an X-ray amorphous oxide phase, and highly dispersed crystalline ZnO and CuO.

3. The method of claim 1, wherein the temperature cut point in step (a) is about 340°C.

4. The method of claim 1, wherein the low boiling temperature fraction includes aliphatic organosulfur compounds.

5. The method of claim 4, wherein the aliphatic organosulfur compounds include sulfides, disulfides, and mercaptans.

6. The method of claim 4, wherein the low boiling temperature fraction further includes thiophene and alkyl derivatives of thiophene.

7. The method of claim 1, wherein the high boiling temperature fraction includes dibenzothiophene, alkyl derivatives of dibenzothiophene and long-chain alkylated derivatives of benzothiophene having a boiling point in the range of the high boiling temperature fraction.

8. The method of claim 1, wherein the hydrocarbon feed is a straight run gas oil boiling in the range of about 180°C to about 450°C.

9. The method of claim 8, wherein the hydrodesulfurizing process is operated at mild operating conditions.

10. The method of claim 9, wherein the hydrogen partial pressure is less than about 55 bars.

11. The method of claim 9, wherein the hydrogen partial pressure is about 25 bars to about 40 bars.

12. The method of claim 9, wherein the operating temperature is about 300°C to about 400°C.

13. The method of claim 9, wherein the operating temperature is about 320°C to about 380°C.

14. The method of claim 9, wherein the hydrogen feed rate in the hydrodesulfurizing process step is from about 100 liters of hydrogen per liter of oil to about 1000 liters of hydrogen per liter of oil.

15. The method of claim 9, wherein the hydrogen feed rate in the hydrodesulfurizing process step is from about 200 liters of hydrogen per liter of oil to about 300 liters of hydrogen per liter of oil.

16. The method of claim 1, wherein the oxidizing agent is selected from the group consisting of oxides of nitrogen, oxygen, and air.

17. The method of claim 1, further comprising recovering the hydrotreated effluent from step (b).

18. The method of claim 1, further comprising combining effluents from steps (b) and (e).

19. The method of claim 1 wherein the catalytic composition used in step (c) further comprises Ce_2O_3.

20. The method of claim 1 wherein the catalytic composition used in step (c) is in granular form.

21. The method of claim 1 wherein the catalytic composition used in step (c) is formed as a cylinder, a sphere, a trilobe, or having a quadrilobate shape.

22. The method of claim 21 wherein particles of the catalytic composition have effective diameter of from 1 mm to 4 mm.

23. The method of claim 21 wherein particles of the catalytic composition have having a specific surface area of from 10 m^2/g to 100 m^2/g.

24. The method of claim 21 wherein particles of the catalytic composition have having a specific surface area of from 50 m^2/g to 100 m^2/g.

25. The method of claim 21 wherein particles of the catalytic composition have pores with effective diameters of from 8 nm to 12 nm.

26. The method of claim 21 wherein particles of the catalytic composition have pores with effective diameters of from 8 nm to 10 nm.

27. The method of claim 21 wherein particles of the catalytic composition have pores with a volume of from about 0.1 cm^3/g to about 0.5 cm^3/g.

28. The method of claim 1 wherein the catalytic composition used in step (c) comprises from 20 wt% to 45 wt% CuO, from 10 wt% to less than 20 wt% ZnO, and from 20 wt% to 70 wt% of Al_2O_3.

29. The method of claim 1 wherein the catalytic composition used in step (c) comprises from 30 wt% to 45 wt% CuO, from 12 wt% to less than 20 wt% ZnO, and from 20 wt% to 40 wt% Al_2O_3.

30. The method of claim 1 wherein x in the catalytic composition used in step (c) is from 0.1 to 0.6.

31. The method of claim 1 wherein x in the catalytic composition used in step (c) is from 0.2 to 0.5.

32. The method of claim 8, wherein step (c) occurs substantially in gas phase.

33. The method of claim 19, wherein the in Ce_2O_3 is in the form of particles ranging in diameter from 5 nm to 10 nm, in an amount ranging from 0.1 wt% to 10 wt% of said catalytic composition.

34. An apparatus for processing a hydrocarbon feed containing undesired organosulfur compounds comprising:

a flashing column operable to flash a hydrocarbon feed at a temperature cut point of about 320°C to about 360°C, the flashing column including

an inlet for receiving the hydrocarbon feed,

a low boiling temperature outlet for discharging a low boiling temperature fraction, and

a high boiling temperature outlet for discharging a high boiling temperature fraction containing refractory organosulfur compounds;

a hydrodesulfurization zone having an inlet in fluid communication with the low boiling temperature outlet and an outlet for discharging hydtrotreated effluent; and

a gas phase catalytic oxidative desulfurization zone containing an oxidizing catalyst having a formula $Cu_xZn_{1-x}Al_2O_4$ wherein x ranges from 0 to 1 and a gaseous oxidizing agent, the gas phase catalytic oxidative desulfurization zone having an inlet in fluid communication with the high boiling temperature outlet, and an outlet for discharging low-sulfur hydrocarbons and SO_x.

35. The apparatus of claim 34, wherein the gas phase catalytic oxidative desulfurization zone operates occurs substantially in gas phase.