

pond peaks and other light gas peaks with retention times between 1.3 minutes and 1.6 minutes dissipate upon sparging with the reformate or other gases. H₂S gas, initially absent, increases at 0 min and holds nearly steady at 10 minutes and then dissipates to very low levels. This observation correlates with the conversion of elemental sulfur compounds to H₂S gas, which is subsequently stripped from solution, and correlates with the observed disappearance from the chromatograms.

2. The method of claim 1, wherein the first hydrogen-containing gas is a reformate product gas obtained from a steam reformer, an autothermal reformer, or a partial oxidation reactor.

3. The method of claim 2, wherein the second hydrogen-containing gas is a reformate product gas obtained from a steam reformer, an autothermal reformer, or a partial oxidation reactor.

TABLE 1

Results for removal of elemental sulfur from HDS-treated JP-8 fuel sparged with reformate gas in presence of an HDS catalyst at 150° C.										
Vial #	PDLE #	~Time (min)	Peak-1 Area *	% Removed	Peak-2 Area **	% Removed	Peak-3 Area ***	% Removed	Peak Area (Total)	% Removed
1	1	-15	19813	-15.1	6970	13.0	41915	-16.3	68698	-12.2
2	2	0	8435	51.0	3448	57.0	15765	56.2	27648	54.9
3	3	10	0	100	0	100	74	99.8	74	99.9
4	4	30	0	100	0	100	0	100	0	100
5	5	60	0	100	0	100	0	100	0	100

Note:

negative removal on vial 1 indicates the elemental sulfur level was analyzed as being higher than an earlier analysis.

* Retention Time (RT) = 14.1 minutes.

** Retention Time (RT) = 17.3 minutes.

*** Retention Time (RT) = 19.9 minutes.

In another test, very low reformate:fuel ratios on a 10 kW_e scale were tested for efficacy in view of the methodology described. In these tests, the ratio of reformate gas to liquid fuel feed in HDS reactor (in reaction step 1 for conversion of organic sulfur) was between about 1 standard liter of gas per cubic centimeter (cm³) of the liquid hydrocarbon and about 0.02 standard liters of gas per cm³ of the liquid hydrocarbon. Feed rates were: 7 (slpm): 60 (ccm) and 0.33 (slpm): 15 (ccm), respectively. The HDS reactor was followed immediately by a ZnO bed which facilitated the conversion of elemental sulfur to H₂S and the reaction of H₂S to form ZnS. Resulting sulfur levels in the liquid fuels for these tests were <0.1 ppm. Even lower gas:liquid ratios can be expected by optimization of the system parameters.

While preferred embodiments of the present invention have been shown and described, it will be apparent to those of ordinary skill in the art that many changes and modifications may be made without departing from the invention in its true scope and broader aspects. The appended claims are therefore intended to cover all such changes and modifications as fall within the spirit and scope of the invention.

What is claimed is:

1. A method for desulfurizing a hydrocarbon, the method comprising:

reacting organic sulfur compounds in the hydrocarbon with a first hydrogen-containing gas in the presence of a first catalyst to form H₂S gas and to convert organic sulfur remaining in the hydrocarbon substantially into the form of elemental sulfur compounds;

separating a first H₂S-containing gas from the hydrocarbon containing the elemental sulfur compounds;

reacting the elemental sulfur compounds in the hydrocarbon with a second hydrogen-containing gas in the presence of a second catalyst to convert the elemental sulfur compounds in the hydrocarbon to H₂S gas; and

separating a second H₂S-containing gas formed from conversion of the elemental sulfur compounds from the hydrocarbon to obtain a desulfurized hydrocarbon.

4. The method of claim 2, wherein the second hydrogen-containing gas is a retentate gas obtained from a hydrogen permeable membrane separation.

5. The method of claim 1, wherein separating the first H₂S-containing gas from the hydrocarbon, reacting elemental sulfur compounds in the hydrocarbon to convert the elemental sulfur compounds to H₂S gas and separating the second H₂S-containing gas, or combinations thereof to obtain the desulfurized hydrocarbon are performed over a solid H₂S sorbent.

6. The method of claim 5, wherein the solid H₂S sorbent contains ZnO.

7. The method of claim 1, wherein the first hydrogen-containing gas is a reformate gas obtained from a steam reformer which has not undergone water gas shift reaction at temperatures below the reformer exit temperature and from which water has been condensed.

8. The method of claim 7, wherein the first hydrogen-containing reformate gas is introduced to the hydrocarbon at a rate at or below 1 standard liter of reformate gas per cubic centimeter (cm³) of the hydrocarbon, with the hydrocarbon volume evaluated in the liquid state.

9. The method of claim 7, wherein the first hydrogen-containing reformate gas is introduced to the hydrocarbon at a rate at or below 0.02 standard liters of reformate gas per cubic centimeter (cm³) of the hydrocarbon.

10. The method of claim 7, wherein the hydrocarbon that contains organic sulfur compounds is a JP-8 fuel and the reaction with the first hydrogen-containing reformate gas is performed at a pressure of about 270 psig and a temperature of about 380° C.

11. The method of claim 1, wherein separating the first H₂S-containing gas from the hydrocarbon containing the elemental sulfur compounds includes:

condensing the hydrocarbon containing the elemental sulfur compounds at a pressure reduced less than 10 psi relative to the reaction pressure used for conversion of organic sulfur to form a liquid;

separating the liquid hydrocarbon containing elemental sulfur compounds from the first H₂S-containing gas