transmix/diesel feed from 271 ppm to 0 ppm according to ASTM D5623 standards and from 334ppm to 2 ppm according to ASTM D5453 standards.

**Results**

Table 1 NGC feedstock - hydrocarbon analysis

**Group Type:**

| | Total(mass%): | Total(vol%): |
|---|---|---|
| Paraffins: | 36.910 | 38.348 |
| I-paraffins: | 44.299 | 45.624 |
| Olefins: | 0.093 | 0.086 |
| Naphthenes: | 13.222 | 11.489 |
| Aromatics: | 2.699 | 2.044 |
| Total C14+: | 2.757 | 2.391 |
| Total Unknowns: | 0.020 | 0.018 |
| Grand Total: | 100.000 | 100.000 |

**Oxygenates:**

| | | |
|---|---|---|
| Total: | 0.000 (mass%) | 0.000 (vol%) |
| Total Oxygen Content: | 0.000 (mass%) | |

**Multisubstituted Aromatics:** 0.211 (mass%) 0.160 (vol%)

**Average Molecular Weight:** 78.627

**Relative Density:** 0.643

**Vapor Pressure,** calc. RVP (EPA method): 10.43 (psi @ 100°F)

**Octane Number (calculated):** 73.95

| | IBP: | T10: | T50: | T90: | FBP |
|---|---|---|---|---|---|
| **Boiling Point (est.):** | 31.10°F | 82.11°F | 96.91°F | 213.67°F | 488.6 |

**Percent Carbon:** 84.060 **Percent Hydrogen:** 15.940

**Bromine Number (calc.):** 0.161

CLAIMS:

1. A process for reducing the sulphur content of a hydrocarbon material containing sulphur compounds, the process comprising:

a) contacting the hydrocarbon material with one or more primary oxidants to oxidize the sulphur compounds to sulphoxide and/or sulphone compounds to provide a primary oxidised hydrocarbon material, wherein the primary oxidant is at least one member selected from the group consisting of N-chloroimide, hypobromous acid, hypochlorous acid, electrolyzed oxidizing water, and catalysed and co-catalysed hydrogen peroxide;

b) contacting the primary oxidised hydrocarbon material with a secondary oxidant to oxidize sulphur compounds not oxidised by the primary oxidant to sulphoxide and/or sulphone compounds to provide a secondary oxidised hydrocarbon material, wherein the secondary oxidant is at least one member selected from the group consisting of hydroxyl radicals, liquid ferrate (iron VI), chlorine dioxide, and hypofluorous acid/polar solvent;

c) contacting the primary and/or secondary oxidised hydrocarbon material with an aqueous extractant to allow at least a portion of the sulphoxide and/or sulphone compounds to be extracted into the aqueous extractant to give a sulphoxide and/or sulphone stream and a low sulphur hydrocarbon stream; and

d) contacting the sulphoxide and/or sulphone stream with a tertiary oxidant to give a sulphite stream and a low sulphur aromatic hydrocarbon stream, wherein the tertiary oxidant oxidises the sulphone and/or sulphoxide compounds to sulphite compounds.

2. The process according to claim 1, wherein the hydrocarbon material containing sulphur compounds has a sulphur mass of greater than 1000 ppm.

3. The process according to claim 1, wherein the secondary oxidant is contacted with the primary oxidised hydrocarbon material in at least a stoichiometric amount.

4. The process according to claim 1, wherein the secondary oxidant is contacted with the primary oxidised hydrocarbon material at a temperature of less than about 35˚C, and at a pressure of less than 700 kPa, and for a period of time in the range of about 30 seconds to 10 minutes.

5. A process for reducing the sulphur content of a hydrocarbon material containing sulphur compounds, the process comprising steps a), c), and d) or steps b), c), and d), as follows:

a) contacting the hydrocarbon material with one or more primary oxidants to give a primary oxidised hydrocarbon material, wherein the primary oxidant is at least one member selected from the group consisting of N-chloroimide, hypobromous acid, hypochlorous acid, electrolyzed oxidizing water and catalysed and co-catalysed hydrogen peroxide, such that the primary oxidant oxidizes the sulphur compounds to sulphoxide and/or sulphone compounds;

or

b) contacting the hydrocarbon material or a primary oxidised hydrocarbon material containing sulphur compounds with a secondary oxidant to give a secondary oxidised hydrocarbon material wherein the secondary oxidant is at least one member selected from the group consisting of hydroxyl radicals, liquid ferrate (iron VI), chlorine dioxide and hypofluorous acid/polar solvent, such that the secondary oxidant oxidizes sulphur compounds to sulphoxide and/or sulphone compounds;

and

c) contacting the primary and/or secondary oxidised hydrocarbon material with an aqueous extractant to allow at least a portion of the sulphoxide and/or sulphone compounds to be extracted into the aqueous extractant to give a sulphoxide and/or sulphone stream and a low sulphur hydrocarbon stream;

and

d) contacting the sulphoxide and/or sulphone stream with a tertiary oxidant to give a sulphite stream and a low sulphur aromatic stream, wherein the tertiary oxidant oxidises the sulphone and/or sulphoxide compounds to sulphite compounds.

6. A process for reducing the sulphur content of a hydrocarbon material containing sulphur compounds according to claim 1 or 5, the process comprising:

a) contacting the hydrocarbon material with one or more primary oxidants to provide a primary oxidised hydrocarbon material such that the primary oxidant oxidizes the sulphur compounds to sulphoxide and/or sulphone compounds, wherein the primary oxidant is at least one member selected from the group consisting of N-chloroimide, hypobromous acid, hypochlorous acid, electrolyzed oxidizing water and catalysed and co-catalysed hydrogen peroxide, and wherein the catalysed and co-catalysed hydrogen peroxide is hydrogen peroxide catalysed by phosphotungstic acid and co-catalysed by a Phase Transfer Catalyst (PTC);

and

b) contacting the primary oxidised hydrocarbon material with a secondary oxidant to give a secondary oxidised hydrocarbon material wherein the secondary oxidant is at least one member selected from the group consisting of hydroxyl radicals, liquid ferrate (iron VI), chlorine dioxide and hypofluorous acid/ polar liquid solvent, such that the secondary oxidant oxidizes sulphur compounds to sulphoxide and/or sulphone compounds;

and

c) contacting the primary and/or secondary oxidised hydrocarbon material with an aqueous extractant to allow at least a portion of the sulphoxide and/or sulphone compounds to be extracted into the aqueous extractant to give a sulphoxide and/or sulphone stream and a low sulphur hydrocarbon stream;

and

d) contacting the sulphoxide and/or sulphone stream with a tertiary oxidant to give an aqueous sulphite stream and a low sulphur aromatic hydrocarbon stream, wherein the tertiary oxidant oxidises sulphone and/or sulphoxide compounds to sulphite compounds.

7. The process according to claim 1 or 5 wherein the primary oxidant is N-chloroimide.

8. The process according to claim 7 wherein the N-chloroimide is prepared by reaction of sodium hypochlorite, water and an imide.

9. The process according to claim 8 wherein the imide is cyanuric acid.

10. The process according to claim 7 wherein N-chloroimide is prepared *in situ.*

11. The process according to claim 1 or 5 wherein the primary oxidant is hypobromous or hypochlorous acid.

12. The process according to claim 11 wherein the hypobromous acid is prepared *in situ* by electrolysis of hydrogen bromide in water.

13. The process according to claim 1 or 5 wherein the primary oxidant is electrolysed oxidising water.

14. The process according to claim 1 or 5 wherein the catalysed and co-catalysed hydrogen peroxide is hydrogen peroxide catalysed by phosphotungstic acid and co-catalysed with a Phase Transfer Catalyst (PTC).

15. The process according to claim 1 or 5 wherein the catalysed and co-catalysed hydrogen peroxide is hydrogen peroxide catalysed by phosphotungstic acid comprising sodium tungstate dihydrate and phosphoric acid and co-catalysed by a Phase Transfer Catalyst (PTC) comprising a quaternary ammonium salt selected from the group consisting of quaternary ammonium hydrogen sulphates, methyltrialkyl($C_8$-$C_{10}$)ammonium chloride and N-Methyl-N,N-dioctyloctane-1-ammonium chlorides.

16. The process according to claim 15 wherein the hydrogen peroxide is catalysed by phosphotungstic acid and co-catalysed by a tri-C8-10-alkylmethyl, hydrogen sulfate.

17. The process according to claim 1 or 5 wherein the hydrocarbon material is contacted with the primary oxidant in at least a stoichiometric amount for the conversion of sulphur compounds to sulphoxide and/or sulphone compounds.

18. The process according to claim 5 wherein the hydrocarbon material is contacted with the primary oxidant or the secondary oxidant.

19. The process according to claim 5 wherein the hydrocarbon material is contacted with the primary oxidant and the primary oxidised hydrocarbon is contacted with the secondary oxidant.

20. The process according to claim 5 wherein the secondary oxidant has an oxidation reduction potential (ORP) of $\geq$ 1550 mV.

21. The process according to claim 5 wherein the secondary oxidant is contacted with the primary oxidised hydrocarbon material or the hydrocarbon material in at least a stoichiometric amount.

22. The process according to claim 5 wherein the secondary oxidant is contacted with the primary oxidised hydrocarbon material or the hydrocarbon material at a temperature of less than about 35ºC, and at a pressure of less than 700 kPa, and for a period of time in the range of about 30 seconds to 10 minutes.

23. The process according to claim 1 or 5 wherein the secondary oxidant is chlorine dioxide, in the form of a stabilised water solution having a chlorine dioxide content in the range of about 3000 ppm (0.3%) to 8000 ppm (0.8%).

24. The process according to claim 1 or 5 wherein the secondary oxidant is hypofluorous acid in acetonitrile, prepared by bubbling a gaseous mixture comprising fluorine and nitrogen into liquid acetonitrile to form $HOF.CH_3CN$, wherein the concentration of fluorine mixed with nitrogen does not exceed 20% by weight fluorine blended with the nitrogen.

25. The process according to claim 1 or 5 wherein the secondary oxidant is hydroxyl radicals.

26. The process according to claim 1 or 5 wherein the secondary oxidant is Liquid Ferrate VI.

27. The process according to claim 1 or 5 wherein in step c) the primary and/or secondary oxidised hydrocarbon material is contacted with an ionic liquid (IL) or a polar extraction solvent for a time and under conditions to allow at least a portion of the sulphoxide and/or sulphone compounds to be extracted or absorbed into the extraction solvent or liquid.

28. The process according to claim 27 wherein the extractant is selected from the group consisting ofDMF, DMSO, methanol, furfural, water, acetonitrile, and combinations thereof.

29. The process according to claim 27 wherein a liquid/liquid extraction or ion exchange adsorption process is used to extract the sulphone/sulphoxide compounds.

30. The process according to claim 1 or 5 wherein the first and/or second oxidised hydrocarbon material obtained from step a) and/or step c) are washed with water.

31. The process according to claim 1 or 5 wherein the tertiary oxidant is a caustic solution, selected from the group consisting of:

i) sodium hydroxide,

ii) potassium hydroxide and

iii) hydroxyl radicals.

32. The process according to claim 1 or 5 wherein the tertiary oxidant is sodium hydroxide and an aqueous sodium sulphite solution is formed.

33. The process according to claim 32 wherein the sodium hydroxide solution is in a concentration of about 30-60%.

34. The process according to claim 1 or 5 wherein the tertiary oxidant is hydroxyl radicals such that following addition of water, sulphuric acid forms.

35. The process according to claim 34 wherein the stoichiometric ratio of hydroxyl radicals to sulphone/sulphoxide is in the range of about 1:1 to 4:1.

36. The process according to claim 1 or 5 wherein the low sulphur hydrocarbon stream and the low sulphur aromatic compound are combined and recycled as low sulphur hydrocarbon fuel.

37. The process according to claim 1 or 5 wherein the process further comprises:

e) contacting the low sulphur hydrocarbon stream obtained in step c) with an adsorbent to remove residual sulphur compounds from the low sulphur hydrocarbon stream (LSD) to provide an ultra low sulphur hydrocarbon stream (ULSD).

38. The process according to claim 37 wherein the adsorbent is selected from physical or physiochemical adsorbents, Y-zeolite, activated carbon and Metal Oxide Framework (MOF).

39. The process according to claim 37 wherein following step e) the loaded absorbent is regenerated/purged using heater N2, stripping to desorb sulfur compounds from the adsorbent.

40. The process according to claim 1 or 5 further including the step of separating the sulphone/sulphoxide stream and the low sulphur hydrocarbon stream produced in step c).

41. The process according to claim 1 or 5 wherein the low sulphur hydrocarbon stream obtained in step c) is polished using adsorbents including MOF (Metal Organic Framework), (C18H6Cu3O12) – Copper Benzene-1,3,5-Tricarboxylate, Metal Oxide Purification Adsorbent group of adsorbents, CuCl2MIL-47 MOF, Y-Zeolite, Molecular Imprinted Chitosan or Activated Carbon.

42. A method for regenerating an aromatic and/or aliphatic sulfone and/or sulphoxide compound to a sulphone and/or sulphoxide free aromatic and/or aliphatic compound comprising contacting the aromatic and/or aliphatic sulfone and/or sulphoxide compound with hydroxyl radicals to form the sulphone and/or sulphoxide free aromatic and/or aliphatic compound and a sulphite, wherein the aromatic and/or aliphatic sulphone and/or sulphoxide compound is the sulphoxide/sulphone compound formed in the process according to steps a) and b) of claim 1 or steps a) or b) of claim 5.

43. A method for regenerating an aromatic and/or aliphatic sulfone and/or sulphoxide compound to a sulphone and/or sulphoxide free aromatic and/or aliphatic compound comprising contacting the aromatic and/or aliphatic sulfone and/or sulphoxide compound with hydroxyl radicals to form the sulphone and/or sulphoxide free aromatic and/or aliphatic compound and a sulphite.

44. The method according to claim 43 wherein the sulphite is hydrated to sulphuric acid.

45. A method of oxidizing a sulphur compound in a hydrocarbon material, comprising providing a quaternary ammonium salt for use as a co-catalyst with catalysed hydrogen peroxide in the oxidation of the sulphur compounds in the hydrocarbon material.

46. The method of claim 45 wherein the catalysed hydrogen peroxide is hydrogen peroxide catalysed by a catalyst selected from transition metals, noble metals and breakdown rate control catalysts.

47. The method of claim 46 wherein the breakdown rate control catalysts is phosphotungstic acid and the quaternary ammonium salt is a PTC selected from the group consisting of tri-C8-10-alkylmethyl, hydrogen sulfates; methyltrialkyl($C_8$-$C_{10}$)ammonium chloride; and N-Methyl-N,N-dioctyloctane-1-ammonium salts such as the chloride.

48. A process for reducing the sulphur content of a hydrocarbon material containing sulphur compounds, the process comprising:

a) contacting the hydrocarbon material with one or more primary oxidants to oxidize the sulphur compounds to sulphoxide and/or sulphone compounds to provide a primary oxidised hydrocarbon material, wherein the primary oxidant comprises a catalysed and co-catalysed hydrogen peroxide or has an ORP of up to about 1550 mV;

b) contacting the primary oxidised hydrocarbon material with a secondary oxidant to oxidize sulphur compounds not oxidised by the primary oxidant to sulphoxide and/or sulphone compounds to provide a secondary oxidised hydrocarbon material, wherein the secondary oxidant comprises chlorine dioxide or has an ORP of greater than about 1550 mV;

c) contacting the primary and/or secondary oxidised hydrocarbon material with an aqueous extractant to allow at least a portion of the sulphoxide and/or sulphone compounds to be extracted into the aqueous extractant to give a sulphoxide and/or sulphone stream and a low sulphur hydrocarbon stream; and

d) contacting the sulphoxide and/or sulphone stream with a tertiary oxidant to give a sulphite stream and a low sulphur aromatic hydrocarbon stream, wherein the tertiary oxidant oxidises the sulphone and/or sulphoxide compounds to sulphite compounds.

49. The process according to claim 48, wherein the primary oxidant is a catalysed and co-catalysed hydrogen peroxide, said hydrogen peroxide being catalysed by phosphotungstic acid and co-catalysed with a Phase Transfer Catalyst (PTC).

50. The process according to claim 48, wherein the primary oxidant is the catalysed and co-catalysed hydrogen peroxide, said hydrogen peroxide being catalysed by phosphotungstic acid comprising sodium tungstate dihydrate and phosphoric acid and co-catalysed by a Phase Transfer Catalyst (PTC) comprising a quaternary ammonium salt selected from the group consisting of quaternary ammonium hydrogen sulphates,

methyltrialkyl($C_8$-$C_{10}$)ammonium chloride and N-Methyl-N,N-dioctyloctane-1-ammonium chlorides.

51. The process according to claim 48, wherein the primary oxidant is the catalysed and co-catalysed hydrogen peroxide, said hydrogen peroxide being catalysed by phosphotungstic acid and co-catalysed by a tri-C8-10-alkylmethyl, hydrogen sulfate.

52. The process according to claim 48, wherein the hydrocarbon material is contacted with the primary oxidant in at least a stoichiometric amount for the conversion of sulphur compounds to sulphoxide and/or sulphone compounds.

53. The process according to claim 48, wherein the secondary oxidant is the chlorine dioxide, in the form of a stabilised water solution having a chlorine dioxide content in the range of about 3000 ppm (0.3%) to 8000 ppm (0.8%).

54. The process according to claim 48, wherein the secondary oxidant is hypofluorous acid in acetonitrile, prepared by bubbling a gaseous mixture comprising fluorine and nitrogen into liquid acetonitrile to form $HOF.CH_3CN$, wherein the concentration of fluorine mixed with nitrogen does not exceed 20% by weight fluorine blended with the nitrogen.

55. The process according to claim 48, wherein the secondary oxidant is hydroxyl radicals.

56. The process according to claim 48, wherein the secondary oxidant is Liquid Ferrate VI.

57. The process according to claim 48, wherein in step c) the primary and/or secondary oxidised hydrocarbon material is contacted with an ionic liquid (IL) or a polar extraction solvent for a time and under conditions to allow at least a portion of the sulphoxide and/or sulphone compounds to be extracted or absorbed into the extraction solvent or liquid.

58. The process according to claim 57, wherein the extractant is selected from the group consisting of DMF, DMSO, methanol, furfural, water, acetonitrile, and combinations thereof.

59. The process according to claim 48, wherein the tertiary oxidant is a caustic solution, selected from the group consisting of:

i) sodium hydroxide,

ii) potassium hydroxide, and

iii) hydroxyl radicals.

60. The process according to claim 48, wherein the low sulphur hydrocarbon stream obtained in step c) is polished using adsorbents including MOF (Metal Organic Framework), ($C_{18}H_6Cu_3O_{12}$)-Copper Benzene-1,3,5-Tricarboxylate, Metal Oxide Purification Adsorbent group of adsorbents, $CuCl_2$MIL-47 MOF, Y-Zeolite, Molecular Imprinted Chitosan or Activated Carbon.