standards for passenger car motor oils. Prior solutions to undesired LSPI events are less than satisfactory because fluid manufactures tended to address LSPI problems with the addition of supplemental fluid componentry, which often places other constraints on the additive package in the fluid not to mention that supplemental additives can, in some instances, provide other unintended effects.

## SUMMARY

**[0004]** In one aspect, the present disclosure refers to a lubricating composition for a spark-ignition engine, the lubricating composition comprising: one or more base oils of lubricating viscosity; one or more phosphorus-containing additives providing no more than 500 ppm of phosphorus to the lubricating composition; a detergent system providing one or more overbased calcium-containing detergents and optionally one or more magnesium-containing detergents, and wherein the detergent system is substantially free of sodium-containing detergents; one or more silicon-containing compounds providing 3 to 20 ppm silicon to the lubricating composition; wherein the lubricating composition includes a calcium content providing no more than 0.19 weight percent of calculated calcium sulfated ash content; a weight ratio of phosphorus content to calcium sulfated ash content of at least 0.1;wherein 30 weight percent or less of total calculated SASH content is provided by the calcium sulfated ash content; wherein the overbased calcium-containing detergent has a total base number (TBN) of at least 250 mg KOH/g as determined by ASTM D2896; and wherein a weight ratio of calcium sulfated ash content to silicon content is 250 or less. In one approach or example, the present disclosure relates to a lubricating composition for a spark-ignition engine to provide good LSPI performance with low levels of phosphorus. In one example, the lubricating composition included one or more base oils of lubricating viscosity; one or more phosphorus-containing additives providing no more than about 500 ppm of phosphorus to the lubricating composition; a detergent system providing one or more calcium-containing detergents and optionally one or more magnesium-containing detergents, and wherein the detergent system is substantially free of sodium-containing detergents; wherein the lubricating composition includes a calcium content such that the lubricating composition has no more than about 0.2 weight percent of calculated calcium sulfated ash content; and a weight ratio of phosphorus content to calcium sulfated ash content of at least about 0.1.

**[0005]** In other approaches or examples, the lubricating composition of the previous paragraph may include one or more optional features or examples in any combination. These optional features or examples may include one or more of the following: wherein the weight ratio of the phosphorus content to the calcium sulfated ash content is about 0.1 to about 0.3; and/or wherein the lubricating composition has a total calculated sulfated ash content (SASH) of about 1 weight percent or less; and/or wherein the lubricating composition has a total calculated sulfated ash content (SASH) of about 0.8 weight percent or less; and/or wherein the lubricating composition has a total calculated sulfated ash content (SASH) of about 0.7 weight percent or less; and/or wherein about 30 weight percent or less of the total calculated SASH content is provided by the calcium sulfated ash content; and/or further comprising one or more silicon-containing compounds providing about 3 to about 20 ppm silicon to the lubricating composition; and/or wherein the one or more silicon-containing compounds provide about 5 to about 15 ppm silicon; and/or wherein a weight ratio of calcium sulfated ash content to silicon content is about 250 or less; and/or wherein the silicon-containing compound is selected from organosilane compounds, fluorosilicone

compounds, polydimethylsiloxane compounds, phenyl-methyl polysiloxane compounds, linear siloxane compounds, cyclic siloxane compounds, branched siloxane compounds, silicone polymers and copolymers, organo-silicone copolymers, silicone oil, or combinations thereof; and/or wherein the detergent system includes the calcium-containing detergent and the magnesium-containing detergent; and/or wherein the detergent system includes calcium sulfonate and optionally magnesium sulfonate; and/or wherein the calcium sulfonate and the optional magnesium sulfonate are each overbased and each having a total base number (TBN) of at least about 250 mg KOH/g as determined by ASTM D2896; and/or wherein the detergent system is free of phenate-based detergents; and/or wherein the one or more base oils of lubricating viscosity are selected from API Group I base oils, API Group II base oils, API Group III base oils, or combinations thereof; and/or wherein the one or more base oils of lubricating viscosity are selected from API Group I base oils, API Group II base oils, or combinations thereof; and/or wherein the lubricating composition exhibits no more than 5 average events pursuant to a Sequence IX low speed pre-ignition test of ASTM D8291 and/or exhibits no more than 8 maximum events pursuant to the Sequence IX low speed pre-ignition test of ASTM D8291; and/or wherein the one or more phosphorus-containing additives provide about 200 to about 400 ppm phosphorus.

**[0006]** In another aspect, the present disclosure refers to a method of lubricating a spark-ignition engine, the method comprising: lubricating the crankcase of a spark-ignition engine with a lubricating composition; wherein the lubricating composition includes (i) one or more base oils of lubricating viscosity; (ii) one or more phosphorus-containing additives providing no more than 500 ppm of phosphorus to the lubricating composition; (iii) a detergent system providing one or more overbased calcium-containing detergents and optionally one or more magnesium-containing detergents, and wherein the detergent system is substantially free of sodium-containing detergents; (iv) one or more silicon-containing compounds providing 3 to 20 ppm silicon to the lubricating composition; (v) wherein the lubricating composition includes a calcium content providing no more than 0.19 weight percent calculated calcium sulfated ash content; and (vi) a weight ratio of phosphorus content to calcium sulfated ash content of at least 0.1; and wherein 30 weight percent or less of total calculated SASH content is provided by the calcium sulfated ash content; wherein the overbased calcium-containing detergent has a total base number (TBN) of at least 250 mg KOH/g as determined by ASTM D2896; and wherein a weight ratio of calcium sulfated ash content to silicon content is 250 or less; and wherein the lubricating composition exhibits no more than 5

average events pursuant to a Sequence IX low speed pre-ignition test of ASTM D8291 and/or exhibits no more than 8 maximum events pursuant to the Sequence IX low speed pre-ignition test of ASTM D8291. In yet further approaches or examples, methods of lubricating a spark-ignition engine with a low phosphorus content lubricant is provided herein. In one example, the method includes lubricating the crankcase of a spark-ignition engine with a lubricating composition; wherein the lubricating composition includes (i) one or more base oils of lubricating viscosity; (ii) one or more phosphorus-containing additives providing no more than about 500 ppm of phosphorus to the lubricating composition; (iii) a detergent system providing one or more calcium-containing detergents and optionally one or more magnesium-containing detergents, and wherein the detergent system is substantially free of sodium-containing detergents; (iv) wherein the lubricating composition includes a calcium content providing no more than about 0.2 weight percent of calculated calcium sulfated ash content; and (v) a weight ratio of phosphorus content to calcium sulfated ash content of at least about 0.1; and wherein the lubricating composition exhibits no more than 5 average events pursuant to a Sequence IX low speed pre-ignition test of ASTM D8291 and/or exhibits no more than 8 maximum events pursuant to the Sequence IX low speed pre-ignition test of ASTM D8291.

**[0007]** In further approaches or examples, the methods of the previous paragraph may include one or more optional steps, features, or examples in any combination. These

optional steps, features, or examples may include more or more of the following: wherein the weight ratio of the phosphorus content to the calcium sulfated ash content is about 0.1 to about 0.3; and/or wherein the lubricating composition further includes one or more silicon-containing compounds providing about 3 to about 20 ppm silicon to the lubricating composition; and/or wherein a weight ratio of calcium sulfated ash content to silicon content is about 250 or less. The methods herein may also include any example of the lubricating composition as described in this Summary.

**[0008]** In yet other approaches or examples, the present application further includes the use of a lubricating compositions having low levels of phosphorus to achieve passing LSPI pursuant to ASTM D8291. In examples, the use includes lubricating the crankcase of a spark-ignition engine with a lubricating composition; wherein the lubricating composition includes (i) one or more base oils of lubricating viscosity; (ii) one or more phosphorus-containing additives providing no more than about 500 ppm of phosphorus to the lubricating composition; (iii) a detergent system providing one or more calcium-containing detergents and optionally one or more magnesium-containing detergents, and wherein the detergent system is substantially free of sodium-containing detergents; (iv) wherein the lubricating composition includes no more than about 0.2 weight percent of calculated calcium sulfated ash content; and (v) a weight ratio of phosphorus content to calcium sulfated ash content of at least about 0.1; and wherein the lubricating composition exhibits no more than 5 average events pursuant to a Sequence IX low speed pre-ignition test of ASTM D8291 and/or exhibits no more than 8 maximum events pursuant to the Sequence IX low speed pre-ignition test of ASTM D8291. The use herein may include any example of the lubricating compositions has described in this Summary.

## DETAILED DESCRIPTION

**[0009]** The present disclosure relates to lubricating compositions and methods of lubricating a spark-ignition engine effective to improve low-speed pre-ignition (LSPI) through selection of lubricant elemental relationships rather than through the addition of supplemental fluid additives with the added benefit that the relationships herein, in some circumstances, improve the low-speed pre-ignition independent of the underlying base oil quality. In approaches or embodiments, the lubricating compositions herein include one or more base oils of lubricating viscosity, one or more phosphorus-containing additives providing no more than about 500 ppm of phosphorus, a detergent system providing calcium

## CLAIMS

What is claimed is:

1. A lubricating composition for a spark-ignition engine, the lubricating composition comprising:

one or more base oils of lubricating viscosity;

one or more phosphorus-containing additives providing no more than 500 ppm of phosphorus to the lubricating composition;

a detergent system providing one or more overbased calcium-containing detergents and optionally one or more magnesium-containing detergents, and wherein the detergent system is substantially free of sodium-containing detergents;

one or more silicon-containing compounds providing 3 to 20 ppm silicon to the lubricating composition;

wherein the lubricating composition includes a calcium content providing no more than 0.19 weight percent of calculated calcium sulfated ash content;

a weight ratio of phosphorus content to calcium sulfated ash content of at least 0.1;

wherein 30 weight percent or less of total calculated SASH content is provided by the calcium sulfated ash content;

wherein the overbased calcium-containing detergent has a total base number (TBN) of at least 250 mg KOH/g as determined by ASTM D2896; and

wherein a weight ratio of calcium sulfated ash content to silicon content is 250 or less.

2. The lubricating composition of claim 1, wherein the weight ratio of the phosphorus content to the calcium sulfated ash content is 0.1 to 0.3.

3. The lubricating composition of claim 2, wherein the lubricating composition has a total calculated sulfated ash content (SASH) of 1 weight percent or less.

4. The lubricating composition of claim 1, wherein the lubricating composition has a total calculated sulfated ash content (SASH) of 0.8 weight percent or less.

5. The lubricating composition of claim 1, wherein the lubricating composition has a total calculated sulfated ash content (SASH) of 0.7 weight percent or less.

6. The lubricating composition of claim 1, wherein the one or more silicon-containing compounds provide 5 to 15 ppm silicon.

7. The lubricating composition of claim 1, wherein the silicon-containing compound is selected from organosilane compounds, fluorosilicone compounds, polydimethylsiloxane compounds, phenyl-methyl polysiloxane compounds, linear siloxane compounds, cyclic siloxane compounds, branched siloxane compounds, silicone polymers and copolymers, organo-silicone copolymers, silicone oil, or combinations thereof.

8. The lubricating composition of claim 1, wherein the detergent system includes the calcium-containing detergent and the magnesium-containing detergent.

9. The lubricating composition of claim 1, wherein the detergent system includes calcium sulfonate and optionally magnesium sulfonate.

10. The lubricating composition of claim 9, wherein the calcium sulfonate and the optional magnesium sulfonate are each overbased and each having a total base number (TBN) of at least 250 mg KOH/g as determined by ASTM D2896.

11. The lubricating composition of claim 1, wherein the detergent system is free of phenate-based detergents.

12. The lubricating composition of claim 1, wherein the one or more base oils of lubricating viscosity are selected from API Group I base oils, API Group II base oils, API Group III base oils, or combinations thereof.

13. The lubricating composition of claim 1, wherein the one or more base oils of lubricating viscosity are selected from API Group I base oils, API Group II base oils, or combinations thereof.

14. The lubricating composition of claim 1, wherein the lubricating composition exhibits no more than 5 average events pursuant to a Sequence IX low speed pre-ignition test of ASTM D8291 and/or exhibits no more than 8 maximum events pursuant to the Sequence IX low speed pre-ignition test of ASTM D8291.

15. The lubricating composition of claim 1, wherein the one or more phosphorus-containing additives provide 200 to 400 ppm phosphorus.

16. A method of lubricating a spark-ignition engine, the method comprising:

lubricating the crankcase of a spark-ignition engine with a lubricating composition;

wherein the lubricating composition includes (i) one or more base oils of lubricating viscosity; (ii) one or more phosphorus-containing additives providing no more than 500 ppm of phosphorus to the lubricating composition; (iii) a detergent system providing one or more overbased calcium-containing detergents and optionally one or more magnesium-containing detergents, and wherein the detergent system is substantially free of sodium-containing detergents; (iv) one or more silicon-containing compounds providing 3 to 20 ppm silicon to the lubricating composition; (v) wherein the lubricating composition includes a calcium content providing no more than 0.19 weight percent calculated calcium sulfated ash content; and (vi) a weight ratio of phosphorus content to calcium sulfated ash content of at least 0.1; and wherein 30 weight percent or less of total calculated SASH content is provided by the calcium sulfated ash content; wherein the overbased calcium-containing detergent has a total base number (TBN) of at least 250 mg KOH/g as determined by ASTM D2896; and wherein a weight ratio of calcium sulfated ash content to silicon content is 250 or less; and

wherein the lubricating composition exhibits no more than 5 average events pursuant to a Sequence IX low speed pre-ignition test of ASTM D8291 and/or exhibits no more than 8 maximum events pursuant to the Sequence IX low speed pre-ignition test of ASTM D8291.

17. The method of claim 16, wherein the weight ratio of the phosphorus content to the calcium sulfated ash content is 0.1 to 0.3.

18. The method of claim 16, wherein the lubricating composition further includes one or more silicon-containing compounds providing 3 to 20 ppm silicon to the lubricating composition.