operated at the high fuel pressures of newer engine technology. Other prior additives may provide some level of injector clean-up performance, but require considerably higher treat rates and/or lengthy clean-up times to achieve performance.

## DESCRIPTION OF FIGURE

**[0005]** FIG. 1 is a graph showing the clean-up performance of fuel injector cleaning mixtures of the present disclosure when combusted in a gasoline engine running at high fuel pressures.

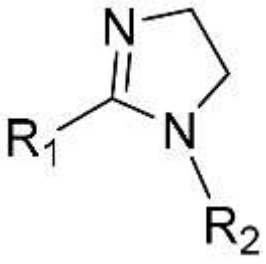
## SUMMARY

**[0005a]** In a first aspect of the present disclosure, there is provided a method of reducing fuel injector deposits in a gasoline engine, the method comprising:

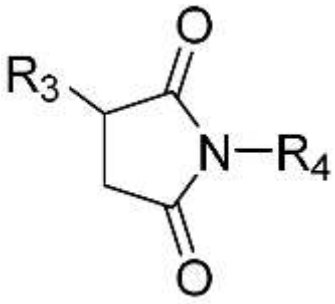
providing a fuel composition at a pressure of 580 to 1,980 psi to a fuel injector of a gasoline engine and combusting the fuel composition in the gasoline engine;

the fuel composition including a major amount of gasoline and a minor amount of a fuel injector clean-up mixture;

the fuel injector clean-up mixture including 1 to 20 ppm of a first additive of a heterocyclic amine of Formula I, an open chain derivative thereof, or mixtures thereof and 1 to 20 ppm of a second additive of Formula II




(Formula I)




(Formula II)

wherein

$R_1$ is a hydrocarbyl group having 14 to 20 carbons; and

$R_2$ is a hydroxyalkyl group having 1 to 10 carbons;

$R_3$ is a hydrocarbyl group derived from a polyisobutylene having a number average molecular weight of 700 to 1000;

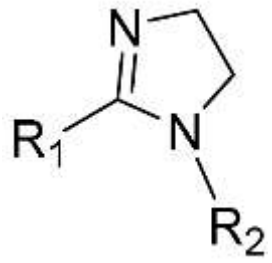
$R_4$ is a polyamine derived from triethylene tetraamine, tetraethylene pentamine, pentaethylene hexamine, or combinations thereof; and

wherein the fuel composition contains a weight ratio between the first additive to the second additive of 2:1 to 1:2; and

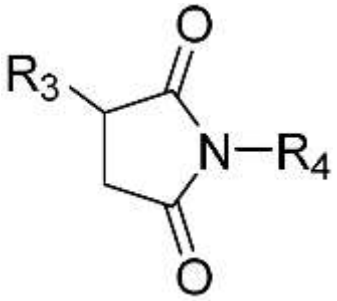
wherein the fuel injector clean-up mixture achieves 40 to 60 percent of the fuel injector clean-up in less than 500 miles.

**[0005b]** In another aspect of the present disclosure, there is provided a fuel additive concentrate for use in gasoline to clean-up fuel injector deposits in a high-pressure gasoline engine, the fuel additive concentrate comprising:

a fuel injector clean-up mixture including 1 to 20 ppm of a first additive of a heterocyclic amine of Formula I, an open chain derivative thereof, or mixtures thereof and 1 to 20 ppm of a second additive of Formula II




(Formula I)




(Formula II)

wherein

$R_1$ is a hydrocarbyl group having 14 to 20 carbons; and

$R_2$ is a hydroxyalkyl group having 1 to 10 carbons;

$R_3$ is a hydrocarbyl group derived from a polyisobutylene having a number average molecular weight of 700 to 1000;

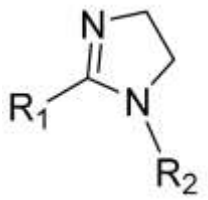
$R_4$ is a polyamine derived from triethylene tetraamine, tetraethylene pentamine, pentaethylene hexamine, or combinations thereof;

a weight ratio of the first additive to the second additive of 2:1 to 1:2; and

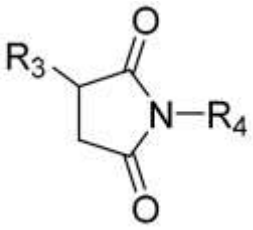
when the fuel additive concentrate is added to gasoline in the weight ratio of the first additive to the second additive, the fuel injector clean-up mixture achieves 50 to 100 percent clean-up of fuel injector deposits in 5 tanks of fuel or less when the gasoline is supplied at pressure of 580 to 1,980 psi and when the clean-up of injector deposits is measured by at least one of long-term fuel trim, injector pulse width, injection duration, injector flow, and combinations thereof.

**[0006]** In one example of this present disclosure, a method of reducing fuel injector deposits in a gasoline engine is described. In one approach or example, the method includes providing a fuel composition at a pressure of about 500 to about 7,500 psi to a fuel injector of a gasoline engine and combusting the fuel composition in the gasoline engine. The fuel composition includes a major amount of gasoline and a minor amount of a

fuel injector clean-up mixture. The fuel injector clean-up mixture includes a first additive of a heterocyclic amine of Formula I, an open chain derivative thereof, or mixtures thereof and a second additive of Formula II




(Formula I)



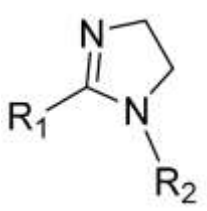

(Formula II)

wherein $R_1$ is a hydrocarbyl group having 6 to 80 carbons; $R_2$ is a hydrogen, a hydrocarbyl group having 1 to 20 carbons, a hydroxyalkyl group having 1 to 10 carbons, an acylated hydroxyalkyl group having 1 to 10 carbons, a polyamino group, or an acylated polyamino group; $R_3$ is a hydrocarbyl group; and $R_4$ is hydrogen, an alkyl group, an aryl group, -OH, -$NHR_5$, or a polyamine and wherein $R_5$ is a hydrogen or an alkyl group.

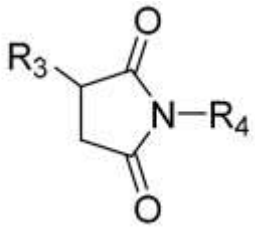
**[0007]** In other examples of this present disclosure, the method of the preceding paragraph may be combined or include one or more optional features in any combination thereof. These optional examples include: wherein a ratio of the first additive to the second additive is about 1:5 to about 5:1; and/or wherein the fuel composition includes about 1.5 to about 100 ppmw of the first additive and about 3 to about 800 ppmw of the second

triethylene tetraamine, tetraethylene pentamine, pentaethylene hexamine, N-N'-(iminodi-2,1,ethanediyl)bis-1,3-propanediamine, and combinations thereof.

**[0008]** In yet a further example of this present disclosure, a fuel additive concentrate for use in gasoline to clean-up fuel injector deposits in a high-pressure gasoline engine is described. In one approach or example, the fuel additive concentrate includes a fuel injector clean-up mixture including a first additive of a heterocyclic amine of Formula I, an open chain derivative thereof, or mixtures thereof and a second additive of Formula II




(Formula I)




(Formula II)

wherein $R_1$ is a hydrocarbyl group having 6 to 80 carbons; $R_2$ is a hydrogen, a hydrocarbyl group having 1 to 20 carbons, a hydroxyalkyl group having 1 to 10 carbons, an acylated hydroxyalkyl group having 1 to 10 carbons, a polyamino group, or an acylated polyamino group; $R_3$ is a hydrocarbyl group; $R_4$ is hydrogen, an alkyl group, an aryl group, -OH, -NHR 5, or a polyamine and wherein $R_5$ is a hydrogen or an alkyl group; a ratio of the first additive to the second additive of about 5:1 to about 1:5; and when the fuel additive concentrate is added to gasoline in amounts of no more than 600 ppmw and in the ratio of the first additive to the second additive, the fuel injector clean-up mixture achieves about 50 to about 100 percent clean-up of fuel injector deposits in 5 tanks of fuel or less when the gasoline is supplied at pressure of about 500 to about 7,500 psi and when the clean-up of injector deposits is measured by at least one of long-term fuel trim, injector pulse width, injection duration, injector flow, and combinations thereof.

**[0009]** The fuel additive concentrate of the previous paragraph may be combined with and/or include optional features or examples in any combination thereof. These optional features include: wherein $R_1$ is derived from a monocarboxylic acid including 2-ethylhexanoic acid, isostearic acid, capric acid, myristic acid, palmitic acid, stearic acid, tall oil fatty acids, linoleic acid, oleic acid, naphthenic acids, or mixtures thereof; and/or wherein $R_2$ is selected from a hydroxy methyl group, a hydroxy ethyl group, a hydroxy propyl group, and mixtures thereof; and/or wherein $R_2$ is a hydroxyalkyl group having 1 to 5 carbons; an acylated hydroxyalkyl group having 1 to 5 carbons; a polyamino group derived from diethyelene triamine, triethylene tetraamine, tetraethylene pentamine, pentaethylene

## CLAIMS

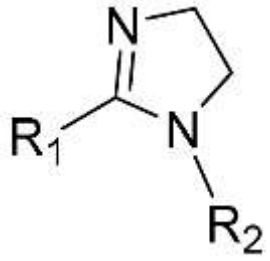
WHAT IS CLAIMED IS

1. A method of reducing fuel injector deposits in a gasoline engine, the method comprising:

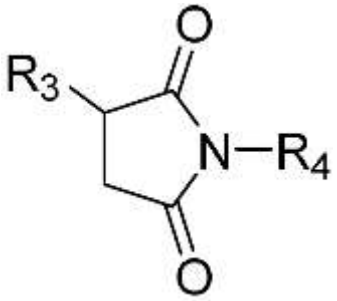
providing a fuel composition at a pressure of 580 to 1,980 psi to a fuel injector of a gasoline engine and combusting the fuel composition in the gasoline engine;

the fuel composition including a major amount of gasoline and a minor amount of a fuel injector clean-up mixture;

the fuel injector clean-up mixture including 1 to 20 ppm of a first additive of a heterocyclic amine of Formula I, an open chain derivative thereof, or mixtures thereof and 1 to 20 ppm of a second additive of Formula II




(Formula I)




(Formula II)

wherein

$R_1$ is a hydrocarbyl group having 14 to 20 carbons; and

$R_2$ is a hydroxyalkyl group having 1 to 10 carbons;

$R_3$ is a hydrocarbyl group derived from a polyisobutylene having a number average molecular weight of 700 to 1000;

$R_4$ is a polyamine derived from triethylene tetraamine, tetraethylene pentamine, pentaethylene hexamine, or combinations thereof; and

wherein the fuel composition contains a weight ratio between the first additive to the second additive of 2:1 to 1:2; and

wherein the fuel injector clean-up mixture achieves 40 to 60 percent of the fuel injector clean-up in less than 500 miles.

2. The method of reducing fuel injector deposits in a gasoline engine according to claim 1, wherein the fuel composition includes 1 to 10 ppmw of the first additive and 1 to 10 ppmw of the second additive.

3. The method of reducing fuel injector deposits in a gasoline engine according to claim 1, wherein the fuel composition includes up to 100 ppmw of the fuel injector clean-up mixture.

4. The method of reducing fuel injector deposits in a gasoline engine according to claim 1, wherein the fuel composition further includes 45 to 1000 ppmw of a separate intake valve deposit (IVD) control additive selected from a Mannich detergent, polyetheramine detergent, hydrocarbyl amine detergent, and combinations thereof.

5. The method of reducing fuel injector deposits in a gasoline engine according to claim 4, wherein the fuel composition further includes at least one additive selected from the group consisting of antioxidants, carrier fluids, metal deactivators, dyes, markers, corrosion inhibitors, biocides, antistatic additives, drag reducing agents, demulsifiers, emulsifiers, dehazers, anti-icing additives, antiknock additives, anti-valve-seat recession additives, lubricity additives, surfactants and combustion improvers.

6. The method of reducing fuel injector deposits in a gasoline engine according to claim 1, wherein the clean-up of injector deposits is measured by at least one of long-term fuel trim, injector pulse width, injection duration, injector flow, and combinations thereof.

7. The method of reducing fuel injector deposits in a gasoline engine according to claim 1, wherein $R_2$ is a hydroxy methyl group, a hydroxy ethyl group, a hydroxy propyl group, or mixtures thereof.

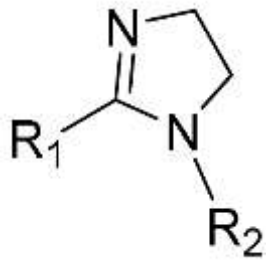
8. The method of reducing fuel injector deposits in a gasoline engine according to claim 1, wherein $R_2$ is a hydroxyalkyl group having 1 to 5 carbons.

9. The method of reducing fuel injector deposits in a gasoline engine according to claim 1, wherein $R_4$ is derived from tetraethylene pentamine or derivatives thereof.

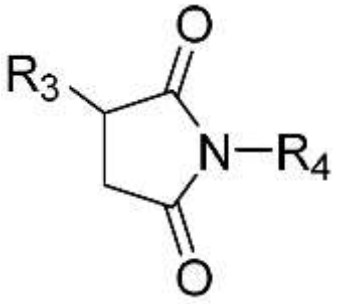
10. The method of reducing fuel injector deposits in a gasoline engine according to claim 1, wherein the fuel composition is provided at a pressure of 580 to 1980 psi.

11. A fuel additive concentrate for use in gasoline to clean-up fuel injector deposits in a high-pressure gasoline engine, the fuel additive concentrate comprising:

a fuel injector clean-up mixture including 1 to 20 ppm of a first additive of a heterocyclic amine of Formula I, an open chain derivative thereof, or mixtures thereof and 1 to 20 ppm of a second additive of Formula II




(Formula I)




(Formula II)

wherein

$R_1$ is a hydrocarbyl group having 14 to 20 carbons; and

$R_2$ is a hydroxyalkyl group having 1 to 10 carbons;

$R_3$ is a hydrocarbyl group derived from a polyisobutylene having a number average molecular weight of 700 to 1000;

$R_4$ is a polyamine derived from triethylene tetraamine, tetraethylene pentamine, pentaethylene hexamine, or combinations thereof;

a weight ratio of the first additive to the second additive of 2:1 to 1:2; and

when the fuel additive concentrate is added to gasoline in the weight ratio of the first additive to the second additive, the fuel injector clean-up mixture achieves 50 to 100 percent clean-up of fuel injector deposits in 5 tanks of fuel or less when the gasoline is supplied at pressure of 580 to 1,980 psi and when the clean-up of injector deposits is measured by at least one of long-term fuel trim, injector pulse width, injection duration, injector flow, and combinations thereof.

12. The fuel additive concentrate of claim 11, wherein $R_2$ is selected from a hydroxy methyl group, a hydroxy ethyl group, a hydroxy propyl group, and mixtures thereof.

13. The fuel additive concentrate of claim 11, wherein $R_2$ is a hydroxyalkyl group having 1 to 5 carbons.

14. The fuel additive concentrate of claim 11, wherein $R_4$ is derived from tetraethylene pentamine or derivatives thereof.

FUEL ADDITIVE MIXTURE PROVIDING RAPID INJECTOR CLEAN-UP IN HIGH PRESSURE GASOLINE ENGINES


## ABSTRACT

The present disclosure relates to methods and fuel compositions for reducing or eliminating fuel injector deposits in high pressure gasoline engines. The fuel compositions include gasoline and a synergistic combination of a fuel injector clean-up mixture including a heterocyclic amine, diamine, or open chain derivative thereof and a hydrocarbyl substituted dicarboxylic anhydride derivative selected from a diamide, acid/amide, acid/ester, diacid, amide/ester, diester, and imide.

[Figure 1]