PHASE-STABILIZED AMMONIUM NITRATE PRILLS AND RELATED PRODUCTS AND METHODS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to Australian Provisional Patent Application No. 2019900348, entitled “PHASE-STABILIZED AMMONIUM NITRATE PRILLS”, filed February 5, 2019 and Australian Provisional Patent Application No. 2019904447, entitled “PHASE-STABILIZED AMMONIUM NITRATE PRILLS AND RELATED PRODUCTS AND METHODS”, filed November 25, 2019, the contents of each of which are hereby incorporated herein by reference in their entirety.

TECHNICAL FIELD

[0002] The present disclosure relates generally to explosives. More specifically, the present disclosure relates to phase-stabilized ammonium nitrate (PSAN) prill including ammonium nitrate and a potassium salt. The PSAN prill can be explosive grade and low density. The present disclosure also relates to methods of preparing the PSAN prill and related emulsions.

SUMMARY

[0002a] In an aspect of the present disclosure, there is provided a phase-stabilized ammonium nitrate (PSAN) prill comprising:

ammonium nitrate;

a porosity enhancing agent; and

a potassium salt, wherein the PSAN prill comprises from 2.1 mole percent (mol%) to 5 mol% potassium ions of the potassium salt based on the ammonium ions of the ammonium nitrate, wherein the potassium salt comprises at least one of potassium hydroxide, potassium nitrate, potassium sulfate or potassium hydrogen sulfate;

wherein the PSAN prill is explosive grade and has a bulk density less than 0.9 kg/L,

wherein the PSAN prill substantially lacks a 32 °C crystalline phase change, and

wherein upon thermal cycling the PSAN prill 20 times, wherein one cycle comprises four hours at 15 °C followed by four hours at 45 °C, an average crush strength of the thermal cycled PSAN prill is greater than an average crush strength of non-thermal cycled control PSAN prill.

[0002b] In another aspect of the present disclosure, there is provided an emulsion explosive blend comprising an emulsion explosive and the PSAN prill disclosed herein blended with the emulsion explosive.

[0002c] In a further aspect of the present disclosure, there is provided a method of preparing a phase-stabilized ammonium nitrate (PSAN) prill disclosed herein, the method comprising:

forming a PSAN solution comprising a potassium salt, a porosity enhancing agent and ammonium nitrate; and

crystallizing the PSAN solution to form a PSAN prill, wherein the PSAN prill comprises from 2.1 mole percent (mol%) to 5 mol% potassium ions of the potassium salt based on the ammonium ions of the ammonium nitrate, wherein the potassium salt comprises at least one of potassium hydroxide, potassium nitrate, potassium sulfate or potassium hydrogen sulfate, and

wherein the PSAN prill is explosive grade and has a bulk density less than 0.9 kg/L, and

wherein the PSAN prill substantially lacks a 32 °C crystalline phase change, and

wherein upon thermal cycling the PSAN prill 20 times, wherein one cycle comprises four hours at 15 °C followed by four hours at 45 °C, an average crush strength of the thermal cycled PSAN prill is greater than an average crush strength of non-thermal cycled control PSAN prill.

[0002d] In another aspect of the present disclosure, there is provided a method of increasing the hardness of a phase-stabilized ammonium nitrate (PSAN) prill, the method comprising:

forming a PSAN solution comprising a potassium salt, a porosity enhancing agent and ammonium nitrate; and

crystallizing the PSAN solution to form a PSAN prill, wherein the PSAN prill comprises from 2.1 mole percent (mol%) to 5 mol% potassium ions of the potassium salt based on the ammonium ions of the ammonium nitrate, wherein the potassium salt comprises at least one of potassium hydroxide, potassium nitrate, potassium sulfate or potassium hydrogen sulfate, and

thermal cycling the PSAN prill 20 times or more,

wherein the PSAN prill is explosive grade, and has a bulk density less than 0.9 kg/L, and

wherein the PSAN prill substantially lacks a 32 °C crystalline phase change

wherein upon thermal cycling the PSAN prill 20 times, wherein one cycle comprises four hours at 15 °C followed by four hours at 45 °C, an average crush strength of the thermal cycled PSAN prill is greater than an average crush strength of non-thermal cycled control PSAN prill.

[0002e] In a further aspect of the present disclosure, there is provided a method of making an emulsion explosive, the method comprising:

melting a PSAN prill disclosed herein into a liquor, the liquor comprising:

ammonium nitrate;

a porosity enhancing agent and

a potassium salt, wherein the PSAN prill comprises from 2.1 mole percent (mol%) to 5 mol% potassium ions of the potassium salt based on the ammonium ions of the ammonium nitrate, wherein the potassium salt comprises at least one of potassium hydroxide, potassium nitrate, potassium sulfate or potassium hydrogen sulfate; and

forming the liquor into a discontinuous oxidizer phase of an emulsion.

[0002f] In another aspect of the present disclosure, there is provided an emulsion explosive comprising:

a discontinuous oxidizer phase comprising a PSAN prill disclosed herein.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] The embodiments disclosed herein will become more fully apparent from the following description and appended claims, taken in conjunction with the accompanying drawings.

Claims:

1. A phase-stabilized ammonium nitrate (PSAN) prill comprising:

ammonium nitrate;

a porosity enhancing agent; and

a potassium salt, wherein the PSAN prill comprises from 2.1 mole percent (mol%) to 5 mol% potassium ions of the potassium salt based on the ammonium ions of the ammonium nitrate, wherein the potassium salt comprises at least one of potassium hydroxide, potassium nitrate, potassium sulfate or potassium hydrogen sulfate;

wherein the PSAN prill is explosive grade and has a bulk density less than 0.9 kg/L,

wherein the PSAN prill substantially lacks a 32 °C crystalline phase change, and

wherein upon thermal cycling the PSAN prill 20 times, wherein one cycle comprises four hours at 15 °C followed by four hours at 45 °C, an average crush strength of the thermal cycled PSAN prill is greater than an average crush strength of non-thermal cycled control PSAN prill.

2. The PSAN prill of claim 1, wherein the mol% of the potassium ions based on the ammonium ions is from 2.1 mol% to 4.0 mol%, or 3 mol%.

3. The PSAN prill of claim 1 or claim 2, wherein the PSAN prill has at least 5.7% porosity.

4. The PSAN prill of claim 3, wherein the porosity enhancing agent comprises an interfacial surface modifier, a pore former, or both.

5. The PSAN prill of claim 4, wherein the interfacial surface modifier comprises at least one of an alkyl sulfonate polymer, an alkaline metal salt of

naphthalenesulfonic acid, an alkaline metal salt of alkyl sulfonic acid, an alkaline metal salt of polystyrene sulfonic acid, or aluminum sulfate hydrate.

6. The PSAN prill of claim 4 or claim 5, wherein the concentration of the interfacial surface modifier is from 400 ppm to 4,000 ppm, from 400 ppm to 1000 ppm, from 500 ppm to 900 ppm, from 600 ppm to 800 ppm, 700 ppm, 2,000 ppm to 4,000 ppm, from 2,500 ppm to 3,900 ppm, from 3,000 ppm to 3,700 ppm, or 3,500 ppm.

7. The PSAN prill of any one of claims 1-6, wherein the potassium salt comprises at least one of potassium hydroxide, potassium nitrate, or potassium sulfate.

8. The PSAN prill of any one of claims 1-7, wherein the PSAN prill substantially lacks an 84 °C crystalline phase change.

9. The PSAN prill of any one of claims 1-8, wherein upon thermal cycling the PSAN prill 50 times, wherein one cycle comprises four hours at 15 °C followed by four hours at 45 °C, the thermal cycled PSAN prill has an average crush strength greater than 0.4 kg, including from 0.4 kg to 2.0 kg, 0.5 kg to 1.5 kg, 0.6 kg to 1.0 kg, or 0.7 kg to 0.9 kg.

10. The PSAN prill of any one of claims 1-9, wherein the shelf life of the PSAN prill is at least two months, at least four months, or at least six months at an average daytime ambient temperature from 30 °C to 50 °C and an average night time temperature of 10 °C to 30 °C.

11. The PSAN prill of any one of claims 1-10, wherein crystal domains of the PSAN prill are more tightly packed and more uniform than the crystal domains of an explosive grade ammonium nitrate prill devoid of potassium and having similar density and porosity to the PSAN prill.

12. The PSAN prill of any one of claims 1-11, wherein the PSAN prill comprises potassium uniformly distributed throughout the prill.

13. An emulsion explosive blend comprising an emulsion explosive and the PSAN prill of any one of claims 1-12 blended with the emulsion explosive.

14. A method of preparing a phase-stabilized ammonium nitrate (PSAN) prill according to claim 1, the method comprising:

forming a PSAN solution comprising a potassium salt, a porosity enhancing agent and ammonium nitrate; and

crystallizing the PSAN solution to form a PSAN prill, wherein the PSAN prill comprises from 2.1 mole percent (mol%) to 5 mol% potassium ions of the potassium salt based on the ammonium ions of the ammonium nitrate, wherein the potassium salt comprises at least one of potassium hydroxide, potassium nitrate, potassium sulfate or potassium hydrogen sulfate, and

wherein the PSAN prill is explosive grade and has a bulk density less than 0.9 kg/L, and

wherein the PSAN prill substantially lacks a 32 °C crystalline phase change, and

wherein upon thermal cycling the PSAN prill 20 times, wherein one cycle comprises four hours at 15 °C followed by four hours at 45 °C, an average crush strength of the thermal cycled PSAN prill is greater than an average crush strength of non-thermal cycled control PSAN prill.

15. A method of increasing the hardness of a phase-stabilized ammonium nitrate (PSAN) prill, the method comprising:

forming a PSAN solution comprising a potassium salt, a porosity enhancing agent and ammonium nitrate; and

crystallizing the PSAN solution to form a PSAN prill, wherein the PSAN prill comprises from 2.1 mole percent (mol%) to 5 mol% potassium ions of the potassium salt based on the ammonium ions of the ammonium nitrate, wherein the potassium salt comprises at least one of potassium hydroxide, potassium nitrate, potassium sulfate or potassium hydrogen sulfate, and

thermal cycling the PSAN prill 20 times or more,

wherein the PSAN prill is explosive grade, and has a bulk density less than 0.9 kg/L, and

wherein the PSAN prill substantially lacks a 32 °C crystalline phase change

wherein upon thermal cycling the PSAN prill 20 times, wherein one cycle comprises four hours at 15 °C followed by four hours at 45 °C, an average crush strength of the thermal cycled PSAN prill is greater than an average crush strength of non-thermal cycled control PSAN prill.

16. A method of making an emulsion explosive, the method comprising:

melting a PSAN prill of any one of claims 1-12 into a liquor, the liquor comprising:

ammonium nitrate;

a porosity enhancing agent and

a potassium salt, wherein the PSAN prill comprises from 2.1 mole percent (mol%) to 5 mol% potassium ions of the potassium salt based on the ammonium

ions of the ammonium nitrate, wherein the potassium salt comprises at least one of potassium hydroxide, potassium nitrate, potassium sulfate or potassium hydrogen sulfate; and

forming the liquor into a discontinuous oxidizer phase of an emulsion.

17. An emulsion explosive comprising:

a discontinuous oxidizer phase comprising the PSAN prill according to any one of claims 1-12.