PHASE-STABILIZED AMMONIUM NITRATE EXPLOSIVES

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to Australian Provisional Patent Application No. 2020902693, entitled PHASE-STABILIZED AMMONIUM NITRATE EXPLOSIVES, filed July 31, 2020, which is hereby incorporated by reference in its entirety.

TECHNICAL FIELD

[0002] The present disclosure relates generally to explosives. More specifically, the present disclosure relates to phase-stabilized ammonium nitrate (PSAN) explosives.

SUMMARY

[0002a] In one aspect, the present disclosure relates to a phase-stabilized ammonium nitrate (PSAN) explosive comprising: a PSAN prill comprising: ammonium nitrate; a potassium salt, wherein the PSAN prill comprises from 0.5 mole percent (mol%) to 5 mol% potassium ions of the potassium salt based on the ammonium ions of the ammonium nitrate; and an inorganic porosity enhancing agent comprising aluminum sulfate; and a fuel.

[0002b] In another aspect, the present disclosure relates to a method of increasing the hardness of a phase-stabilized ammonium nitrate (PSAN) explosive, the method comprising: providing the PSAN explosive as defined herein, and thermal cycling the PSAN explosive 20 times or more.

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.

[0004] FIG. 1 is a graph showing the crush strength versus thermal cycles of ammonium nitrate fuel oil (ANFO) made with conventional ammonium nitrate (AN) prills and ANFO made with exemplary PSAN prills.

[0005] FIG. 2 is a graph showing the temperature of PSAN prills compared to conventional LOAN prills when cycled in an oven.

[0006] FIG. 3 is a graph showing the time taken to heat PSAN prills to 50 °C compared to conventional LOAN prills.

Claims:

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

ammonium nitrate;

a potassium salt, wherein the PSAN prill comprises from 0.5 mole percent (mol%) to 5 mol% potassium ions of the potassium salt based on the ammonium ions of the ammonium nitrate; and

an inorganic porosity enhancing agent comprising aluminum sulfate;

and a fuel.

2. The PSAN explosive of claim 1, wherein the mol% of the potassium ions based on the ammonium ions is from 2 mol% to 5 mol%, 2 mol% to 4 mol%, 2.1 mol% to 4 mol%, or about 3 mol%.

3. The PSAN explosive of claim 1 or claim 2, wherein the fuel comprises a liquid fuel, including fuel oil, diesel oil, distillate, furnace oil, kerosene, gasoline, or naphtha; waxes including microcrystalline wax, paraffin wax, or slack wax; oils including paraffin oils, benzene, toluene, or xylene oils, asphaltic materials, polymeric oils, animal oils, or other mineral, hydrocarbon, or fatty oils; and mixtures thereof.

4. The PSAN explosive of any one of claims 1-3, wherein a weight ratio of the PSAN prill to fuel is 80:20 to 97:3, 85:15 to 96:4, 90:10 to 95:5, or 94:6.

5. The PSAN explosive of any one of claims 1-4, wherein the fuel is not an emulsion.

6. The PSAN explosive of any one of claims 1-5, wherein the concentration of the inorganic porosity enhancing agent in the prill is from 400 ppm to 4,000 ppm, from 400 ppm to 1,000 ppm, from 500 ppm to 900

ppm, from 600 ppm to 800 ppm, about 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 about 3,500 ppm.

7. The PSAN explosive 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 explosive of any one of claims 1-7, wherein the PSAN prill has a bulk density less than 0.9 kg/L, including less than 0.84 kg/L.

9. The PSAN explosive of any one of claims 1-8, wherein the PSAN prill is explosive grade.

10. The PSAN explosive of any one of claims 1-9, wherein the PSAN prill has at least 5.7% porosity.

11. The PSAN explosive of any one of claims 1-10, wherein the PSAN prill substantially lacks a 32 °C crystalline phase change.

12. The PSAN explosive of any one of claims 1-11, wherein the PSAN prill substantially lacks an 84 °C crystalline phase change.

13. The PSAN explosive of claim 11 or claim 12, wherein the presence of the 32 °C crystalline phase change or the 84 °C crystalline phase change is determined by thermal analysis or x-ray diffraction measurements.

14. The PSAN explosive of claim 13, wherein the thermal analysis comprises differential scanning calorimeter and thermogravimetric analyzer analysis.

15. The PSAN explosive of any one of claims 1-14, wherein upon thermal cycling the PSAN explosive 50 times, wherein one cycle comprises four hours at 15 °C followed by four hours at 45 °C, the thermal cycled PSAN explosive 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.

16. The PSAN explosive of any one of claims 1-15, wherein upon thermal

cycling the PSAN explosive 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 explosive is greater than an average crush strength of non-thermal cycled control PSAN explosive.

17. The PSAN explosive of claim 16, wherein the average crush strength of the thermal cycled PSAN explosive is from 5% to 100%, 10% to 80%, 20% to 60%, or 25% to 40% greater than the average crush strength of the non-thermal cycled control PSAN explosive.

18. The PSAN explosive of any one of claims 1-17, wherein the shelf life of the PSAN explosive 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 nighttime temperature of 10 °C to 30 °C.

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

providing the PSAN explosive of any one of claims 1-18, and

thermal cycling the PSAN explosive 20 times or more.

20. The method of claim 19, wherein the average crush strength of the thermal cycled PSAN explosive is increased by at least 5% greater than the average crush strength of a non-thermal cycled control PSAN explosive, including from 5% to 100%, 10% to 80%, 20% to 60%, or 25% to 40% greater than the average crush strength of a non-thermal cycled control PSAN explosive.