CLAIMS

What is claimed is:

1. A gasification system for high ash, high ash fusion temperature bituminous coal comprising:

a gasifier combining a bituminous coal stream and a gasifier oxidant stream to produce a gasifier syngas stream containing an unwanted species at a first concentration, wherein the gasifier operates within an operating gasfier temperature range, an operating gasifier gas superficial velocity range, and an operating gasifier pressure range at an exit of the gasifier;

a partial oxidizer that combines the gasifier syngas stream and a partial oxidizer oxidant stream to produce a partial oxidizer syngas stream containing the unwanted species at a second concentration being lower than the first concentration, wherein the partial oxidizer operates within an operating partial oxidizer temperature range, an operating partial oxidizer gas superficial velocity range, and an operating partial oxidizer pressure range at an exit of the partial oxidizer;

an unwanted species removal system that removes at least a portion of an unwanted species from the partial oxidizer syngas stream; and

a syngas cooler to cool the partial oxidizer syngas stream.

2. The gasification system of Claim 1 further comprising a removal system-to-partial oxidizer return feed to return at least a portion of an unwanted species via an unwanted species stream from the removal system to the partial oxidizer, wherein the partial oxidizer combines steam and the unwanted species stream with the gasifier syngas stream and a partial oxidizer oxidant stream to produce the partial oxidizer syngas stream.

3. The gasification system of Claim 1 further comprising a filtration system through which the cooled partial oxidizer syngas stream passes.

4. The gasification system of Claim 1, wherein the system achieves over approximately 90% carbon conversion into syngas gasifying bituminous coals with ash content above approximately 15 wt% and the ash having initial deformation temperatures above approximately 1500°C.

5. The gasification system of Claim 1, wherein the system achieves over approximately 98% carbon conversion into syngas gasifying bituminous coals with ash content above approximately 15 wt% and the ash having initial deformation temperatures above approximately 1500°C.

6. The gasification system of Claim 1, wherein the gasifier is a circulating fluidized bed transport gasifier, and wherein the partial oxidizer is a fluidized bed partial oxidizer.

7. The gasification system of Claim 1, wherein steam is combined with the bituminous coal stream and a gasifier oxidant stream to produce the gasifier syngas stream.

8. The gasification system of Claim 1, wherein the operating gasfier temperature range is approximately 900°C to approximately 1100°C, the operating gasifier gas superficial velocity range is approximately 12 ft/s to approximately 50 ft/s, and the operating gasifier pressure range at an exit of the gasifier is approximately 30 psia to approximately 1000 psia.

9. The gasification system of Claim 1, wherein the operating partial oxidizer temperature range is approximately 1100°C to approximately 1400°C, the operating partial oxidizer gas superficial velocity range is approximately 3 ft/s to approximately 6 ft/s, and the operating partial oxidizer pressure range at an exit of the partial oxidizer is approximately 5 psia to approximately 35 psia lower than the gasifier pressure range at the exit of the gasifier.

10. The gasification system of Claim 4, wherein the operating gasfier temperature range is at least 350°C below the ash initial deformation temperature.

11. The gasification system of Claim 1, the unwanted species comprising char carbon.

12. The gasification system of Claim 1, the unwanted species comprising tar.

13. The gasification system of Claim 1, the unwanted species comprising ash fines.

14. A gasification system for high ash, high ash fusion temperature bituminous coal comprising:

a gasifier combining bituminous coal and an oxidant to produce gasifier syngas, the gasifier syngas containing at least one unwanted species;

a partial oxidizer that receives the gasifier syngas and converts at least a portion of the unwanted species into syngas to produce partial oxidizer syngas;

an unwanted species removal system that removes at least a portion of the unwanted species from the partial oxidizer syngas;

a syngas cooler to cool the partial oxidizer syngas; and

a removal system-to-partial oxidizer return feed to return at least a portion of the unwanted species from the removal system to the partial oxidizer.

15. The gasification system of Claim 14 further comprising a filtration unit through which the cooled syngas passes.

16. The gasification system of Claim 14, the gasifier operating at a temperature of approximately 900°C to approximately 1100°C and at least approximately 350°C below the ash initial deformation temperature to produce the gasifier syngas containing at least one unwanted species.

17. The gasification system of Claim 14, the partial oxidizer operating at a temperature of approximately 1100°C to approximately 1400°C.

18. The gasification system of Claim 14, the unwanted species comprising char carbon.

19. The gasification system of Claim 14, the unwanted species comprising char carbon and tar.

20. The gasification system of Claim 18, the unwanted species removal system comprising a cyclone that collects at least a portion of unreacted char carbon.

21. The gasification system of Claim 18, the removal system-to-partial oxidizer return feed feeding at least a portion of the char carbon collected by the unwanted species removal system downstream of the syngas cooler to the partial oxidizer to achieve higher carbon utilization.

22. The gasification system of Claim 19, the partial oxidizer receiving the gasifier syngas containing char carbon and tar from the gasifier, and converting at least a portion of the char carbon and tar into additional syngas, the partial oxidizer operating in a temperature range of approximately 1100°C to approximately 1400°C.

23. The gasification system of Claim 15, the syngas cooler comprising a multistage syngas cooler cooling the partial oxidizer syngas from the partial oxidizer operating temperature to an inlet filtration unit temperature.

24. The gasification system of Claim 14, wherein the system achieves over approximately 90% carbon conversion into syngas gasifying bituminous coals with ash content above approximately 15 wt% and the ash having initial deformation temperatures above approximately 1500°C.

25. The gasification system of Claim 14, wherein the system achieves over approximately 98% carbon conversion into syngas gasifying bituminous coals with ash content above approximately 15 wt% and the ash having initial deformation temperatures above approximately 1500°C.

26. The gasification system of Claim 14, wherein the gasifier is a circulating fluidized bed transport gasifier with bituminous coal fed tangentially into a dense bed and in an oxygen rich lower region of the gasifier to minimize caking tendencies of bituminous coal.

27. The gasification system of Claim 14, wherein the partial oxidizer is a turbulent fluidized bed at a gas superficial velocity in the range of approximately 3 ft/s to approximately 6 ft/s with steam and an oxidant used to further gasify fine refractory char carbon and tar in the syngas.

28. The gasification system of Claim 14, wherein the syngas cooler is an internally circulating fluidized bed cooler to cool the partial oxidizer syngas from an inlet temperature of approximately 1100°C to approximately 1400°C to an exit temperature of approximately 300°C to approximately 500 °C while generating steam and superheated steam.

29. A method of gasifying high ash, high ash fusion temperature bituminous coal and achieve above 90% carbon conversion, the method comprising:

feeding bituminous coals with ash in the range of approximately 15 wt% to approximately 45 wt%;

feeding bituminous coals with ash fusion temperatures greater than approximately 1150°C;

feeding bituminous coal particles of an average size in the range of approximately 150 to approximately 300 microns into an oxygen rich, lower riser dense bed environment of a circulating fluidized bed transport gasifier;

feeding caking bituminous coals into the riser of a loop seal of the circulating fluidized bed transport gasifier with solid circulation rates at least 100 times the coal feed rate to limit agglomerate formation;

operating the gasifier in the range of approximately 900°C to approximately 1100°C to form syngas;

feeding fine refractory char carbon and tar in the syngas from the gasifier to a partial oxidizer;

operating the partial oxidizer in the range of approximately 1100°C to approximately 1400°C to generate additional syngas;

cooling the syngas from the partial oxidizer in an internally circulating fluidized bed cooler using an inert circulating media to transfer heat from the syngas to heat transfer surfaces without the heat transfer surfaces directly contacting the syngas;

separating fine char carbon and ash from the syngas in a cyclone operating in the range of approximately 300°C to approximately 500°C to reduce loading to a downstream dust filtration unit;

recycling fines, as necessary, to the partial oxidizer to achieve a desired carbon conversion percentage;

filtering dust in a dust filtration unit to produce a clean syngas stream for further downstream processing; and

depressurizing the dust from the cyclone and filtration unit for storage and disposal.

30. The method of Claim 29, wherein the system achieves over approximately 98% carbon conversion into syngas gasifying bituminous coals with ash content above approximately 15 wt% and the ash having initial deformation temperatures above approximately 1500°C.

31. The method of Claim 29 further comprising combining steam and a gasifier oxidant with the bituminous coals to produce syngas.

32. The method of Claim 29 further comprising operating the gasifier with a gas superficial velocity range from approximately 12 ft/s to approximately 50 ft/s.

33. The method of Claim 29 further comprising operating the gasifier in a pressure range at an exit of the gasifier from approximately 30 psia to approximately 1000 psia.

34. The method of Claim 29 further comprising operating the partial oxidizer with a gas superficial velocity range from approximately 3 ft/s to approximately 6 ft/s.

35. The method of Claim 29 further comprising operating the partial oxidizer in a pressure range at an exit of the partial oxidizer from approximately 5 psia to approximately 35 psia lower than the gasifier pressure range at the exit of the gasifier.

36. The method of Claim 29 further comprising controlling the gas velocity in the gasifier, controlling the solids circulation rate in the gasifier, and controlling the feed coal particle size to adjust the discharge of char carbon and ash from the gasifier, and unreacted char carbon and ash exiting the gasifier along with the syngas.

37. The method of Claim 36 further comprising controlling the partial oxidizer operating temperature by adjusting the oxidant flow and steam-to-oxygen ratio based on the char carbon and tar contents in the syngas entering the oxidizer.

1. A gasification system for high ash, high ash fusion temperature bituminous coal comprising:

a gasifier combining a bituminous coal stream and a gasifier oxidant stream to produce a gasifier syngas stream containing an unwanted species at a first concentration, wherein the gasifier operates within an operating gasifier temperature range, an operating gasifier gas superficial velocity range, and an operating gasifier pressure range at an exit of the gasifier;

a partial oxidizer that combines the gasifier syngas stream and a partial oxidizer oxidant stream to produce a partial oxidizer syngas stream containing the unwanted species at a second concentration being lower than the first concentration, wherein the partial oxidizer operates within an operating partial oxidizer temperature range, an operating partial oxidizer gas superficial velocity range, and an operating partial oxidizer pressure range at an exit of the partial oxidizer;

an unwanted species removal system that removes at least a portion of an unwanted species from the partial oxidizer syngas stream;

a syngas cooler to cool the partial oxidizer syngas stream;

a filtration system through which the cooled partial oxidizer syngas stream passes; and

a removal system-to-partial oxidizer return feed to return at least a portion of an unwanted species via an unwanted species stream from the removal system to the partial oxidizer, wherein the partial oxidizer combines steam and the unwanted species stream with the gasifier syngas stream and a partial oxidizer oxidant stream to produce the partial oxidizer syngas stream.

2. The gasification system of Claim 1, wherein the system achieves over approximately 98% carbon conversion into syngas gasifying bituminous coals with ash content above approximately 15 wt% and the ash having initial deformation temperatures above approximately 1500°C.

3. The gasification system of Claim 1, wherein the gasifier is a circulating fluidized bed transport gasifier, and wherein the partial oxidizer is a fluidized bed partial oxidizer.

4 The gasification system of Claim 1, wherein steam is combined with the bituminous coal stream and a gasifier oxidant stream to produce the gasifier syngas stream.

5 The gasification system of Claim 1, wherein the operating gasifier temperature range is approximately 900°C to approximately 1100°C, the operating gasifier gas superficial velocity range is approximately 12 ft/s to approximately 50 ft/s, and the operating gasifier pressure range at an exit of the gasifier is approximately 30 psia to approximately 1000 psia.

6 The gasification system of Claim 1, wherein the operating partial oxidizer temperature range is approximately 1100°C to approximately 1400°C, the operating partial oxidizer gas superficial velocity range is approximately 3 ft/s to approximately 6 ft/s, and the operating partial oxidizer pressure range at an exit of the partial oxidizer is approximately 5 psia to approximately 35 psia lower than the gasifier pressure range at the exit of the gasifier.

7 The gasification system of Claim 2, wherein the operating gasifier temperature range is at least 350°C below the ash initial deformation temperature.

8 The gasification system of Claim 1, the unwanted species comprising char carbon.

9 The gasification system of Claim 1, the unwanted species comprising tar.

10 The gasification system of Claim 1, the unwanted species comprising ash fines.

11 The gasification system of Claim 1, wherein the system achieves over approximately 90% carbon conversion into syngas gasifying bituminous coals with ash content above approximately 15 wt%.

12 The gasification system of Claim 1, wherein the gasifier is configured as a circulating fluidized bed transport gasifier with bituminous coal particles of an average size in the range of approximately 150 to approximately 300 microns fed tangentially into a dense bed and in an oxygen rich lower region of the gasifier.

13 The gasification system of Claim 1, wherein the gasifier is configured as a circulating fluidized bed transport gasifier comprising an oxygen rich lower region and a loop seal including a riser;

wherein bituminous coal is fed into a dense bed and in the oxygen rich lower region of the gasifier; and

wherein caking bituminous coals are fed into the riser of the loop seal of the circulating fluidized bed transport gasifier with solid circulation rates at least 100 times the bituminous coal feed rate to limit agglomerate formation.

14 The gasification system of Claim 1, wherein the unwanted species removal system comprises a cyclone downstream from the syngas cooler to separate unwanted species from the partial oxidizer syngas stream;

wherein the unwanted species comprises fine char carbon and ash; and

wherein the cyclone operates in the range of approximately 300°C to approximately 500°C and separates fine char carbon and ash from the partial oxidizer syngas stream from the syngas cooler to reduce loading to the downstream filtration system.

15 The gasification system of Claim 14, wherein the syngas cooler comprises an internally circulating fluidized bed cooler using an inert circulating media to transfer heat from the partial oxidizer syngas stream to heat transfer surfaces without the heat transfer surfaces directly contacting the partial oxidizer syngas stream.

16 The gasification system of Claim 15 further comprising a removal system-to-partial oxidizer return feed to return at least a portion of unwanted species via an unwanted species stream from the cyclone to the partial oxidizer, wherein the partial oxidizer combines steam and the unwanted species stream with the gasifier syngas stream and a partial oxidizer oxidant stream to produce the partial oxidizer syngas stream.

17 The gasification system of Claim 15 further comprising a removal system-to-partial oxidizer return feed to return at least a portion of unwanted species via an unwanted species stream from the cyclone to the partial oxidizer, wherein the amount of unwanted species recycled to the partial oxidizer achieves a desired carbon conversion percentage.

18 The gasification system of Claim 16, wherein unwanted species is filtered in the filtration system to produce a clean syngas stream for further downstream processing.

19 The gasification system of Claim 18, wherein unwanted species is depressurized from the cyclone and filtration system for storage and disposal.