CLAIMS:

What is claimed is:

1. A process for fractionating a steam cracker effluent, comprising:

contacting a steam cracker effluent with a quench oil to produce a cooled steam cracker effluent;

separating a tar product and a light product from the cooled steam cracker effluent;

indirectly transferring heat from the light product to a first heat transfer medium in a first heat exchange stage to produce a cooled light product and a first heated heat transfer medium;

introducing the cooled light product into a primary fractionator;

separating a steam cracker quench oil, a steam cracker gas oil, and an overhead product from the primary fractionator, wherein the overhead product comprises steam cracker naphtha and a process gas comprising ethylene, wherein ≥ 136 tonnes per hour of ethylene is separated from the overhead product;

separating the steam cracker naphtha and the process gas from the overhead product;

indirectly transferring heat from the steam cracker quench oil to a second heat transfer medium in a second heat exchange stage to produce a first cooled steam cracker quench oil and a second heated heat transfer medium;

indirectly transferring heat from at least a portion of the first cooled steam cracker quench oil to a third heat transfer medium in a third heat exchange stage to produce a second cooled steam cracker quench oil and a third heated heat transfer medium; and

introducing at least a portion of the second cooled steam cracker quench oil into the primary fractionator as a quench medium, wherein:

a total heat duty equal to a sum of heat duties generated in the first heat exchange stage, the second heat exchange stage, and the third heat exchange stage is equal to Q_{T1} joules/sec,

a heat duty equal to a sum of heat duties generated in the first heat exchange stage and the second heat exchange stage is $\geq 0.5Q_{T1}$ joules/sec, and

a heat duty generated in the third heat exchange stage is $< 0.5Q_{T1}$ joules/sec.

2. The process of claim 1, wherein:

the first heat transfer medium comprises water, steam, or a mixture thereof,

the heated first heat transfer medium comprises medium pressure steam at a pressure of ~~about~~ 827 kPag to ~~about~~ 1,720 kPag,

the second heat transfer medium comprises water, steam, or a mixture thereof,

the heated second heat transfer medium comprises medium pressure steam at a pressure of ~~about~~ 827 kPag to ~~about~~ 1,720 kPag,

the third heat transfer medium comprises water, steam, or a mixture thereof, and

the heated third heat transfer medium comprises low pressure steam at a pressure of < 827 kPag.

3. The process of claim 1 or 2, wherein:

the heat duty equal to the sum of heat duties generated in the first heat exchange stage and the second heat exchange stage is $\geq 0.6Q_{T1}$ joules/sec, and

the heat duty generated in the third heat exchange stage is $\leq 0.4Q_{T1}$ joules/sec.

4. The process of claim 1 or 2, wherein:

the heat duty equal to the sum of heat duties generated in the first heat exchange stage and the second heat exchange stage is ~~about~~ $0.7Q_{T1}$ joules/sec to ~~about~~ $0.95Q_{T1}$ joules/sec, and

the heat duty generated in the third heat exchange stage is ~~about~~ $0.3Q_{T1}$ joules/sec to ~~about~~ $0.05Q_{T1}$ joules/sec.

5. The process of any one of claims 1 to 4, wherein the second cooled steam cracker quench oil introduced into the primary fractionator as the quench medium has a viscosity of ~~about~~ 250 cP to ~~about~~ 3,000 cP at a temperature of ~~about~~ 60°C, as measured according to ASTM D2171 / D2171M-18.

6. The process of any one of claims 1 to 5, wherein the steam cracker effluent is produced by exposing a hydrocarbon feed to a temperature of ≥ 400°C under steam cracking conditions, wherein the hydrocarbon feed comprises naphtha, gas oil, vacuum gas oil, waxy residues, atmospheric residues, residue admixtures, crude oil, or a mixture thereof.

7. The process of any one of claims 1 to 6, wherein the second cooled steam cracker quench oil is at a temperature of ≤ 200°C when introduced into the primary fractionator as the quench medium.

8. The process of any one of claims 1 to 7, further comprising indirectly transferring heat from at least a portion of the steam cracker gas oil to a fourth heat transfer medium in a fourth heat exchange stage to produce a cooled steam cracker gas oil, wherein:

a total heat duty equal to a sum of heat duties generated in the first heat exchange stage, the second heat exchange stage, the third heat exchange stage, and the fourth heat exchange stage is equal to Q_{T2} joules/sec, and

a heat duty generated in the fourth heat exchange stage is ~~about~~ $0.05Q_{T2}$ to ~~about~~ $0.15Q_{T2}$.

9. The process of claim 8, wherein a heat duty equal to the sum of the heat duties generated in the first heat exchange stage and the second heat exchange stage is $\geq 0.5Q_{T2}$.

10. The process of claim 8 or 9, further comprising introducing a portion of the cooled steam cracker gas oil and a portion of the steam cracker naphtha into the primary fractionator, wherein:

the steam cracker quench oil is withdrawn from a first outlet into a bottom pump-around loop,

the second cooled steam cracker quench oil introduced into the primary fractionator is introduced into a first inlet located above the first outlet,

the steam cracker gas oil is withdrawn from a second outlet into a top pump-around loop, the second outlet located above the first inlet,

the cooled steam cracker gas oil introduced into the primary fractionator is introduced into a second inlet located above the second outlet, and

the steam cracker naphtha introduced into the primary fractionator is introduced into a third inlet located above the second inlet.

11. The process of claim 10, wherein:

the second cooled steam cracker quench oil introduced into the primary fractionator is introduced onto a first tray comprising two or more liquid passes,

the cooled steam cracker gas oil introduced into the primary fractionator is introduced onto a second tray comprising two or more liquid passes.

12. The process of any one of claims 1 to 11, wherein the steam cracker naphtha has a final boiling point of $\leq 260°C$, as measured according to ASTM D2887-18.

13. The process of any one of claims 1 to 12, wherein the light product is at a temperature of ≥ 155°C to ≤ 315°C when separated from the cooled steam cracker effluent.

14. The process of any one of claims 1 to 13, wherein the cooled light product is at a temperature of ≤ 280°C when introduced into the primary fractionator.

15. The process of any one of claims 1 to 14, wherein ~~≥ 1, ≥ 10, ≥ 50, ≥ 57, ≥ 75, ≥ 100, ≥ 125, ≥ 136,~~ ≥142, ≥ 150, ≥ 176, or ≥ 194 tons per hour of ethylene is separated from the overhead product.

16. A process for fractionating a steam cracker effluent, comprising:

contacting a steam cracker effluent with a quench fluid to produce a cooled steam cracker effluent;

separating a tar product and a light product from the cooled steam cracker effluent;

indirectly transferring heat from the light product to water, steam, or a mixture of water and steam to produce a cooled light product and a first medium pressure steam, wherein the first medium pressure steam is at a pressure of ~~about~~ 827 kPag to ~~about~~ 1,720 kPag;

introducing the cooled light product into a primary fractionator having a maximum inner diameter of ≤ 16.8 meters;

separating a steam cracker quench oil, a steam cracker gas oil, and an overhead product from the primary fractionator, wherein the overhead product comprises steam cracker naphtha and a process gas comprising ethylene;

separating the steam cracker naphtha and the process gas from the overhead product, wherein ≥ 136 tonnes per hour of ethylene is separated from the overhead product;

cooling the steam cracker quench oil by indirect heat exchange with water, steam, or a mixture of water and steam to produce a first cooled steam cracker quench oil and a second medium pressure steam, wherein the second medium pressure steam is at a pressure of ~~about~~ 827 kPag to ~~about~~ 1,720 kPag;

cooling at least a portion of the first cooled steam cracker quench oil by indirect heat exchange with water, steam, or a mixture of water and steam to produce a second cooled steam cracker quench oil and low pressure steam, wherein the low pressure steam is at a pressure of < 827 kPag; and

introducing at least a portion of the second cooled steam cracker quench oil into the primary fractionator a quench medium.

17. The process of claim 16, wherein the steam cracker naphtha has a final atmospheric boiling point of ≤ 260°C, as measured according to ASTM D2887.

18. The process of claim 16 or 17, wherein:

the steam cracker naphtha has a final atmospheric boiling point of ~~about~~ 221°C to ~~about~~ 250°C, as measured according to ASTM D2887-18,

the steam cracker gas oil has a final atmospheric boiling point of ≤ 300°C, as measured according to ASTM D2887-18,

the steam cracker quench oil has a final atmospheric boiling point of ≤ 500°C, as measured according to ASTM D2887-18,

the tar product has a final atmospheric boiling point of > 600°C, as measured according to ASTM D2887-18.

19. The process of any one of claims 16 to 18, wherein:

a total heat duty equal to a sum of heat duties generated by cooling the light product by indirect heat exchange, cooling the steam cracker quench oil by indirect heat exchange, and cooling at least a portion of the first cooled steam cracker quench oil by indirect heat exchange is equal to Q_{T1} joules/sec,

a heat duty equal to a sum of heat duties generated by cooling the light product by indirect heat exchange and cooling the steam cracker quench oil by indirect heat exchange is ≥ $0.5Q_{T1}$ joules/sec, and

a heat duty generated by cooling at least a portion of the first cooled steam cracker quench oil is < $0.5Q_{T1}$ joules/sec.

20. The process of any one of claims 16 to 19, wherein:

the primary fractionator comprises a flash zone section located toward a first end of the primary fractionator, a bottom pump-around section located above the flash zone section, a mid-fractionation section located above the bottom pump-around section, a top pump-around section located above the mid-fractionation section, and a top-fractionation section located above the top pump-around section, wherein:

one or more vapor distribution devices is disposed within the flash zone section,
one or more first trays is disposed within the bottom pump-around section,
one or more second trays is disposed within the mid-fractionation section,

one or more third trays is disposed within the top pump-around section, and
one or more fourth trays is disposed within the top-fractionation section.

21. The process of claim 20, wherein each of the one or more first trays and the one or more third trays comprises two or more liquid passes.

22. The process of claim 20 or 21, wherein the one or more first trays comprise one or more jet tab trays, and wherein the one or more third trays comprise one or more jet tab trays.

23. The process of any one of claims 16 to 22, further comprising introducing a portion of the steam cracker naphtha into the top-fractionation section, wherein the steam cracker naphtha is introduced into the top-fractionation section, relative to a weight of hydrocarbons in the steam cracker effluent, at a weight ratio of ~~about~~ 0.2:1 to ~~about~~ 0.45:1.

24. A system for fractionating a steam cracker effluent, comprising:

a steam cracker comprising a steam cracker effluent outlet;

a quench stage comprising a quench stage inlet in fluid communication with the steam cracker effluent outlet, a quench oil inlet, and a quench stage outlet;

a tar knockout drum comprising an inlet in fluid communication with the quench stage outlet, a tar product outlet, and a light product outlet;

a first heat exchange stage comprising a first heat exchange stage inlet in fluid communication with the light product outlet and a first heat exchange stage outlet, the first heat exchange stage configured to produce medium pressure steam at a pressure of ~~about~~ 827 kPag to ~~about~~ 1,720 kPag;

a primary fractionator comprising a fractionator inlet in fluid communication with the first heat exchange stage outlet, a bottoms outlet, a bottom pump-around inlet, a top pump-around outlet located above the bottom pump-around inlet, a top pump-around inlet located above the top pump-around outlet, a reflux inlet located above the top pump-around inlet, and an overhead outlet located above the reflux inlet;

a bottom pump-around loop fluidly connecting the bottoms outlet to the bottom pump-around inlet, the bottom pump-around loop comprising a second heat exchange stage and a third heat exchange stage, wherein the second heat exchange stage configured to produce medium pressure steam at a pressure of ~~about~~ 827 kPag to ~~about~~ 1,720 kPag, and wherein the third heat exchange stage is configured to produce low pressure stem at a pressure of < 827 kPag, and wherein:

the first heat exchange stage, the second heat exchange stage, and the third heat exchange stage are configured to generate a total heat duty that is equal to Q_{T1} joules/sec,

the first heat exchange stage and the second heat exchange stage are configured to generate a heat duty that is $\geq 0.5Q_{T1}$ joules/sec, and

a the third heat exchange stage is configured to generate a heat duty that is $< 0.5Q_{T1}$ joules/sec.

25. A process for fractionating a steam cracker effluent, comprising:

contacting a steam cracker effluent with a quench fluid to produce a cooled steam cracker effluent, wherein the steam cracker effluent is at a temperature of ≥ 400°C when initially contacted with the quench fluid;

separating a tar product and a light product from the cooled steam cracker effluent, wherein the light product is substantially in a vapor phase and at a temperature of ≥ 155°C to ≤ 315°C;

cooling the light product by indirect heat exchange with water, steam, or a mixture of water and steam to produce a cooled light product and a first medium pressure steam, wherein the cooled light product is at a temperature of ≥ 150°C to ≤ 300°C, wherein the first medium pressure steam is at a pressure of ~~about~~ 827 kPag to ~~about~~ 1,720 kPag, and wherein the cooled light product is in the vapor phase and liquid phase;

introducing the cooled light product into a flash zone section of a primary fractionator, wherein the cooled light product is at a temperature of ≥ 150°C to ≤ 280°C when introduced into the primary fractionator, and wherein the primary fractionator comprises the flash zone section located toward a bottom of the primary fractionator, a bottom pump-around section located above the flash zone, a mid-fractionation section located above the bottom pump-around section, a top pump-around section located above the mid-fractionation section, and a top-fractionation section located above the top pump-around section, wherein:

one or more first trays is disposed within the bottom pump-around section,

one or more second trays is disposed within the mid-fractionation section,

one or more third trays is disposed within the top pump-around section, and

one or more fourth trays is disposed in the top-fractionation section;

separating a steam cracker quench oil from the flash zone section;

separating a steam cracker gas oil from the mid-fractionation section;

separating an overhead product comprising steam cracker naphtha and a process gas comprising ethylene from the top-fractionation section, wherein ≥ 136 tonnes per hour of ethylene is separated from the overhead product;

separating the steam cracker naphtha and the process gas from the overhead product, wherein the steam cracker naphtha has a final atmospheric boiling point of ≤ 260°C, as measured according to ASTM D2887-18;

cooling the steam cracker quench oil by indirect heat exchange with water, steam, or a mixture of water and steam to produce a first cooled steam cracker quench oil and a second medium pressure steam, wherein the second medium pressure steam is at a pressure of ~~about~~ 827 kPag to ~~about~~ 1,720 kPag;

cooling at least a portion of the first cooled steam cracker quench oil by indirect heat exchange with water, steam, or a mixture of water and steam to produce a second cooled steam cracker quench oil and low pressure steam, wherein the low pressure steam is at a pressure of < 827 kPag; and

introducing a portion of the steam cracker naphtha into the top-fractionation section, wherein the steam cracker naphtha is introduced into the top-fractionation section, relative to a weight of hydrocarbons in the steam cracker effluent, at a weight ratio of ~~about~~ 0.2:1 to ~~about~~ 0.45:1.

26. The process of claim 25, wherein the flow rate of the portion of the steam cracker naphtha introduced into the top-fractionation section, the flow rate of the steam cracker gas oil recovered from the fractionation section, and the temperature of the cooled light product introduced into the primary fractionator are adjusted to maintain a predetermined vapor and liquid loading on (1) the one or more first trays, (2) the one or more second trays, (3) the one or more third trays, (4) the one or more fourth trays, or (5) a combination thereof.

27. The process of claim 24 or 25, wherein the primary fractionator has a maximum inner diameter of ≤ 16.8 meters~~, and wherein ≥ 136 tonnes per hour of ethylene is separated from the overhead product~~.