CLAIMS

WHAT IS CLAIMED IS:

~~1. A hybrid heat exchanger comprising:~~

~~a metallic serpentine tube having an inlet end portion to receive a process fluid, an outlet end portion, and a series of runs and return bends directing the process fluid from the inlet end portion toward the outlet end portion;~~

~~a thermally conductive polymer body thermally integrated with the serpentine tube and having an outer surface to be contacted by a fluid, the thermally conductive polymer body configured to transfer heat between the metallic serpentine tube and the fluid contacting the outer surface of the thermally conductive polymer body; and~~

~~surface enhancement features of the outer surface of the thermally conductive polymer body that affect flow of the fluid at the outer surface of the thermally conductive polymer body.~~

~~2. The hybrid heat exchanger of claim 1 wherein the runs of the metallic serpentine tube have a total outer surface area; and~~

~~wherein the outer surface of the thermally conductive polymer body has a surface area larger than the total outer surface area of the runs of the metallic serpentine tube.~~

~~3. The hybrid heat exchanger of claim 1 wherein the thermally conductive polymer body includes sheath portions;~~

~~wherein the runs extend in the sheath portions; and~~

~~wherein the thermally conductive polymer body includes wall portions extending between adjacent sheath portions that include the surface enhancement features.~~

~~4. The hybrid heat exchanger of claim 1 wherein the runs of the metallic serpentine tube each have a length; and~~

~~wherein the thermally conductive polymer body is in thermal contact with the runs of the metallic serpentine tube for at least a majority of the lengths of the runs.~~

5. The hybrid heat exchanger of claim 4 wherein the runs each have an outer surface and cross-section normal to the length; and

wherein the thermally conductive polymer body is in thermal contact with the outer surfaces of the runs about at least a majority of the cross-sections of the runs.

6. The hybrid heat exchanger of claim 1 further comprising a thermally conductive paste thermally connecting the thermally conductive polymer body and the metallic serpentine tube.

7. The hybrid heat exchanger of claim 1 wherein at least one of the runs of the serpentine tube has a length and a cross-section normal to the length; and

wherein the thermally conductive polymer body has a sheath portion extending about the entire cross-section of the serpentine tube for at least a portion of the length of the run.

8. The hybrid heat exchanger of claim 1 wherein the thermally conductive polymer body has a thermal conductivity of at least two Watts per meter-Kelvin.

9. The hybrid heat exchanger of claim 1 wherein the thermally conductive polymer body comprises:

a matrix phase of a polymer material; and

a particulate phase of at least one of metal and graphite.

10. The hybrid heat exchanger of claim 1 wherein the thermally conductive polymer body comprises a polymer material and metallic wire.

11. The hybrid heat exchanger of claim 1 wherein the runs of the metallic serpentine tube are received in the thermally conductive polymer body; and

wherein the inlet end portion and outlet end portion of the metallic serpentine tube are outside of the thermally conductive polymer body.

~~12. The hybrid heat exchanger of claim 1 wherein the thermally conductive polymer body is a plate.~~

~~13. The hybrid heat exchanger of claim 1 wherein the thermally conductive polymer body includes portions of the thermally conductive polymer body assembled with the metallic serpentine tube.~~

~~14. The hybrid heat exchanger of claim 13 wherein the portions of the thermally conductive polymer body include collars that compliment outer surfaces of the runs of the metallic serpentine tube.~~

~~15. The hybrid heat exchanger of claim 1 wherein the metallic serpentine tube has a unitary construction.~~

~~16. The hybrid heat exchanger of claim 1 wherein the metallic serpentine coil comprises at least one of:~~

~~a stainless steel tube;~~

~~an aluminum tube;~~

~~a copper tube; and~~

~~a carbon steel tube.~~

~~17. The hybrid heat exchanger of claim 1 wherein the metallic serpentine tube is configured to withstand an operating pressure of the process fluid of at least 150 psig.~~

~~18. The hybrid heat exchanger of claim 1 wherein the thermally conductive polymer body includes a fill portion extending away from the metallic serpentine tube.~~

~~19. The hybrid heat exchanger of claim 1 wherein the thermally conductive polymer body comprises thermally conductive material and a phase change material encapsulated in the thermally conductive material; and~~

~~wherein the phase change material is configured to change phase in response to heat transfer between the thermally conductive material and the phase change material.~~

~~20~~1. A heat exchanger system comprising:

an inlet header to receive a process fluid;

an outlet header;

a plurality of fluid conduits of a first thermally conductive material, the fluid conduits each having an inlet end portion connected to the inlet header, an outlet end portion connected to the outlet header, and an intermediate portion between the inlet and outlet end portions along the fluid conduits, the fluid conduits configured to permit process fluid to flow from the inlet header to the outlet header;

a body of a thermally conductive polymer different than the first thermally conductive material and having an outer surface; and

the thermally conductive polymer body in thermal contact with the intermediate portions of the fluid conduits and configured to facilitate heat transfer between the process fluid as the process fluid travels through the intermediate portions of the fluid conduits and a fluid at the outer surface of the thermally conductive polymer body.

~~21~~2. The heat exchanger system of claim ~~20~~1 wherein the thermally conductive polymer body is secured to the intermediate portions of the fluid conduit and is spaced from the inlet and outlet header.

~~22~~3. The heat exchanger system of claim ~~20~~1 wherein the fluid conduits each have a length; and

at least one of the fluid conduits is embedded in the thermally conductive polymer body for at least a portion of the length of the at least one fluid conduit.

~~23~~4. The heat exchanger system of claim ~~20~~ 1 wherein the fluid conduits each have a length; and

wherein the thermally conductive polymer body is in thermal contact with the fluid conduits for at least a majority of the lengths of the fluid conduits.

~~24~~5. The heat exchanger system of claim ~~23~~ 4 wherein the fluid conduits each have an outer surface and a cross-section normal to the length thereof; and

wherein the thermally conductive polymer body is in thermal contact with the outer surfaces of the fluid conduits about at least a majority of the cross-sections of the fluid conduits.

~~25~~6. The hybrid heat exchanger of claim ~~20~~ 1 further comprising a thermally conductive paste thermally connecting the thermally conductive polymer body and the fluid conduits.

~~26~~7. The hybrid heat exchanger of claim ~~20~~ 1 wherein the thermally conductive polymer body has a thermal conductivity of at least two Watts per meter-Kelvin.

~~27~~8. The hybrid heat exchanger of claim ~~20~~ 1 further comprising:

a fan operable to generate airflow relative to the thermally conductive polymer body;

an evaporative liquid distribution system configured to distribute the fluid onto the outer surface of the thermally conductive polymer body; and

a sump to collect the fluid from the outer surface of the thermally conductive polymer body.

~~28~~9. The hybrid heat exchanger of claim ~~20~~ 1 wherein the thermally conductive polymer body comprises a polymer material and at least one of:

graphite particles;

metallic particles;

a metallic wire; and

a phase change material.

~~29~~10. The hybrid heat exchanger of claim ~~20~~ 1 wherein the fluid conduit comprises at least one of:

a stainless steel tube;

an aluminum tube;

a copper tube; and

a carbon steel tube.

~~30~~11. The hybrid heat exchanger of claim ~~20~~ 1 wherein the fluid conduits are micro channels.

~~31~~12. A method of forming a hybrid heat exchanger, the method comprising:

providing a metallic tube having an interior to receive a process fluid;

manufacturing a body of a thermally conductive polymer, the body having an outer surface with surface enhancement features to affect fluid flow at the body outer surface; and

thermally integrating the thermally conductive polymer body and the metallic tube.

~~32~~13. The method of claim ~~31~~ 12 wherein the metallic tube comprises an inlet end portion, an outlet end portion, runs, and at least one bend connecting the runs.

~~33~~14. The method of claim ~~31~~ 12 wherein the metallic tube has an outer surface portion with a first surface area;

wherein thermally integrating the thermally conductive polymer body and the metallic tube comprises securing the thermally conductive polymer body and the outer surface portion of the metallic tube; and

wherein the thermally conductive polymer body includes an outer surface having a second surface area larger than the first surface area.

~~34~~15. The method of claim ~~31~~ 12 wherein manufacturing the thermally conductive polymer body comprises manufacturing the thermally conductive polymer body using additive manufacturing.

~~35~~16. The method of claim ~~34~~ 15 wherein thermally integrating the thermally conductive polymer body and the metallic tube comprises additive manufacturing the thermally conductive polymer in situ with the metallic tube.

~~36~~17. The method of claim ~~31~~ 12 wherein manufacturing the thermally conductive polymer body comprises manufacturing portions of the thermally conductive polymer body using additive manufacturing; and

wherein thermally integrating the thermally conductive polymer body and the metallic tube comprises assembling the portions of the thermally conductive polymer body and the metallic tube.

~~37~~18. The method of claim ~~31~~12 wherein manufacturing the thermally conductive polymer body comprises molding the thermally conductive polymer body.

~~38~~19. The method of claim ~~37~~ 18 wherein thermally integrating the thermally conductive polymer body and the metallic tube comprises molding the thermally conductive polymer body in situ with the metallic tube.

~~39~~20. The method of claim ~~31~~ 12 wherein thermally integrating the thermally conductive polymer body comprises positioning thermally conductive paste between the thermally conductive polymer body and the metallic tube.

~~40~~21. The method of claim ~~31~~ 12 wherein thermally integrating the thermally conductive polymer body and the metallic tube comprises melting a portion of the thermally conductive polymer body so that the molten portion of the thermally conductive polymer body fills openings between the thermally conductive polymer body and the metallic tube.

~~41~~22. The method of claim ~~31~~ 12 wherein manufacturing the thermally conductive polymer body comprises using additive manufacturing of a polymeric material infused with discontinuous conductive particles.

4223. The method of claim 31 12 wherein manufacturing the thermally conductive polymer body comprises using additive manufacturing including forming a bead comprising a metallic strand and a polymer annulus extending around the strand.

4324. The method of claim 31 12 wherein the metallic tube comprises at least one of:

a stainless steel tube;

an aluminum tube;

a copper tube; and

a carbon steel tube.

4425. The method of claim 31 12 wherein providing the metallic tube comprises providing at least three metallic tubes; and

wherein thermally integrating the thermally conductive polymer body and the metallic tube comprises integrating a single polymer body with the metallic tubes.