CLAIMS

What is claimed is:

1. A keel cooler assembly for use on a marine vessel, said keel cooler assembly exchanging heat with an internal coolant flowing through the keel cooler assembly, said keel cooler assembly comprising:

a header;

at least one coolant tube extending in a longitudinal direction from said header, said at least one coolant tube comprising:

at least one inlet for ingress of the coolant;

at least one outlet for egress of the coolant;

an elongated body portion extending between said at least one inlet and said at least one outlet, said elongated body portion including an interior surface forming an internal channel for allowing flow of the coolant in a longitudinal direction along a length of said elongated body portion; and

a means for enhancing the turbulence of the coolant flowing through said at least one coolant tube for improving heat transfer without substantially increasing pressure drop of the coolant above an identical at least one coolant tube lacking said means for enhancing turbulence.

2. The keel cooler assembly of claim 1 wherein said means for enhancing turbulence comprises a means for generating turbulent wakes in the coolant for enhancing eddying motion and improving heat transfer without substantially increasing pressure drop of the coolant above an identical at least one coolant tube lacking said means for generating turbulent wakes.

3. The keel cooler assembly of claim 1 wherein said means for enhancing turbulence comprises a means for generating turbulent vortexes in the coolant for enhancing coolant mixing and improving heat transfer without substantially increasing pressure drop of the coolant above an identical at least one coolant tube lacking said means for generating turbulent vortexes.

4. The keel cooler assembly of claim 1 wherein said means for enhancing turbulence of the coolant for improving heat transfer without substantially increasing pressure drop of the coolant above an identical at least one coolant tube lacking said means for enhancing turbulence comprises at least one of (i) a means for generating turbulent wakes in the coolant for enhancing eddying motion, and (ii) a means for generating turbulent vortexes in the coolant for enhancing coolant mixing.

5. The keel cooler assembly of claim 1 wherein said means for enhancing turbulence comprises a plurality of turbulence enhancers extending inwardly into said internal channel from said elongated body portion interior surface, said plurality of turbulence enhancers being arranged in a predetermined pattern.

6. The keel cooler assembly of claim 5 wherein said predetermined pattern comprises a plurality of longitudinal rows of said turbulence enhancers, said plurality of longitudinal rows of said turbulence enhancers including a first longitudinal spacing (X_L) between respective longitudinally adjacent turbulence enhancers located in the same longitudinal row, and a second transverse spacing (X_H) between respective transversely adjacent turbulence enhancers located in adjacent longitudinal rows.

7. The keel cooler assembly of claim 6 wherein said respective longitudinally adjacent turbulence enhancers located in the same longitudinal rows are transversely offset in an alternating staggered configuration.

8. The keel cooler assembly of claim 7 wherein a spacing ratio (β) of said first longitudinal spacing (X_L) to said second transverse spacing (X_H) is greater than about 3.5 for generating and propagating turbulent vortexes in the coolant for enhancing coolant mixing and improving heat transfer without substantially increasing pressure drop of the coolant.

9. The keel cooler assembly of claim 7 wherein a spacing ratio (β) of said first longitudinal spacing (X_L) to said second transverse spacing (X_H) is in the range between about 1.0 and 7.0 for generating turbulent wakes in the coolant for enhancing eddying motion and improving heat transfer without substantially increasing pressure drop of the coolant.

10. The keel cooler assembly of claim 5 wherein each of said plurality of turbulence enhancers include a body portion extending inwardly into said internal channel from said coolant tube elongated body portion interior surface, said body portion being disposed in a bulk region of the coolant when the coolant is flowing through said at least one coolant tube for generating turbulent wakes in said bulk region for enhancing eddying motion and improving heat transfer without substantially increasing pressure drop of the coolant above an identical keel cooler assembly lacking said plurality of turbulence enhancers.

11. The keel cooler assembly of claim 1 wherein:

said header comprises an upper wall, an end wall, a bottom wall, opposing side walls, and an inclined surface operatively connecting said upper wall, bottom wall and side walls; and

said at least one coolant tube comprises at least one inner coolant tube configured as a rectangular parallelepiped comprising opposing upper and lower walls, and opposing first and second sidewalls transverse to said opposing upper and lower walls, said first and second sidewalls operatively connecting said upper and lower walls for forming said internal channel, wherein said elongated body portion includes at least one open end portion being received by at least one spacing in said inclined surface of said header, said at least one open end portion having a rectangular cross-sectional configuration defining said at least one inlet.

12. The keel cooler assembly of claim 1 wherein:

said header comprises an upper wall, an end wall, a bottom wall, opposing side walls, and an inclined surface operatively connecting said upper wall, bottom wall and side walls; and

said at least one coolant tube comprises at least one outer coolant tube configured as a rectangular parallelepiped comprising opposing upper and lower walls, and opposing first and second sidewalls transverse to said opposing upper and lower walls, said first and second sidewalls operatively connecting said upper and lower walls for forming said internal channel, said first sidewall being an interior sidewall and said second sidewall being an outermost sidewall;

wherein said outermost sidewalls extend between the side portions of said header upper wall and said header lower wall for forming said header side walls, and wherein said interior sidewalls separate a header chamber from said header side walls, said interior sidewalls including said at least one inlet configured as an orifice located between said respective outermost sidewalls and said header chamber for allowing flow of the coolant through said orifice and along said internal channel.

13. A keel cooler assembly for use on a marine vessel, said keel cooler assembly exchanging heat with an internal coolant flowing through the keel cooler assembly, said keel cooler assembly comprising:

a header;

at least one coolant tube extending in a longitudinal direction from said header, said coolant tube comprising:

an elongated body portion comprising an interior surface forming an internal channel for allowing flow of the coolant in a longitudinal direction along a length of said elongated body portion; and

a plurality of turbulators extending inwardly into said internal channel from said elongated body portion interior surface and being configured to interact with the coolant for enhancing the turbulence of the coolant for improving heat transfer without substantially increasing pressure drop of the coolant above an identical at least one coolant tube lacking said turbulators.

14. The keel cooler assembly of claim 13, wherein said at least one coolant tube is configured as a rectangular parallelepiped, said at least one coolant tube comprising opposing upper and lower walls, and opposing first and second sidewalls transverse to said opposing upper and lower walls, said first and second sidewalls operatively connecting said upper and lower walls for forming said internal channel.

15. The keel cooler assembly of claim 14, wherein each of said plurality of turbulators includes a body portion extending inwardly into said internal channel from said coolant tube elongated body portion interior surface, said body portion being disposed in a bulk region of the coolant when the coolant is flowing through said at least one coolant tube for generating turbulent wakes in said bulk

region for enhancing eddying motion and improving heat transfer without substantially increasing pressure drop of the coolant above an identical at least one coolant tube lacking said turbulators.

16. The keel cooler assembly according to claim 15, wherein said respective turbulator body portions extend from one of said respective upper wall, lower wall, first sidewall, and second sidewall to a different one of said upper wall, lower wall, first sidewall and second sidewall.

17. The keel cooler assembly according to claim 15, wherein the respective adjacent walls of said at least one coolant tube meet at coolant tube wall intersections, and wherein said respective turbulator body portions extend from a selected one of said respective upper wall, lower wall, first sidewall, second sidewall and coolant wall intersections, to a different upper wall, lower wall, first sidewall, second sidewall and coolant tube wall intersection.

18. The keel cooler assembly of claim 15, wherein said respective turbulator body portions comprise elongated body portions, said elongated body portions being arranged substantially orthogonal to at least one of said respective opposing walls.

19. The keel cooler assembly of claim 15, wherein each of said plurality of turbulators includes an elongated body portion having a cross-sectional configuration selected from the group consisting of: round, ellipsoid, oval, rectangular, square, triangular, wing-shaped, airfoil-shaped, polygonal, and irregular.

20. The keel cooler assembly of claim 19, wherein said plurality of turbulators is a first plurality of turbulators, and said turbulators in said at least one coolant tube comprise a second plurality of turbulators having a different cross-sectional configuration than said first plurality of turbulators.

21. The keel cooler assembly of claim 14, wherein each of said plurality of turbulators comprises an elongated body portion extending between at least one of (i) said opposing first and second sidewalls and (ii) said opposing upper and lower walls, said respective turbulator elongated body portions having opposing end portions being operatively connected to each of said respective opposing walls.

22. The keel cooler assembly of claim 21, wherein said respective turbulator elongated body portions are configured as at least one of:

a solid cylinder having a round cross-section for enhancing the turbulence of the coolant for improving heat transfer without substantially increasing pressure drop above an identical at least one coolant tube lacking said turbulators;

a hollow cylinder having a round cross-section, said hollow cylinder having round openings on said opposing end portions with an interior channel formed therebetween for allowing flow of ambient fluid through said turbulator interior channel for increasing heat transfer of the coolant flowing through said coolant tube and around said turbulator elongated body portion; and

a solid bar having a wing-shaped cross-section for directing turbulent wakes of the coolant in

~~a predetermined direction for increasing heat transfer without substantially increasing pressure drop of the coolant above an identical at least one coolant tube lacking said turbulators.~~

~~23. The keel cooler assembly of claim 14, wherein said plurality of turbulators are arranged in a predetermined pattern selected from the group consisting of: symmetrical, asymmetrical, parallelogram, rectangular, square, diamond, triangular, polygonal, spiral, undulating, sinuous, irregular, and random.~~

~~24. The keel cooler assembly of claim 14, wherein said plurality of turbulators are arranged in a predetermined pattern, said predetermined pattern comprising a plurality of longitudinal rows of said turbulators, said plurality of longitudinal rows of said turbulators including a first longitudinal spacing (X_L) between respective longitudinally adjacent turbulators located in the same longitudinal row, and a second transverse spacing (X_H) between respective transversely adjacent turbulators located in adjacent longitudinal rows.~~

~~25. The keel cooler assembly of claim 24, wherein said respective longitudinally adjacent turbulators located in the same longitudinal rows are transversely offset in an alternating staggered configuration.~~

~~26. The keel cooler assembly of claim 25, wherein a spacing ratio (β) of said first longitudinal spacing (X_L) to said second transverse spacing (X_H) is in the range between about 1.0 and 7.0 for generating turbulent wakes in the coolant for enhancing eddying motion and improving heat transfer without substantially increasing pressure drop of the coolant above an identical at least one coolant tube lacking said turbulators.~~

~~27. The keel cooler assembly of claim 25, wherein a spacing ratio (β) of said first longitudinal spacing (X_L) to said second transverse spacing (X_H) is greater than about 3.5 for generating and propagating turbulent vortexes in the coolant for enhancing coolant mixing and improving heat transfer without substantially increasing pressure drop of the coolant above an identical at least one coolant tube lacking said turbulators.~~

~~28. The keel cooler assembly of claim 27, wherein each of said plurality of turbulators comprises opposing turbulator end portions and an elongated body portion extending between said opposing turbulator end portions, said respective turbulator elongated body portions extending between said opposing first and second sidewalls, said opposing turbulator end portions being operatively connected to each of said respective sidewalls, wherein:~~

~~said respective turbulator elongated body portions are arranged orthogonally to each of said opposing first and second sidewalls; and~~

~~wherein said respective turbulator elongated body portions are configured as least one of the group consisting of:~~

~~a solid cylinder having a round cross-section for enhancing the turbulence of the~~

coolant for improving heat transfer without substantially increasing pressure drop above an identical at least one coolant tube lacking said turbulators;

a hollow cylinder having a round cross-section, said hollow cylinder having round openings on said opposing end portions with an interior channel formed therebetween for allowing flow of ambient fluid through said turbulator interior channel for increasing heat transfer of the coolant flowing through said coolant tube and around said turbulator elongated body portion; and

a solid bar having a wing-shaped cross-section for directing turbulent wakes of the coolant in a predetermined direction for increasing heat transfer without substantially increasing pressure drop of the coolant above an identical at least one coolant tube lacking said turbulators.

29. The keel cooler assembly of claim 28, wherein said turbulator elongated body portion being configured as a solid bar having a wing-shaped cross-section comprises a leading head portion, an intermediate portion having a concave surface, and a trailing tail portion;

said concave surface of said turbulator intermediate portion being arranged in an alternating pattern, wherein said concave surface of respective longitudinally adjacent turbulators in the same longitudinal row face generally opposite directions.

30. The keel cooler assembly of claim 29, wherein said respective wing-shaped turbulators are rotatably arranged in a predetermined pattern for effecting said concave surface to generally face at least one of (i) an upstream bulk coolant flow and (ii) a downstream bulk coolant flow.

31. The keel cooler assembly of claim 14, wherein:

said header comprises an upper wall, an end wall, a bottom wall, opposing side walls, and an inclined surface operatively connecting said upper wall, bottom wall and side walls; and

said at least one coolant tube comprises an inner coolant tube, said elongated body portion including at least one open end portion having a rectangular cross-sectional configuration, said at least one open end portion defining at least one inlet for ingress of the coolant, said at least one inlet being received by at least one spacing in said inclined surface of said header.

32. The keel cooler assembly of claim 14, wherein:

said header comprises an upper wall, an end wall, a bottom wall, opposing side walls, and an inclined surface operatively connecting said upper wall, bottom wall and side walls; and

said at least one coolant tube comprises an outer coolant tube, said first sidewall being an interior sidewall and said second sidewall being an outermost sidewall;

wherein said outermost sidewalls extend between the side portions of said header upper wall and said header lower wall for forming said header side walls, and wherein said interior sidewalls separate a header chamber from said header side walls, said interior sidewalls having at least one

inlet configured as an orifice located between said respective outermost sidewalls and said header chamber for allowing flow of the coolant through said orifice and along said internal channel.

33. The keel cooler assembly of claim 13, wherein said turbulators are operatively connected to said at least one coolant tube elongated body portion interior surface by at least one of brazing, soldering, welding, and integrally forming.

34. A coolant tube for use in a keel cooler, said coolant tube exchanging heat with an internal coolant flowing through the coolant tube, said coolant tube extending in a longitudinal direction from a header, the header including an upper wall, an end wall, a bottom wall, opposing side walls, and an inclined surface operatively connecting said upper wall, bottom wall and side walls, said coolant tube comprising:

an elongated body portion comprising:

an interior surface forming an internal channel for allowing flow of the coolant in a longitudinal direction along a length of said elongated body portion;

opposing upper and lower walls, and opposing first and second sidewalls transverse to said opposing upper and lower walls, said first and second sidewalls operatively connecting said upper and lower walls for forming said internal channel; said elongated body portion having a rectangular cross-sectional configuration; and

a plurality of turbulators extending inwardly into said internal channel from said elongated body portion interior surface and being configured to interact with the coolant for enhancing the turbulence of the coolant without substantially increasing pressure drop of the coolant above an identical at least one coolant tube lacking said turbulators.

35. The coolant tube of claim 34, wherein each of said plurality of turbulators comprises an elongated body portion extending between at least one of (i) said opposing first and second sidewalls and (ii) said opposing upper and lower walls, said respective turbulator elongated body portions having opposing end portions being operatively connected to each of said respective opposing walls.

36. The coolant tube of claim 35, wherein said plurality of turbulators are arranged in a predetermined pattern, said predetermined pattern comprising a plurality of longitudinal rows of said turbulators, said plurality of longitudinal rows of said turbulators including a first longitudinal spacing (X_L) between respective longitudinally adjacent turbulence enhancers located in the same longitudinal row, and a second transverse spacing (X_H) between respective transversely adjacent turbulence enhancers located in adjacent longitudinal rows.

37. The coolant tube of claim 36, wherein said respective longitudinally adjacent turbulators located in the same longitudinal rows are transversely offset in an alternating staggered configuration.

38. The coolant tube of claim 37, wherein said respective turbulator elongated body portions are configured as at least one of:

a solid cylinder having a round cross-section for enhancing the turbulence of the coolant for improving heat transfer without substantially increasing pressure drop above an identical at least one coolant tube lacking said turbulators;

a hollow cylinder having a round cross-section, said hollow cylinder having round openings on said opposing end portions with an interior channel formed therebetween for allowing flow of ambient fluid through said turbulator interior channel for increasing heat transfer of the coolant flowing through said coolant tube and around said turbulator elongated body portion; and

a solid bar having a wing-shaped cross-section for directing turbulent wakes of the coolant in a predetermined direction for increasing heat transfer without substantially increasing pressure drop of the coolant above an identical at least one coolant tube lacking said turbulators.

39. The coolant tube of claim 38, wherein a spacing ratio (β) of said first longitudinal spacing (X_L) to said second transverse spacing (X_H) is in the range between about 1.0 and 7.0 for generating turbulent wakes in the coolant for enhancing eddying motion and improving heat transfer without substantially increasing pressure drop of the coolant above an identical at least one coolant tube lacking said turbulators.

40. The coolant tube of claim 38, wherein a spacing ratio (β) of said first longitudinal spacing (X_L) to said second transverse spacing (X_H) is greater than about 3.5 for generating and propagating turbulent vortexes in the coolant for enhancing coolant mixing and improving heat transfer without substantially increasing pressure drop of the coolant above an identical at least one coolant tube lacking said turbulators.

41. The coolant tube of claim 38, wherein said turbulator elongated body portion being configured as a solid bar having a wing-shaped cross-section comprises a leading head portion, an intermediate portion having a concave surface, and a trailing tail portion;

said concave surface of said turbulator intermediate portion being arranged in an alternating pattern, wherein said concave surface of respective longitudinally adjacent turbulators in the same longitudinal row face generally opposite directions.

42. The coolant tube of claim 34, wherein said at least one coolant tube comprises an inner coolant tube, said elongated body portion including at least one open end portion having a rectangular cross-sectional configuration, said at least one open end portion defining at least one inlet for ingress of the coolant, said at least one inlet being received by at least one spacing in the inclined surface of the header.

43. The coolant tube of claim 34, wherein said at least one coolant tube comprises an outer coolant tube, said first sidewall being an interior sidewall and said second sidewall being an outermost sidewall;

wherein said outermost sidewalls extend between the side portions of the header upper wall

~~and the header lower wall for forming the header side walls, and wherein said interior sidewalls separate a header chamber from the header side walls, said interior sidewalls having at least one inlet configured as an orifice located between said respective outermost sidewalls and said header chamber for allowing flow of the coolant through said orifice and along said internal channel.~~

~~44. The coolant tube of claim 34 being constructed of a copper-nickel alloy, wherein said turbulators are operatively connected to said at least one coolant tube elongated body portion interior surface by at least one of the group consisting of brazing, soldering, welding, and integrally forming.~~

CLAIMS

What is claimed is:

1. A keel cooler assembly for use on a marine vessel, said keel cooler assembly exchanging heat with an internal coolant flowing through the keel cooler assembly, said keel cooler assembly comprising:

a header;

at least one coolant tube extending in a longitudinal direction from said header, said at least one coolant tube comprising:

at least one inlet for ingress of the coolant;

at least one outlet for egress of the coolant;

an elongated body portion extending between said at least one inlet and said at least one outlet, said elongated body portion including an interior surface forming an internal channel for allowing flow of the coolant in a longitudinal direction along a length of said elongated body portion; and

a means for enhancing the turbulence of the coolant flowing through said at least one coolant tube for improving heat transfer without substantially increasing pressure drop of the coolant above an identical at least one coolant tube lacking said means for enhancing turbulence;

wherein said means for enhancing turbulence comprises a plurality of turbulence enhancers extending inwardly into said internal channel from said elongated body portion interior surface, said plurality of turbulence enhancers being arranged in a predetermined pattern;

wherein said predetermined pattern comprises a plurality of longitudinal rows of said turbulence enhancers, said plurality of longitudinal rows of said turbulence enhancers including a first longitudinal spacing (X_L) between respective longitudinally adjacent turbulence enhancers located in the same longitudinal row, and a second transverse spacing (X_H) between respective transversely adjacent turbulence enhancers located in adjacent longitudinal rows.

2. The keel cooler assembly of claim 1 wherein said respective longitudinally adjacent turbulence enhancers located in the same longitudinal rows are transversely offset in an alternating

staggered configuration.

3. The keel cooler assembly of claim 2 wherein a spacing ratio (β) of said first longitudinal spacing (X_L) to said second transverse spacing (X_H) is greater than about 3.5 for generating and propagating turbulent vortexes in the coolant for enhancing coolant mixing and improving heat transfer without substantially increasing pressure drop of the coolant.

4. The keel cooler assembly of claim 2 wherein a spacing ratio (β) of said first longitudinal spacing (X_L) to said second transverse spacing (X_H) is in the range between about 1.0 and 7.0 for generating turbulent wakes in the coolant for enhancing eddying motion and improving heat transfer without substantially increasing pressure drop of the coolant.

5. A keel cooler assembly for use on a marine vessel, said keel cooler assembly exchanging heat with an internal liquid coolant flowing through the keel cooler assembly, said keel cooler assembly comprising:

a header;

at least one coolant tube extending in a longitudinal direction from said header, configured as a rectangular parallelepiped, said at least one coolant tube comprising opposing upper and lower walls, and opposing first and second sidewalls transverse to said opposing upper and lower walls, said first and second sidewalls operatively connecting said upper and lower walls for forming said internal channel, said coolant tube further comprising:

an elongated body portion comprising an interior surface forming an internal channel for allowing flow of the coolant in a longitudinal direction along a length of said elongated body portion; and

a plurality of turbulators extending inwardly into said internal channel from said elongated body portion interior surface and being configured to interact with the coolant for enhancing the turbulence of the coolant for improving heat transfer without substantially increasing pressure drop of the coolant above an identical at least one coolant tube lacking said turbulators, wherein each of said plurality of turbulators comprises an elongated body portion extending between at least one of (i) said opposing first and second sidewalls and (ii)

said opposing upper and lower walls, said respective turbulator elongated body portions having opposing end portions being operatively connected to each of said respective opposing walls; and

wherein said respective turbulator elongated body portions are configured as at least one of:

a solid cylinder having a round cross-section for enhancing the turbulence of the coolant for improving heat transfer without substantially increasing pressure drop above an identical at least one coolant tube lacking said turbulators;

a hollow cylinder having a round cross-section, said hollow cylinder having round openings on said opposing end portions with an interior channel formed therebetween for allowing flow of ambient fluid through said turbulator interior channel for increasing heat transfer of the coolant flowing through said coolant tube and around said turbulator elongated body portion; and

a solid bar having a wing-shaped cross-section for directing turbulent wakes of the coolant in a predetermined direction for increasing heat transfer without substantially increasing pressure drop of the coolant above an identical at least one coolant tube lacking said turbulators.

6. A keel cooler assembly for use on a marine vessel, said keel cooler assembly exchanging heat with an internal liquid coolant flowing through the keel cooler assembly, said keel cooler assembly comprising:

a header;

at least one coolant tube extending in a longitudinal direction from said header, configured as a rectangular parallelepiped, said at least one coolant tube comprising opposing upper and lower walls, and opposing first and second sidewalls transverse to said opposing upper and lower walls, said first and second sidewalls operatively connecting said upper and lower walls for forming said internal channel, said coolant tube further comprising:

an elongated body portion comprising an interior surface forming an internal channel for allowing flow of the coolant in a longitudinal direction along a length of said elongated body portion; and

a plurality of turbulators extending inwardly into said internal channel from said elongated

body portion interior surface and being configured to interact with the coolant for enhancing the turbulence of the coolant for improving heat transfer without substantially increasing pressure drop of the coolant above an identical at least one coolant tube lacking said turbulators, wherein said plurality of turbulators are arranged in a predetermined pattern, said predetermined pattern comprising a plurality of longitudinal rows of said turbulators, said plurality of longitudinal rows of said turbulators including a first longitudinal spacing (X_L) between respective longitudinally adjacent turbulators located in the same longitudinal row, and a second transverse spacing (X_H) between respective transversely adjacent turbulators located in adjacent longitudinal rows.

7. The keel cooler assembly of claim 6, wherein said respective longitudinally adjacent turbulators located in the same longitudinal rows are transversely offset in an alternating staggered configuration.

8. The keel cooler assembly of claim 7, wherein a spacing ratio (β) of said first longitudinal spacing (X_L) to said second transverse spacing (X_H) is in the range between about 1.0 and 7.0 for generating turbulent wakes in the coolant for enhancing eddying motion and improving heat transfer without substantially increasing pressure drop of the coolant above an identical at least one coolant tube lacking said turbulators.

9. The keel cooler assembly of claim 7, wherein a spacing ratio (β) of said first longitudinal spacing (X_L) to said second transverse spacing (X_H) is greater than about 3.5 for generating and propagating turbulent vortexes in the coolant for enhancing coolant mixing and improving heat transfer without substantially increasing pressure drop of the coolant above an identical at least one coolant tube lacking said turbulators.

10. The keel cooler assembly of claim 9, wherein each of said plurality of turbulators comprises opposing turbulator end portions and an elongated body portion extending between said opposing turbulator end portions, said respective turbulator elongated body portions extending between said opposing first and second sidewalls, said opposing turbulator end portions being operatively connected to each of said respective sidewalls, wherein:

said respective turbulator elongated body portions are arranged orthogonally to each of said

opposing first and second sidewalls; and

wherein said respective turbulator elongated body portions are configured as least one of the group consisting of:

a solid cylinder having a round cross-section for enhancing the turbulence of the coolant for improving heat transfer without substantially increasing pressure drop above an identical at least one coolant tube lacking said turbulators;

a hollow cylinder having a round cross-section, said hollow cylinder having round openings on said opposing end portions with an interior channel formed therebetween for allowing flow of ambient fluid through said turbulator interior channel for increasing heat transfer of the coolant flowing through said coolant tube and around said turbulator elongated body portion; and

a solid bar having a wing-shaped cross-section for directing turbulent wakes of the coolant in a predetermined direction for increasing heat transfer without substantially increasing pressure drop of the coolant above an identical at least one coolant tube lacking said turbulators.

11. The keel cooler assembly of claim 10, wherein said turbulator elongated body portion is configured as a solid bar having a wing-shaped cross-section and comprises a leading head portion, an intermediate portion having a concave surface, and a trailing tail portion;

said concave surface of said turbulator intermediate portion being arranged in an alternating pattern, wherein said concave surface of respective longitudinally adjacent turbulators in the same longitudinal row face generally opposite directions.

12. The keel cooler assembly of claim 11, wherein said respective wing-shaped turbulators are rotatably arranged in a predetermined pattern for effecting said concave surface to generally face at least one of (i) an upstream bulk coolant flow and (ii) a downstream bulk coolant flow.

13. A coolant tube for use in a keel cooler, said coolant tube exchanging heat with an internal liquid coolant flowing through the coolant tube, said coolant tube extending in a longitudinal direction from a header, the header including an upper wall, an end wall, a bottom wall, opposing

sidewalls, and an inclined surface operatively connecting said upper wall, bottom wall and sidewalls, said coolant tube comprising:

an elongated body portion comprising:

an interior surface forming an internal channel for allowing flow of the coolant in a longitudinal direction along a length of said elongated body portion;

opposing upper and lower walls, and opposing first and second sidewalls transverse to said opposing upper and lower walls, said first and second sidewalls operatively connecting said upper and lower walls for forming said internal channel; said elongated body portion having a rectangular cross-sectional configuration; and

a plurality of turbulators extending inwardly into said internal channel from said elongated body portion interior surface and being configured to interact with the coolant for enhancing the turbulence of the coolant without substantially increasing pressure drop of the coolant above an identical at least one coolant tube lacking said turbulators, wherein each of said plurality of turbulators comprises an elongated body portion extending between at least one of (i) said opposing first and second sidewalls and (ii) said opposing upper and lower walls, said respective turbulator elongated body portions having opposing end portions being operatively connected to each of said respective opposing walls, and wherein said plurality of turbulators is arranged in a predetermined pattern, said predetermined pattern comprising a plurality of longitudinal rows of said turbulators, said plurality of longitudinal rows of said turbulators including a first longitudinal spacing (X_L) between respective longitudinally adjacent turbulence enhancers located in the same longitudinal row, and a second transverse spacing (X_H) between respective transversely adjacent turbulence enhancers located in adjacent longitudinal rows.

14. The coolant tube of claim 13, wherein said respective longitudinally adjacent turbulators located in the same longitudinal rows are transversely offset in an alternating staggered configuration.

15. The coolant tube of claim 14, wherein said respective turbulator elongated body portions are configured as at least one of:

a solid cylinder having a round cross-section for enhancing the turbulence of the coolant for improving heat transfer without substantially increasing pressure drop above an identical at least one coolant tube lacking said turbulators;

a hollow cylinder having a round cross-section, said hollow cylinder having round openings on said opposing end portions with an interior channel formed therebetween for allowing flow of ambient fluid through said turbulator interior channel for increasing heat transfer of the coolant flowing through said coolant tube and around said turbulator elongated body portion; and

a solid bar having a wing-shaped cross-section for directing turbulent wakes of the coolant in a predetermined direction for increasing heat transfer without substantially increasing pressure drop of the coolant above an identical at least one coolant tube lacking said turbulators.

16. The coolant tube of claim 15, wherein a spacing ratio (β) of said first longitudinal spacing (X_L) to said second transverse spacing (X_H) is in the range between about 1.0 and 7.0 for generating turbulent wakes in the coolant for enhancing eddying motion and improving heat transfer without substantially increasing pressure drop of the coolant above an identical at least one coolant tube lacking said turbulators.

17. The coolant tube of claim 15, wherein a spacing ratio (β) of said first longitudinal spacing (X_L) to said second transverse spacing (X_H) is greater than about 3.5 for generating and propagating turbulent vortexes in the coolant for enhancing coolant mixing and improving heat transfer without substantially increasing pressure drop of the coolant above an identical at least one coolant tube lacking said turbulators.

18. The coolant tube of claim 15, wherein said turbulator elongated body portion being configured as a solid bar having a wing-shaped cross-section comprises a leading head portion, an intermediate portion having a concave surface, and a trailing tail portion;

said concave surface of said turbulator intermediate portion being arranged in an alternating pattern, wherein said concave surface of respective longitudinally adjacent turbulators in the same longitudinal row face generally opposite directions.

19. A keel cooler assembly for use on a marine vessel, said keel cooler assembly exchanging heat

with an internal liquid coolant flowing through the keel cooler assembly, said keel cooler assembly comprising:

a header;

at least one coolant tube extending in a longitudinal direction from said header, said at least one coolant tube comprising:

at least one inlet for ingress of the coolant;

at least one outlet for egress of the coolant;

an elongated body portion extending between said at least one inlet and said at least one outlet, said elongated body portion including an interior surface forming an internal channel for allowing flow of the coolant in a longitudinal direction along a length of said elongated body portion; and

a means for enhancing the turbulence of the coolant flowing through said at least one coolant tube for improving heat transfer without substantially increasing pressure drop of the coolant above an identical at least one coolant tube lacking said means for enhancing turbulence.

20. The keel cooler assembly of claim 19 wherein said means for enhancing turbulence comprises a means for generating turbulent wakes in the coolant for enhancing eddying motion and improving heat transfer without substantially increasing pressure drop of the coolant above an identical at least one coolant tube lacking said means for generating turbulent wakes.

21. The keel cooler assembly of claim 19 wherein said means for enhancing turbulence comprises a means for generating turbulent vortexes in the coolant for enhancing coolant mixing and improving heat transfer without substantially increasing pressure drop of the coolant above an identical at least one coolant tube lacking said means for generating turbulent vortexes.

22. The keel cooler assembly of claim 19 wherein said means for enhancing turbulence of the coolant for improving heat transfer without substantially increasing pressure drop of the coolant above an identical at least one coolant tube lacking said means for enhancing turbulence comprises at least one of (i) a means for generating turbulent wakes in the coolant for enhancing eddying motion,

and (ii) a means for generating turbulent vortexes in the coolant for enhancing coolant mixing.

23. The keel cooler assembly of claim 19 wherein said means for enhancing turbulence comprises a plurality of turbulence enhancers extending inwardly into said internal channel from said elongated body portion interior surface, said plurality of turbulence enhancers being arranged in a predetermined pattern.

24. The keel cooler assembly of claim 23 wherein each of said plurality of turbulence enhancers includes a body portion extending inwardly into said internal channel from said coolant tube elongated body portion interior surface, said body portion being disposed in a bulk region of the coolant when the coolant is flowing through said at least one coolant tube for generating turbulent wakes in said bulk region for enhancing eddying motion and improving heat transfer without substantially increasing pressure drop of the coolant above an identical keel cooler assembly lacking said plurality of turbulence enhancers.

25. The keel cooler assembly of claim 19 wherein:

said header comprises an upper wall, an end wall, a bottom wall, opposing sidewalls, and an inclined surface operatively connecting said upper wall, bottom wall and sidewalls; and

said at least one coolant tube comprises at least one inner coolant tube configured as a rectangular parallelepiped comprising opposing upper and lower walls, and opposing first and second sidewalls transverse to said opposing upper and lower walls, said first and second sidewalls operatively connecting said upper and lower walls for forming said internal channel, wherein said elongated body portion includes at least one open end portion being received by at least one spacing in said inclined surface of said header, said at least one open end portion having a rectangular cross-sectional configuration defining said at least one inlet.

26. The keel cooler assembly of claim 19 wherein:

said header comprises an upper wall, an end wall, a bottom wall, opposing sidewalls, and an inclined surface operatively connecting said upper wall, bottom wall and sidewalls; and

said at least one coolant tube comprises at least one outer coolant tube configured as a rectangular parallelepiped comprising opposing upper and lower walls, and opposing first and second

sidewalls transverse to said opposing upper and lower walls, said first and second sidewalls operatively connecting said upper and lower walls for forming said internal channel, said first sidewall being an interior sidewall and said second sidewall being an outermost sidewall;

wherein said outermost sidewalls extend between the side portions of said header upper wall and said header lower wall for forming said header sidewalls, and wherein said interior sidewalls separate a header chamber from said header sidewalls, said interior sidewalls including said at least one inlet configured as an orifice located between said respective outermost sidewalls and said header chamber for allowing flow of the coolant through said orifice and along said internal channel.

27. A keel cooler assembly for use on a marine vessel, said keel cooler assembly exchanging heat with an internal liquid coolant flowing through the keel cooler assembly, said keel cooler assembly comprising:

a header;

at least one coolant tube extending in a longitudinal direction from said header, said coolant tube comprising:

an elongated body portion comprising an interior surface forming an internal channel for allowing flow of the coolant in a longitudinal direction along a length of said elongated body portion; and

a plurality of turbulators extending inwardly into said internal channel from said elongated body portion interior surface and being configured to interact with the coolant for enhancing the turbulence of the coolant for improving heat transfer without substantially increasing pressure drop of the coolant above an identical at least one coolant tube lacking said turbulators.

28. The keel cooler assembly of claim 27, wherein said at least one coolant tube is configured as a rectangular parallelepiped, said at least one coolant tube comprising opposing upper and lower walls, and opposing first and second sidewalls transverse to said opposing upper and lower walls, said first and second sidewalls operatively connecting said upper and lower walls for forming said internal channel.

29. The keel cooler assembly of claim 28, wherein each of said plurality of turbulators includes a body portion extending inwardly into said internal channel from said coolant tube elongated body portion interior surface, said body portion being disposed in a bulk region of the coolant when the coolant is flowing through said at least one coolant tube for generating turbulent wakes in said bulk region for enhancing eddying motion and improving heat transfer without substantially increasing pressure drop of the coolant above an identical at least one coolant tube lacking said turbulators.

30. The keel cooler assembly according to claim 29, wherein said respective turbulator body portions extend from one of said respective upper wall, lower wall, first sidewall, and second sidewall to a different one of said upper wall, lower wall, first sidewall and second sidewall.

31. The keel cooler assembly according to claim 29, wherein the respective adjacent walls of said at least one coolant tube meet at coolant tube wall intersections, and wherein said respective turbulator body portions extend from a selected one of said respective upper wall, lower wall, first sidewall, second sidewall and coolant wall intersections, to a different upper wall, lower wall, first sidewall, second sidewall and coolant tube wall intersection.

32. The keel cooler assembly of claim 29, wherein said respective turbulator body portions comprise elongated body portions, said elongated body portions being arranged substantially orthogonal to at least one of said respective opposing walls.

33. The keel cooler assembly of claim 29, wherein each of said plurality of turbulators includes an elongated body portion having a cross-sectional configuration selected from the group consisting of: round, ellipsoid, oval, rectangular, square, triangular, wing-shaped, airfoil-shaped, polygonal, and irregular.

34. The keel cooler assembly of claim 33, wherein said plurality of turbulators is a first plurality of turbulators, and said turbulators in said at least one coolant tube comprise a second plurality of turbulators having a different cross-sectional configuration than said first plurality of turbulators.

35. The keel cooler assembly of claim 28, wherein each of said plurality of turbulators comprises an elongated body portion extending between at least one of (i) said opposing first and second sidewalls and (ii) said opposing upper and lower walls, said respective turbulator elongated body

portions having opposing end portions being operatively connected to each of said respective opposing walls.

36. The keel cooler assembly of claim 35, wherein said plurality of turbulators are arranged in a predetermined pattern selected from the group consisting of: symmetrical, asymmetrical, parallelogram, rectangular, square, diamond, triangular, polygonal, spiral, undulating, sinuous, irregular, and random.

37. The keel cooler assembly of claim 28, wherein:

said header comprises an upper wall, an end wall, a bottom wall, opposing sidewalls, and an inclined surface operatively connecting said upper wall, bottom wall and sidewalls; and

said at least one coolant tube comprises an inner coolant tube, said elongated body portion including at least one open end portion having a rectangular cross-sectional configuration, said at least one open end portion defining at least one inlet for ingress of the coolant, said at least one inlet being received by at least one spacing in said inclined surface of said header.

38. The keel cooler assembly of claim 28, wherein:

said header comprises an upper wall, an end wall, a bottom wall, opposing sidewalls, and an inclined surface operatively connecting said upper wall, bottom wall and sidewalls; and

said at least one coolant tube comprises an outer coolant tube, said first sidewall being an interior sidewall and said second sidewall being an outermost sidewall;

wherein said outermost sidewalls extend between the side portions of said header upper wall and said header lower wall for forming said header sidewalls, and wherein said interior sidewalls separate a header chamber from said header sidewalls, said interior sidewalls having at least one inlet configured as an orifice located between said respective outermost sidewalls and said header chamber for allowing flow of the coolant through said orifice and along said internal channel.

39. The keel cooler assembly of claim 27, wherein said turbulators are operatively connected to said at least one coolant tube elongated body portion interior surface by at least one of brazing, soldering, welding, and integrally forming.

40. A coolant tube for use in a keel cooler, said coolant tube exchanging heat with an internal

coolant flowing through the coolant tube, said coolant tube extending in a longitudinal direction from a header, the header including an upper wall, an end wall, a bottom wall, opposing sidewalls, and an inclined surface operatively connecting said upper wall, bottom wall and sidewalls, said coolant tube comprising:

an elongated body portion comprising:

an interior surface forming an internal channel for allowing flow of the coolant in a longitudinal direction along a length of said elongated body portion;

opposing upper and lower walls, and opposing first and second sidewalls transverse to said opposing upper and lower walls, said first and second sidewalls operatively connecting said upper and lower walls for forming said internal channel; said elongated body portion having a rectangular cross-sectional configuration; and

a plurality of turbulators extending inwardly into said internal channel from said elongated body portion interior surface and being configured to interact with the coolant for enhancing the turbulence of the coolant without substantially increasing pressure drop of the coolant above an identical at least one coolant tube lacking said turbulators.

41. The coolant tube of claim 40, wherein each of said plurality of turbulators comprises an elongated body portion extending between at least one of (i) said opposing first and second sidewalls and (ii) said opposing upper and lower walls, said respective turbulator elongated body portions having opposing end portions being operatively connected to each of said respective opposing walls.

42. The coolant tube of claim 41 wherein said plurality of turbulators is arranged in a predetermined pattern, said predetermined pattern comprising a plurality of longitudinal rows of said turbulators, said plurality of longitudinal rows of said turbulators including a first longitudinal spacing (X_L) between respective longitudinally adjacent turbulence enhancers located in the same longitudinal row, and a second transverse spacing (X_H) between respective transversely adjacent turbulence enhancers located in adjacent longitudinal rows.

43. The coolant tube of claim 42, wherein said respective longitudinally adjacent turbulators located in the same longitudinal rows are transversely offset in an alternating staggered configuration.

44. The coolant tube of claim 43, wherein said respective turbulator elongated body portions are configured as at least one of:

a solid cylinder having a round cross-section for enhancing the turbulence of the coolant for improving heat transfer without substantially increasing pressure drop above an identical at least one coolant tube lacking said turbulators;

a hollow cylinder having a round cross-section, said hollow cylinder having round openings on said opposing end portions with an interior channel formed therebetween for allowing flow of ambient fluid through said turbulator interior channel for increasing heat transfer of the coolant flowing through said coolant tube and around said turbulator elongated body portion; and

a solid bar having a wing-shaped cross-section for directing turbulent wakes of the coolant in a predetermined direction for increasing heat transfer without substantially increasing pressure drop of the coolant above an identical at least one coolant tube lacking said turbulators.

45. The coolant tube of claim 44, wherein a spacing ratio (β) of said first longitudinal spacing (X_L) to said second transverse spacing (X_H) is in the range between about 1.0 and 7.0 for generating turbulent wakes in the coolant for enhancing eddying motion and improving heat transfer without substantially increasing pressure drop of the coolant above an identical at least one coolant tube lacking said turbulators.

46. The coolant tube of claim 44, wherein a spacing ratio (β) of said first longitudinal spacing (X_L) to said second transverse spacing (X_H) is greater than about 3.5 for generating and propagating turbulent vortexes in the coolant for enhancing coolant mixing and improving heat transfer without substantially increasing pressure drop of the coolant above an identical at least one coolant tube lacking said turbulators.

47. The coolant tube of claim 44, wherein said turbulator elongated body portion being configured as a solid bar having a wing-shaped cross-section comprises a leading head portion, an intermediate portion having a concave surface, and a trailing tail portion;

said concave surface of said turbulator intermediate portion being arranged in an alternating pattern, wherein said concave surface of respective longitudinally adjacent turbulators in the same

longitudinal row face generally opposite directions.

48. The coolant tube of claim 44, wherein said at least one coolant tube comprises an inner coolant tube, said elongated body portion including at least one open end portion having a rectangular cross-sectional configuration, said at least one open end portion defining at least one inlet for ingress of the coolant, said at least one inlet being received by at least one spacing in the inclined surface of the header.

49. The coolant tube of claim 40, wherein said at least one coolant tube comprises an outer coolant tube, said first sidewall being an interior sidewall and said second sidewall being an outermost sidewall;

wherein said outermost sidewalls extend between the side portions of the header upper wall and the header lower wall for forming the header sidewalls, and wherein said interior sidewalls separate a header chamber from the header sidewalls, said interior sidewalls having at least one inlet configured as an orifice located between said respective outermost sidewalls and said header chamber for allowing flow of the coolant through said orifice and along said internal channel.

50. The coolant tube of claim 40 being constructed of a copper-nickel alloy, wherein said turbulators are operatively connected to said at least one coolant tube elongated body portion interior surface by at least one of the group consisting of brazing, soldering, welding, and integrally forming.

51. The keel cooler assembly of claim 23 wherein said predetermined pattern comprises a plurality of longitudinal rows of said turbulence enhancers, said plurality of longitudinal rows of said turbulence enhancers including a first longitudinal spacing (X_L) between respective longitudinally adjacent turbulence enhancers located in the same longitudinal row, and a second transverse spacing (X_H) between respective transversely adjacent turbulence enhancers located in adjacent longitudinal rows.

52. The keel cooler assembly of claim 51 wherein said respective longitudinally adjacent turbulence enhancers located in the same longitudinal rows are transversely offset in an alternating staggered configuration.

53. The keel cooler assembly of claim 52 wherein a spacing ratio (β) of said first longitudinal

spacing (X_L) to said second transverse spacing (X_H) is greater than about 3.5 for generating and propagating turbulent vortexes in the coolant for enhancing coolant mixing and improving heat transfer without substantially increasing pressure drop of the coolant.

54. The keel cooler assembly of claim 52 wherein a spacing ratio (β) of said first longitudinal spacing (X_L) to said second transverse spacing (X_H) is in the range between about 1.0 and 7.0 for generating turbulent wakes in the coolant for enhancing eddying motion and improving heat transfer without substantially increasing pressure drop of the coolant.