

CLAIMS

What is claimed is:

- 5 1. A heat transfer surface monitoring (HTSM) cell (10) for use in monitoring scaling, fouling, pitting, and corrosion, of a heat transfer surface, the HTSM cell comprising:
 - a) a heat transfer plate (16) having a first surface (106) on a fluid inlet feed side;
 - b) an edge-lit light guide (60) having an aperture (72) forming a fluid flow channel (42), the heat transfer plate (16) positioned adjacent to the edge-lit light guide (60) and overlay the aperture (72), wherein the edge-lit light guide (60) is comprised of a transparent or translucent material to illuminate the first surface (106) of the heat transfer plate (16);
 - c) an edge illumination light source (62) adjacent to the edge-lit light guide (60), the edge illumination light source (62) operable to illuminate the edge-lit light guide (60), thereby providing illumination substantially parallel to the heat transfer plate (16) and allowing an observer to view scaling, fouling, pitting, and corrosion on the first surface (106) of the heat transfer plate (16);
 - d) a fluid flow channel module (102) having:
 - i) a fluid flow channel module support block (68),
 - ii) an optical window (64) within the fluid flow channel support block (68), the optical window (64) operable to view the heat transfer plate (16),
 - iii) a fluid inlet conduit (52) operable to allow entry of a fluid stream within the fluid flow channel module (102),
 - iv) a fluid outlet conduit (54) operable to allow exit of the fluid stream away from the fluid flow channel module (102); and,
 - e) a heating/cooling module (104) capable of transferring heat to the heat transfer plate (16), the heating/cooling (104) module having:
 - i) a heating/cooling support block (130),
 - ii) a heating/cooling element (126), the heating/cooling element (126) capable of being temperature controlled,

wherein the heating/cooling support block (130) is capable of conducting heat between the heating/cooling element (126) and the heat transfer plate (16).

2. The HTSM cell (10) of Claim 1,
wherein the fluid flow channel module support block (68) is characterized as having an opaque region, thereby minimizing image distortion due to stray light,
wherein the optical window (64) is a transparent optical window; and,
5 wherein the fluid inlet conduit (52) and fluid outlet conduit (54) are integrated within the fluid flow channel module.
3. The HTSM cell (10) of Claim 1,
wherein the edge-lit light guide (60) is positioned between the fluid flow channel
10 module (102) and the heating/cooling module (104).
4. The HTSM cell (10) of Claim 1 further comprising a plurality of seals (76), the plurality of seals (76) positioned between at least one of:
a) the optical window (64) and the fluid flow channel module support block (68),
15 b) the fluid flow channel support block (68) and the edge-lit light guide (60), and;
c) the edge-lit light guide (60), the heat transfer plate (16), a heat transfer medium (128), and the heating/cooling support block (130).
5. The HTSM cell (10) of Claim 1, wherein the edge-lit light guide (60) is positioned such
20 that the aperture (72) of the edge-lit light guide (60) forms a fluid flow channel (42) between the fluid inlet conduit (52) and the fluid outlet conduit (54), thereby allowing fluid to pass over the heat transfer plate (16).
6. The HTSM cell (10) of Claim 1, wherein the fluid flow channel (42) has a height and a
25 width, wherein the height the width of the fluid flow channel (42) is capable of being adjusted by having a light guide (60) of predetermined dimensions to form a desired fluid flow channel (42) height and width.
7. The HTSM cell (10) of Claim 1 further comprising a heat flux sensor (HF-1), a heat
30 transfer plate temperature transmitter (TT-1), and a heating/cooling element temperature transmitter (TT-3), each operably connected to the HTSM cell (10).
8. The HTSM cell (10) of Claim 1, wherein HTSM cell (10) is a removable cassette (88).

9. A heat transfer surface monitoring (HTSM) system (26) for use in monitoring scaling, fouling, pitting, and corrosion, of a heat transfer surface, the system comprising:

- a) the heat transfer surface monitoring (HTSM) cell (10) of Claim 1;
- b) a surface imaging module (44) having imaging components of a camera (66) and a lens (82), the surface imaging module (44) configured and located relative to the heat transfer surface monitoring system so as to be operable to:
 - i) capture at least one of an image and a reflectance spectra of the first surface (106) of the heat transfer plate (16) of the HTSM cell (10);
 - ii) create at least one of an image data signal and a spectral signal indicative of the image and the reflectance spectra;
- c) an image processing system operatively linked to the surface imaging module (44) so as to receive the image data signal therefrom, the image processing system being operable to analyze the image data signal so as to provide an indication of an extent of at least one of scaling, fouling, corrosion, and pitting, on the heat transfer plate (16); and,
- d) a system controller (12) operable to control at least one of illumination, image capturing, spectra capturing, image data management, image analysis, and external data communication (100), inlet flow rate, and pressure on a fluid inlet feed side to be approximately that of a heat exchange equipment being monitored.

10. The HTSM system (26) of Claim 9, wherein the HTSM cell (10) is a removable cassette (88) capable of being inserted removed from the HTSM system without repositioning of the surface imaging module (44).

11. The HTSM system (26) of Claim 9, wherein the image processing system is configured to determine at least one of:

- a) a percent and density of surface area of the heat transfer plate (16) of at least one of fouling, scaling, corrosion, and pitting; and,
- b) a type of fouling, scaling, corrosion, and pitting based on geometric shape analysis and spectral analysis of images.

12. The HTSM system (26) of Claim 11, wherein the image processing system is configured to identify at least one of fouling, scaling, pitting and corrosion on the first surface

(106) of the heat transfer plate (16) based on at least one of:

- a) a geometric shape and a size analysis; and,
- b) a spectral analysis of images capture by the image processing system, through the use of spectral analysis and pattern recognition.

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13. The HTSM system (26) of Claim 9 further comprises:

a heat flux sensor (HF-1), a heat transfer plate temperature transmitter (TT-1), and a heating/cooling element temperature transmitter (TT-3) operably connected to the HTSM cell (10); and,

10 a flow meter (FT-1), a flow control valve (CV), a feed temperature transmitter (TT-2), an inlet pressure meter (PT-1), an outlet temperature transmitter (TT-4), and a conductivity transmitter (CT-1) operatively connected to the system controller (12),

wherein the system controller (12) is operable to receive, control, and adjust flow rate, temperature, heat flux and pressure in response to received signals transmitted from at least
15 one of the heat flux sensor, the heat transfer plate temperature transmitter, the heating/cooling element temperature transmitter, the flow meter, the feed temperature transmitter, the inlet pressure meter, the outlet temperature transmitter, and the conductivity transmitter,

wherein the HTSM system (26) is capable of being operated at a substantially same pressure as a heat exchange equipment (110) segment being monitored, and wherein flow
20 velocity and heat transfer surface plate temperature in the HTSM cell (10) is capable of being regulated and set at specific values to establish target hydrodynamic and heat transfer conditions relative to conditions of the heat exchange equipment (110) segment being monitored.

25 14. A method of monitoring fouling, scaling, corrosion and pitting of a heat transfer surface, the method comprising:

- a) providing the HTSM cell (10) of Claim 1;
- b) passing a fluid intake stream across the first surface (106) of the heat transfer plate (16);
- 30 c) collecting data of at least one of visual and spectral imaging from an illuminated portion of the first surface (106) of the heat transfer plate (16); and,
- d) transmitting the collected data to an image processing system;
- e) interpreting the collected data with the image processing system to determine an extent of fouling, scaling, corrosion, and pitting.

15. The method of Claim 14, further comprising a step of adjusting at least one of flow rate, pressure, and temperature in response to the extent of fouling, scaling, corrosion and pitting.
- 5 16. The method of Claim 14, wherein the step of interpreting the collected data includes at least one of:
- a) displaying a real-time image of the surface of the heat transfer plate (16) and surface imaging spectra; and,
 - b) correlating the collected data to at least one of fouling, scaling, corrosion, and
 - 10 pitting to a heat exchange equipment (110) being monitored.
17. The method of Claim 14, wherein the light source (62) emits light in a range of at least one of visible light, UV light, and near infrared light.
- 15 18. A heat transfer surface monitoring (HTSM) cell for use in monitoring scaling, fouling, pitting, and corrosion, of a heat transfer surface, the cell comprising:
- a) a heat exchanger cylindrical tube (200) having a viewable inner surface (140);
 - b) a light guide operable to allow light to enter from outside of the heat exchanger cylindrical tube to illuminate the viewable inner surface (140);
 - 20 c) a light source (140, 62) operable to illuminate the viewable inner surface (140) of the heat exchanger cylindrical tube (200);
 - d) an fluid inlet conduit (52) positioned to allow fluid to enter within the heat exchanger cylindrical tube (148), and a fluid outlet conduit (54) designed to allow fluid to exit the heat exchanger cylindrical tube (148); and
 - 25 e) a surface imaging module affixed to the heat exchanger cylindrical tube and positioned above an optical window to view the viewable inner surface (140) of the heat exchanger cylindrical tube (200).
19. The HTSM cell of Claim 18, further comprising a heating/cooling element
- 30 circumferentially affixed at least over a segment of the heat exchanger cylindrical tube, thereby adding control over heat transfer in the HTSM cell.
20. The HTSM cell of Claim 18, wherein the light guide is a side transparent window (142)

positioned at the longitudinal end of the heat exchanger cylindrical tube (200), and the light source (62) is positioned adjacent the side transparent window (200) to allow for low-angle illumination of the viewable surface of the heat exchange cylindrical tube (140).

- 5 21. The HTSM cell of Claim 18, wherein the light guide is a slit light guide (148) incorporated within an outer circumference of a wall of the heat exchanger cylindrical tube (200) and extending to an inner circumference of the heat exchanger cylindrical tube (200), thereby allowing light illuminate the viewable inner surface (140), and wherein the light source (146) is positioned along an inner surface of the heat exchanger cylindrical tube.

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22. A method of monitoring fouling, scaling, corrosion and pitting of a heat transfer surface, the method comprising:

- a) providing the HTSM cell of Claim 18;
- b) passing a fluid intake stream through the heat exchanger cylindrical tube and
15 over the viewable inner surface;
- c) collecting data of at least one of visual and spectral imaging from an illuminated portion of the viewable inner surface;
- d) transmitting the collected data to an image processing system; and,
- e) interpreting the collected data with the image processing system to determine
20 an extent of fouling, scaling, corrosion, and pitting.