

TITLE: Severe Service Redundant Pathway System and Method**BACKGROUND**

[1] Severe service equipment items such as control valves, filters, heat exchangers and the like, are utilized in several processes and under a variety of conditions, including extreme
5 temperatures, high pressures, abrasive particles, acidic fluids, heavy solids buildup, critical safety applications, large pressure differentials, velocity control, noise control, etc. Severe service control valves, for example, may be characterized as valves suitable for use under relatively high pressures, pressure drops and/or temperatures. Pressure and/or pressure differentials may exceed 0.7 MPa (100 psi), 7 MPa (1000 psi) or even 70 MPa (10,000 psi),
10 and temperatures may exceed 100 °C, 200 °C or even 500 °C, e.g., exceeding 14 MPa and 200 °C. Difficult process streams may be corrosive, may include abrasive particulates, may be prone to solidification unless maintained above or below a particular temperature, or within a particular temperature range, may be prone to solids buildup, and the like.

[2] For example, a pressure letdown valve in a hydrocarbon upgrading process
15 involving black oil as a process medium may require a pressure drop of 14 MPa (2000 psi) or more at temperatures above 400 °C and involve erosive and corrosive media such as catalyst particulates and coke fines that contribute to high rates of wear on the flow control element. Severe service control valves are often critical to maintaining proper process control, and yet are prone to high rates of failure. In various processes, critical equipment items such as control
20 valves in severe service may be employed in redundant legs or pathways of a process for a configuration which allows for selectively isolating the two pathways to maintain a process flow (or isolation) via one pathway or train, while providing service or maintenance on the unused, isolated leg or train. See, for example, US 9366347 B2. However, switching the process stream from one pathway to the other can impose high stresses due to temperature and
25 pressure differences. But the equipment item can be critical to operation of the process, and there is not usually time to gradually heat the equipment item being brought into service and its piping. Moreover, the now-isolated leg can be filled with media prone to solidification that must be removed prior to servicing the control valve in the isolated leg and can lead to fouling of valves used to isolate the equipment item for service.

30 [3] What is needed is a redundant-pathway severe service system that avoids or minimizes the problems noted in the prior art. Such a system would allow slow heating or cooling to avoid thermal shocks, would allow for rapid switching between pathways without the introduction of unacceptable differential temperature or pressure stresses, would inhibit or prevent process media from fouling isolation valves in the pathways, would safely allow

isolation of the critical control valve or other equipment item for service, and/or would allow the process control valve or other equipment item to be quickly returned to service when needed. Further, such a system would use a minimum quantity of purge media, which must be absorbed in downstream processes or separately processed.

5 SUMMARY

[4] We have discovered a way to circulate a hot purge media through a redundant-pathway system that allows one train to be slowly heated and then maintained in a hot standby mode of operation while the other train is maintained in a steady state mode of operation receiving a hot process stream, all while supplying the purge media to valve bodies adjacent
10 respective flow control elements of primary and secondary isolation valves. In this manner, the hot standby train can be quickly placed in service in the event of failure or failure onset of the critical equipment item in the other train. Moreover, the newly isolated train can be automatically purged of process media and returned to hot standby mode. Subsequently, the newly isolated train can be cooled down and flushed in a way that inhibits or prevents process
15 media from fouling the isolation valves. Then, the redundant equipment item can be double-isolated upstream and downstream for service, e.g., repair or replacement. Finally, the isolated leg can be slowly heated using the hot purge media and placed in hot standby mode, ready to quickly receive the process stream, thereby avoiding damage to the critical redundant item and process shutdown.

20 [5] In one aspect of the invention, embodiments herein provide a severe service system for processing a hot process stream ($>200\text{ }^{\circ}\text{C}$) from a process unit using redundant equipment. The system comprises: an inlet primary isolation valve assembly to receive the process stream and comprising first and second inlet valves to selectively divert the process stream to either or both respective first and second parallel processing trains; and an outlet primary isolation
25 valve assembly comprising first and second outlet valves to selectively receive the process stream from either or both respective first and second parallel processing trains and pass the process stream into downstream piping. The first and second parallel processing trains each comprise a redundant equipment item, an upstream secondary isolation valve between the inlet primary isolation valve assembly and the redundant equipment item, and a downstream
30 secondary isolation valve between the redundant equipment item and the outlet primary isolation valve assembly.

[6] A displacement media system is associated with the first and second trains and is adapted to continuously supply a hot purge media to valve bodies adjacent respective flow control elements of the first and second inlet valves and of the first and second outlet valves.

One of the first and second trains is configured for a steady state operating mode to pass the hot process stream from the respective inlet primary isolation valve assembly, through the respective redundant equipment item, and through the outlet primary isolation valve assembly. The other one of the first and second trains is configured in an isolated or semi-isolated mode wherein the inlet primary isolation valve assembly blocks the hot process stream from entering the isolated or semi-isolated train, wherein the outlet primary isolation valve assembly blocks communication between the isolated process train and the process stream in the isolated mode, and wherein the outlet primary isolation valve assembly allows communication between the semi-isolated train and the downstream piping in the semi-isolated mode. The displacement media system is adapted to pass the hot purge media through the semi-isolated train in a process media removal mode to downstream piping and is also adapted to pass the hot purge media through the isolated process train to maintain the isolated process train in a hot standby mode within 100 °C, preferably 50 °C, of the hot process stream. The displacement media system is further adapted to continuously supply the purge media to valve bodies adjacent respective flow control elements of the upstream and downstream secondary isolation valves during the steady state, hot standby, and process media removal modes.

[7] In some embodiments of the system, the redundant equipment items comprise process control valves, the process stream comprises black oil, and the displacement media system is adapted to continuously supply the hot purge media to a valve stem bore of the process control valve.

[8] If desired, the system just described can be automated for switching between the steady state and hot standby operating modes, wherein the first train is initially in the steady state mode and the second train is initially in the hot standby mode, and wherein the first train is subsequently in the hot standby mode and the second train is subsequently in the steady state mode.

[9] In another aspect of the present invention, a method is provided for operation of the system just described. The method comprises the steps of:

- (a) operating the first (or second) train in steady state mode with the first inlet and first outlet valves open to continuously pass the hot process stream through the first train;
- (b) operating the second (or first) train in isolated, hot standby mode to pass hot flushing media through the second train to maintain the second train within 100 °C, preferably within 50 °C, of the hot process stream;
- (c) opening the second inlet and second outlet valves to allow the hot process stream to pass through both first and second trains simultaneously;

- (d) closing the first inlet valve to place the first train in semi-isolated mode and the second train in steady state mode;
- (e) passing the hot purge media through the first train through the open first outlet valve to the downstream piping in the process media removal mode;
- 5 (f) after displacing process media from the first train, automatically closing the first outlet valve to isolate the first train from the process stream;
- (g) automatically operating the first train in isolated, hot standby mode to pass the hot purge media through the first train to maintain the first train within 100 °C, preferably 50 °C, of the hot process stream;
- 10 (h) continuously supplying purge media to valve bodies adjacent respective flow control elements of the first and second inlet valves and first and second outlet valves; and
- (i) supplying purge media to valve bodies adjacent respective flow control elements of the respective upstream and downstream secondary isolation valves in the steady state, process media removal, and hot standby modes.

15 **BRIEF DESCRIPTION OF THE DRAWINGS**

- [10]** FIG. 1 shows a redundant equipment processing module according to embodiments disclosed herein.
- [11]** FIG. 2 shows a pressure letdown module in a hydrocarbon upgrading process according to embodiments disclosed herein.
- 20 **[12]** FIG. 3 shows a displacement media system according to embodiments disclosed herein.
- [13]** FIG. 4 shows a method for switching train A from steady state to hot standby and train B from hot standby to steady state according to embodiments disclosed herein.
- [14]** FIG. 5 shows a method for switching train B from steady state to hot standby and
25 train A from hot standby to steady state according to embodiments disclosed herein.
- [15]** FIG. 6 shows a method for taking the trains A/B from hot standby to service mode according to embodiments disclosed herein.
- [16]** FIG. 7 shows a method for taking the trains A/B from service mode to hot standby according to embodiments disclosed herein.
- 30 **[17]** FIG. 8 shows a type I purge media connection (seat pocket) according to embodiments disclosed herein.
- [18]** FIG. 9 shows a type II purge media connection (body cavity) according to embodiments disclosed herein.
- [19]** FIG. 10 shows a type III purge media connection (drain) according to embodiments

disclosed herein.

[20] FIG. 11 shows a type IV purge media connection (body cavity/spring/upstream piping) according to embodiments disclosed herein.

[21] FIG. 12 shows a type V purge media connection (flush) according to embodiments disclosed herein.

[22] FIG. 13 shows control valve purge details according to embodiments disclosed herein.

DETAILED DESCRIPTION

[23] Throughout the entire specification, including the claims, the words and phrases used herein shall have the meaning consistent with the words and phrases used by those skilled in the relevant art. The following definitions of specific terms used in this disclosure is intended to clarify the meanings of the terms in a manner consistent with their ordinary meaning. No special definition of a term or phrase different from the ordinary and customary meaning as understood by those skilled in the art is intended to be implied except where expressly set forth.

[24] The terms “and/or” and “and or” refer to both the inclusive “and” case and the exclusive “or” case, and such term is used herein for brevity. For example, a composition comprising “A and/or B” may comprise A alone, B alone, or both A and B.

[25] The term “assembly” refers to a group of items gathered together in one place for at least one common purpose.

[26] The term “ball valve” refers to valves with a spherical or frusto-spherical flow control element and usually metal-to-metal sealing contact. The metal sealing surfaces are sometimes coated with a high nickel or cobalt content material for better corrosion resistance in high temperature and/or high sulfur environments.

[27] The term “black oil” refers to a hydrocarbonaceous stream that is prone to the formation, deposition, or other sedimentation of solids such as coke, asphaltenes, resins, or the like that is generally but not always black in appearance.

[28] The term “double block and bleed” refers to a double isolation arrangement with a valved bleed or vent line connected between the two isolation valves.

[29] The term “circulation” refers to movement to and fro or around something, especially that of fluid in a closed system.

[30] The term “comprising” refers to making up or constituting. The term “comprising” is open-ended and does not generally exclude the presence of unspecified components, features, or limitations.

- [31] The term “consisting of” refers to making up or constituting, however, the term is closed in that it generally excludes the presence of additional components or features.
- [32] The term “deadleg” refers to a section of pipe with no outlet and no or little flow, e.g., the flow bore into or from a valve that is closed.
- 5 [33] The term “control valve” refers to a valve that is opened or partially opened to increase or decrease a related process variable such as pressure, temperature, vessel level, flow rate, or the like, toward a desired set point.
- [34] The term “divert” refers to causing something to change course or turn from one direction to another.
- 10 [35] The terms “double isolation” or “secondary isolation” refer to isolation at least two points, e.g., using two isolation valves in a line.
- [36] The term “drain” refers to a channel, pipe or opening carrying off surplus liquid.
- [37] The term “feed” as used herein refers to any reactant, reagent, diluent, additive, and/or other component supplied to a reactor or other vessel during the process.
- 15 [38] The term “flash point” is the temperature at which a liquid will ignite when exposed to an ignition source. Unless otherwise indicated, flash point is determined herein according to ASTM D 93 by Pensky Martens closed cup apparatus.
- [39] The term “flashing” refers to rapid vaporization of a liquid or portion thereof when the pressure is suddenly reduced, e.g., when a hot hydrocarbon partially vaporizes when
- 20 passing through a pressure letdown valve.
- [40] The term “flow control element” refers to a gate, ball, diaphragm, or other device in a valve used to control flow through the valve or effect isolation of a process stream.
- [41] The term “flush” refers to cleansing something by causing large quantities of fluid to pass through it.
- 25 [42] The term “in” refers to a first material or component that is within, on, or adjacent to a second material or component.
- [43] The term “inlet” refers to a place or means of entry.
- [44] The term “isolate” refers to causing a place to be or remain alone or apart from others.
- 30 [45] The term “isolation valve” refers to a valve which blocks a process stream from flowing past.
- [46] As used herein, the terms “less than” or “up to” a specific amount of a component, without specification of a lower limit, include zero, i.e., the component is optional.

- [47] The term “media” refers to a material or form of a substance, e.g., a gas, liquid, foam, mist, slurry, or the like.
- [48] The term “metal” refers to an opaque lustrous elemental chemical substance that is a good conductor of heat and electricity and, when polished, a good reflector of light.
- 5 [49] The term “method” refers to a particular form of procedure for accomplishing or approaching something.
- [50] The term “outlet” refers to a pipe or hole through which fluid such as gas or liquid may escape.
- [51] The term “parallel processing train” refers to processing trains that are similar or
10 analogous.
- [52] The term “process” refers to a series of actions or steps taken to achieve a particular end.
- [53] The term “process unit” refers to the equipment used in a process or in a particular process action or step.
- 15 [54] The term “purge” refers to physically removing or expelling something.
- [55] The term “recovering” as used herein refers to the collection or isolation of a material.
- [56] The term “recycling” as used herein refers to returning a material already present in a cyclic process to a previous stage in the process; “recycle” refers to the material recycled.
- 20 [57] The term “redundant” refers to a duplicate or alternate item or system.
- [58] The term “valve seat” refers to a ring providing surfaces against which the valve body and/or flow control element rests to form a seal.
- [59] The term “seat pocket” refers to a void area or region in a valve designed to receive the valve seat.
- 25 [60] The term “selectively” refers to a way that involves the selection of only particular things.
- [61] The term “severe service” refers to a service involving high temperature above 200 °C, high pressure above 0.7 MPa (100 psig), and a corrosive and/or erosive process media.
- [62] The term “spring” refers to a resilient device that can be pressed or pulled but
30 returns to its former shape when released, used chiefly to exert constant tension or absorb movement. A spring is commonly a helical metal coil but it can also be a cupped spring washer in the case of a Belleville spring,
- [63] The term “stream” is used herein to refer to a flow of fluid such as liquid, gas, slurry,

mist, foam, and so on. Reference numerals may be used interchangeably to refer to process piping as well as the process stream therein.

[64] The term “switchover” refers to an instance of adopting a new position or mode.

[65] The term “system” refers to a set of things working together as parts of a mechanism
5 or an interconnecting network.

[66] The term “T-pattern” refers to a pipe with a pair of branches joining it at a 90 degree angle; piping in the shape of the letter T; a tee.

[67] The term “train” refers to a progression or series of steps in a process and related equipment that produce an intermediate or finished product or condition.

10 **[68]** The term “type I purge connection” refers to a purge connection designed to purge the vicinity of a seat pocket.

[69] The term “type II purge connection” refers to a purge connection designed to purge a valve body cavity.

[70] The term “type III purge connection” refers to a drain to remove fluid from a valve
15 body cavity.

[71] The term “type IV purge connection” refers to a valve body cavity purge used in combination with a specially designed seat and spring pocket to allow purge media to flow between the back of the seat and the spring, between the back of the spring and the seat pocket, and into upstream process piping.

20 **[72]** The term “type V purge connection” refers to a flushing connection between the sealing seat and valve body end connection (clamp, flange, weld, etc.) to introduce clean purge media into bore and piping.

[73] The terms “upstream” and “downstream” are generally in reference to the normal direction of fluid flow; however, in the case of closed isolation valves, “upstream” refers to the
25 high pressure side and “downstream” to the low pressure side but only when the valve is closed.

[74] The term “valve body cavity” refers to the generally annular space between a valve body and the flow control element.

[75] The term “Y-pattern” refers to a piping system with a branch or pair of branches joining at an acute angle; piping in the shape of the letter Y; a wye.

30 **[76]** With reference to the drawing figures in which like reference numerals indicate like parts and steps, and in which the suffixed letter indicates the respective train, it is noted that the drawing figures are simplified and do not show all the valves and parts that one of skill in the art would readily recognize, e.g., instrumentation, double block and bleed valves, bypasses, safety valves, check valves, emergency vent lines, etc.

[77] FIG. 1 shows a preferably skid-mounted parallel processing module 100 in a hydrocarbon upgrading process, having inlet Y-pattern isolation valve assembly 102 comprising inlet valves 102A/B and Y connector 103, and an outlet Y-pattern isolation valve assembly 104 comprising outlet valves 104A/B and Y connector 105, between the respective
5 inlets and outlets of parallel processing trains A/B. A preferably short deadleg 103', 105' results when the valves 102B, 104B are closed. Each of trains A/B includes upstream double isolation valves 106A/B, redundant equipment items 108A/B, such as heat exchangers or filters, and downstream double isolation valves 110A/B. The valves and piping are generally steam-traced and insulated as the skilled artisan will readily appreciate.

10 [78] According to embodiments herein, and with reference to FIGs. 1 and 2, a severe service system (100, 100') is provided for processing a hot process stream ($>200^{\circ}\text{C}$) (112) from a process unit using redundant equipment (108A/B), such as a control valve (109A/B) as best seen in FIG. 2. The system comprises an inlet primary isolation valve assembly (102) to receive the process stream. The inlet assembly comprises first and second inlet valves (102A/B)
15 to selectively divert the process stream to either or both of respective first and second parallel processing trains (A/B). Similarly, an outlet primary isolation valve assembly (104) comprises first and second outlet valves (104A/B) to selectively receive the process stream from either or both respective first and second parallel processing trains and pass the process stream into downstream piping (114).

20 [79] The first and second trains (A/B) each comprise (in addition to the piping from the first/second inlet valves (102A/B) and the piping to the first/second outlet valves (104A/B)) a redundant equipment item (108A/B, 109A/B), an upstream secondary isolation valve (106A/B) between the inlet primary isolation valve assembly (102) and the redundant equipment item, and a downstream secondary isolation valve (110A/B) between the redundant equipment item
25 (108A/B, 109A/B) and the outlet primary isolation valve assembly (104).

[80] One of the first and second trains (A/B) is configured for a steady state operating mode to pass the hot process stream (112) from the respective inlet primary isolation valve assembly (102), through the respective redundant equipment item (108A/B, 109A/B), and through the outlet primary isolation valve assembly (104). The other one of the first and second
30 trains (B/A) is configured in an isolated or semi-isolated mode wherein the inlet primary isolation valve assembly (102) blocks the hot process stream (112) from entering the isolated or semi-isolated train. In the isolated mode, the outlet primary isolation valve assembly (104) also blocks communication between the isolated process train and the process stream (114). In the semi-isolated mode, the outlet primary isolation valve assembly (104) allows

communication between the semi-isolated train and the downstream piping (114).

[81] With reference also to FIGs. 3 and 9, a displacement media system (300) is associated with the first and second trains, which is adapted to continuously supply purge media (302) to valve bodies (816) adjacent respective flow control elements (814) of the first and second inlet valves (102A/B), and to valve bodies adjacent respective flow control elements of the first and second outlet valves (104A/B).

[82] The displacement media system (300) is adapted to pass hot purge media (via line 310), through the semi-isolated train to downstream piping (114) in a process media removal mode. The displacement media system (300) is also adapted to pass hot purge media through the isolated process train to maintain the isolated process train in a hot standby mode within 100 °C, preferably 50 °C, of the hot process stream (112). In general, the temperature of the hot process stream refers to the temperature of the steady state process control valve (109A/B) or other redundant equipment item (108A/B). The displacement media system (300) is further adapted to continuously supply the purge media to valve bodies adjacent respective flow control elements of the upstream and downstream secondary isolation valves (104A/B, 110A/B) during the steady state (402A/B), hot standby (404A/B), and process media removal (424A/B) modes, as best seen in FIGs. 4-5.

[83] Purge and/or flushing media (see FIG. 3), which can be the same or different than the purge media, can be supplied via media supply lines 116A/B. Lines 116A/B contain respective media supply valves 118A/B and terminate at respective type V purge connections 120A/B. Purge media can be returned from trains A/B at type V purge connections 122A/B on outlet valves 104A/B and through return lines 124A/B into downstream piping 114. Return isolation valves 126A/B and return control valves 128A/B are provided in respective lines 124A/B. Purge and/or flushing media can also exit trains A/B via recovery lines 130A/B, connected between redundant equipment items 108A/B and downstream secondary isolation valves 110A/B, and passing to one of flushing media recovery lines 132, 134, and/or 136 and recovery systems 142, 144, 146 via valves 152, 154, 156. Lines 130A/B contain recovery valves 138A/B and temperature/pressure control valves 140A/B. Recovery lines 132, 134, 136 can be, for example, to high pressure recovery system 142 (>0.5 MPa), low pressure recovery system 144 (<0.5 MPa), and/or drain system 146 (1 atm).

[84] FIG. 3 also shows the supply of flushing media to lines 116A/B. The flushing media can be purge media via lines 310 and 310A/B, or it can be Flush Media I 350, Flush Media II 352, and/or an inert gas such as nitrogen from source 354 supplied via respective valves 315, 317, 319, lines 312A/B, and valves 313A/B. In general, Flush Media I is a high temperature

(e.g., 120-180 °C) flush media such as heavy or medium vacuum gas oil and flush media II is a low temperature (e.g., 50-90 °C) flush media such as light gas oil or diesel. Additional flushing media can be supplied as desired.

[85] FIG. 2 shows a preferred embodiment 100' where the redundant equipment items 108A/B in FIG. 1 comprise process control valves 109A/B. Generally, process control valve 109A/B is operated in automatic mode to control an upstream or downstream process variable such as pressure, temperature, vessel level, and so on, and can be critical to proper operation of the overall process.

[86] FIG. 3 shows the supply side of the displacement media system 300 according to embodiments of the present invention. Pressurized purge media source 302 supplies pressurized purge media, which may be a clean oil (free of solids) of suitable viscosity, density, boiling point, etc., to heater 304. Heater 304 is preferably an immersion-type heater controlled by temperature controller 306 to provide hot purge media at the desired temperature, e.g., within 100 °C or within 50 °C of the process stream 112. Purge media can be supplied via line 310 to lines 310A/B and 116A/B (see FIGs. 1-2). Additionally, a separate flushing media can be supplied from one or more alternate sources 350, 352, 354 via lines 312A/B and 116A/B for use in offline operations.

[87] Purge media 302 is supplied via line 308 to purge panels I-VI. As seen in Table 1, purge panel I supplies purge media to purge connections 1001-1004 to valve assembly 102 (see FIGs. 1-2); panel II to purge connections 2001-2004 to valve assembly 104 (see FIGs. 1-2); panel III to train A purge connections 3001-3005 to valve 106A (two connections), item 108A and/or control valve 109A, valve 118A, and valve 160A (see FIGs. 1-2); panel IV to train B purge connections 4001-4005 to valve 106B (two connections), item 108B and/or valve 109B, valve 118B, and valve 160B (see FIGs. 1-2); panel V to train A purge connections 5001-5005 to valves 110A (two connections), 138A, 126A, and 162A (see FIG. 1); and panel VI to train B purge connections to valves 110B (two connections), 138B, 126B, and 162B (see FIGs. 1-2). Purge media is supplied from displacement media system 300 (see FIG. 3) to flush the valves according to the following Table 1:

TABLE 1. Purge connections

Valve/Item	Purge panel	Purge connection	Purge type
102A	I	1002	II
102B	I	1001	II
102A	I	1004	I

TABLE 1 (cont.)

Valve/Item	Purge panel	Purge connection	Purge type
102B	I	1003	I
102A	N/A	120A	V
102B	N/A	120B	V
104A	II	2001	II
104B	II	2002	I
104A	II	2003	I
104B	II	2004	II
104A	N/A	122A	V
104B	N/A	122B	V
106A	III	3001	I
106B	IV	4001	I
106A	III	3002	II
106B	IV	4002	II
108A	III	3003	II
108B	IV	4003	II
110A	V	5001	I
110B	VI	6001	I
110A	V	5002	II
110B	VI	6002	II
118A	III	3004	IV
118B	IV	4004	IV
126A	V	5004	IV
126B	VI	6004	IV
138A	V	5003	IV
138B	VI	6003	IV
160A	III	3005	IV
160B	IV	4005	IV
162A	V	5005	IV
162B	VI	6005	IV

[88] Purge panels I and II supply purge media to the indicated valves regardless of the

status of process conditions. It is noted, however, that purge panels III-VI are locked open or closed via valves 320, 322, 324, and 326 during certain process status conditions via a safety interlock system 330 (see also FIGs. 1-2). If the inlet isolation valve 102A is not closed, valves 320 and 324 are locked open to ensure that purge media supply is not lost to purge panels III and V, respectively; and the same is true for train B and valves 102B, 322, 326 with respect to purge panels IV and VI. Conversely, if the train is in low pressure status or in double isolation mode, the respective valves 320/324 or 322/326 are locked closed to prevent introducing purge media into the respective train.

[89] The redundant equipment items (108A/B) shown in FIG. 1 can comprise filters, heat exchangers, or preferably process control valves (109A/B), as shown in FIG. 2. In any embodiment, the process stream (112, 114) can comprise black oil. Filters or heat exchangers in coking or other black oil service are particularly prone to fouling or coking and can be critical to the process such that they could benefit from the present invention.

[90] The inlet and outlet primary isolation valve assemblies (102, 104) can comprise a T-pattern and/or preferably a Y-pattern arrangement as seen in FIGs. 1 and 2. A Y-connector and associated isolation valves (see FIG. 1 of US 9,366,347 B2) can have an inlet/outlet deadleg of from 25 to 60 cm, or it can be a Y-connector (103, 105) preferably with integral isolation valves (see FIG. 2 of US 9,366,347 B2) or otherwise having an inlet/outlet deadleg (103, 105) of from 2 to 25 cm.

[91] Preferably, the displacement media system (300) comprises an insertion type heater (304) comprising a heating element (305) for heating the purge media (302), valving and control logic (see FIG. 3) to maintain a set point temperature of the purge media within 100 °C (preferably within 50 °C) of a temperature of the hot process stream (112, 114).

[92] By way of illustration and not limitation, the following discussion is in reference to the redundant equipment item being a control valve (109A/B) as seen in FIG. 2, the process media being black oil, and the inlet and outlet primary isolation valves (102A/B, 104A/B) having a Y-pattern arrangement, with the understanding that this is merely one example. In this embodiment, or in any other embodiment, the system is preferably automated for switching between the steady state and hot standby operating modes. By way of example, when the first (or second) train is initially in the steady state mode and the second (first) train is initially in the hot standby mode, the first (second) train is subsequently in the hot standby mode and the second (first) train is subsequently in the steady state mode. Additionally, the steady state train can be taken off steady state and cycled through the offline sequences as shown in FIGs. 4-7.

[93] In this or any other embodiment, the severe service system can further comprise

media supply connections (120A/B) to the respective first and second inlet valves (102A/B, e.g., in outlet flow passages (842) thereof as shown in FIG. 12. Supply lines (308, 310, 310A/B, 116A/B) run from a purge media supply (302) to the respective media supply connections. Respective purge/flushing media supply valves (118A/B) are disposed in the supply lines
5 (116A/B) adjacent the media supply connections (120A/B). Downstream media return connections (122A/B) are provided from the respective first and second outlet valves (104A/B), e.g., in flow passages (842) thereof as best seen in FIG. 12. Return lines (124A/B) run from the media return connections (122A/B) to bypass the outlet valves (104A/B) to the downstream piping (114). The return lines (124A/B) comprise respective return valves (126A/B) adjacent
10 the return connections (122A/B). The displacement media system (300) can further comprise lines (308) to supply the purge media to valve bodies (816) of the media supply valves (118A/B) and the media return valves (126A/B).

[94] In this or any other embodiment, the purge media can be supplied to type IV purge connections (3004, 4004, 5004, 6004) to the flushing/purge media supply valves (118A/B
15 (Figs. 1&2)) and the media return isolation valves (126A/B) to bleed purge media to the respective upstream and downstream supply/return connections (120A/B, 122A/B).

[95] In this or any other embodiment, the system can further comprise return control valves (128A/B) located in the respective return lines (124A/B) to control temperature of the respective trains in semi isolated hot standby mode, i.e., to control the temperature of the
20 process control valve (109A/B) or other redundant equipment item (108A/B).

[96] In this or any other embodiment, the system (100, 100') can further comprise media recovery lines (130A/B) connected to the respective first and second parallel processing trains (A/B) at respective connection points between the process control valve (109A/B) and the downstream secondary isolation valves (110A/B) to return purge/flushing media to the
25 designated media recovery systems (142, 144, 146). The recovery lines (130A/B) can comprise respective recovery valves (138A/B) adjacent the connection points (131A/B). The displacement media system (300) can comprise lines (see FIG. 3) to supply the purge media to valve bodies (816) of the recovery valves (138A/B) as best seen in FIG. 11. If desired, the media recovery system can comprise a plurality of different systems (142, 144, 146) for the
30 recovery of different purge and/or flushing media, e.g., having different chemical compositions and/or different pressures or temperatures, or for different purge/flushing media processing schemes.

[97] The purge media is preferably supplied to type IV purge connections (5003, 6003) to the media recovery valves (138A/B) to bleed purge media to the respective connection points

(131A/B). The type IV purge connection (FIG. 11) allows purge media to flow between a back of a seat (806) and a spring (830) of the valve, between a back of the spring (830) and a spring pocket (832) of the valve, and into process piping (808). In this or any other embodiment, the system can further comprise recovery control valves (140A/B) located in the respective recovery lines (130A/B) to control temperature and or pressure of the respective trains.

[98] In this or any other embodiment, with reference to FIG. 2, the system (101') preferably comprises a control system to automate switching between the steady state and hot standby modes. For example, beginning with the first train (A) in steady state mode and the second train (B) in hot standby mode, the switching can comprise, with the second train process control valve (109B) in the manual closed position, opening the second inlet and second outlet isolation valves (102B, 104B) for fluid communication between the hot process stream (112) and the second processing train (B). Next, the second train process control valve (109B) is manually opened partway, e.g., initially 5% and then in 5% increments, allowing the system to reach steady state between increased openings. Then the first train process control valve (109A) is switched from automatic to manual and the second train process control valve (109B) is switched to automatic control, thereby placing the second train (B) in steady state mode. The switching then comprises placing the first train process control valve (109A) on manual closed, e.g., in 5% increments while allowing the system to reach steady state between closings. Then, the first inlet isolation valve (102A) is closed and the first train process control valve (109A) is placed on manual open.

[99] Next, the switching can comprise removing black oil or other process media from the first train by supplying purge media into the first train (A) adjacent the first inlet isolation valve (102A), through the first train (A), and out through the first outlet isolation valve (104A) into the hot process stream (114). Finally, the first train (A) is placed in hot standby mode by closing the first outlet isolation valve (104A), removing purge media from the first train just upstream from the first outlet isolation valve (104A), bypassing the outlet primary isolation valve assembly (104) and returning the flushing media to the downstream piping (114).

[100] Preferably, the black oil removal and placing the first train in hot standby mode are automated based on a cumulative volumetric flow of the flushing media through the first (second) train exceeding a volume of the first (second) train. By matching the volumetric flow to the train volume plus a safety factor, say 10%, the amount of purge media entering the process to displace the black oil is kept to a minimum. After the black oil is displaced and the train is placed in hot standby, the flow of purge media can be reduced to a minimum amount required to maintain the temperature of the hot standby train within 100 °C (preferably 50 °C)

of the steady state train.

[101] In a preferred embodiment, the system can further comprise an interlock system (330) to prevent switching between hot standby and steady state modes unless the pressure and temperature of the hot standby train is at or near (within 0.5 MPa and 100 °C (preferably 50 °C)) the pressure and temperature of the hot process stream.

[102] The control system can further comprise a cooldown mode to circulate cooling media through the respective trains (A/B), a drain mode to drain the cooling media from the respective trains, and a service mode to close and lock out operation of the respective inlet isolation valve (102A/B), upstream secondary isolation valve (106A/B), downstream secondary isolation valve (110A/B), and outlet isolation valve (104A/B) until service of the respective process control valve (109A/B) is completed. The control system can further comprise sets of permissives comprising valve positions, temperature and/or pressure readings which must be satisfied for changing from the hot standby, steady state, black oil removal, cool down, drain and service modes to another mode.

[103] In this or any other embodiment, the control system preferably further comprises a low pressure interlock and a service mode interlock. The low pressure interlock works to prevent operation of the inlet and outlet isolation valves (102A/B, 104A/B) and to cut off a supply of purge oil to the upstream and downstream secondary isolation valves (106A/B, 110A/B), and preferably to the media supply valves (118A/B), media return valves (126A/B) and media recovery valves (138A/B), when the pressure of the isolated train is less than 0.5 MPa or another low pressure limit set by the operator. The service mode interlock works to prevent operation of the inlet and outlet isolation valves (102A/B, 104A/B), and of the upstream and downstream secondary isolation valves (106A/B, 110A/B), and to cut off a supply of purge oil to the upstream and downstream secondary isolation valves (106A/B, 110A/B) and preferably to the media supply valves (118A/B), media return valves (126A/B) and media recovery valves (138A/B) until servicing the respective process control valve (109A/B) is complete.

[104] In this or any other embodiment, the upstream and downstream secondary isolation valves (106A/B, 110A/B) are provided with seat pocket purge connections (3001, 4001, 5001, 6001), body cavity purge connections (3002, 4002, 5002, 6002) and optionally a body cavity drain (820) (see FIG. 10).

[105] In another aspect, with reference to FIGs. 4 and 5, the present invention provides embodiments of a method for operating the severe service system just described (400A, 400B). The method can comprise the steps of:

- (a) operating the first train (A) in steady state mode (402A) with the first inlet and first outlet isolation valves (102A, 104A) open to continuously pass the hot process stream through the first train (402A);
- (b) operating the second train (B) in isolated, hot standby mode (404B) to pass hot purge media through the second train to maintain the second train within 100 °C (preferably 50 °C) of the hot process stream (112,114);
- (c) opening the second inlet and second outlet isolation valves (102B, 104B) to allow the hot process stream to pass through both first and second trains simultaneously (412B);
- (d) closing the first inlet valve (102A) to place the first train in semi-isolated mode (406A) and the second train in steady state mode (418A, 402B);
- (e) opening media supply valve (118A) in step 422A to pass hot purge media through the first train in a process media removal mode (424A) to the downstream piping (114);
- (f) after displacing process media from the first train (A) (426A), automatically closing the second downstream isolation valve (104A) to isolate the first train from the process stream (112, 114) (428A);
- (g) operating the first train (A) in isolated, hot standby mode (404A) to pass hot purge media through the first train to maintain the first train within 100 °C (preferably 50 °C) of the hot process stream (112,114); and
- (h) during the steady state mode (402A, 402B), the isolated hot standby mode (404A, 404B), and the semi-isolated mode (406A, 406B), continuously supplying purge media to valve bodies (816) adjacent respective flow control elements (814) of the first and second inlet valves (102A/B), to valve bodies (816) adjacent respective flow control elements (814) of the first and second outlet valves (104A/B), and to valve bodies (816) adjacent respective flow control elements (814) of the upstream and downstream secondary isolation valves (106A/B, 110A/B).

[106] In this method, the purge supply to valves 102A/B, 118A/B, 106A/B, 109A/B, 138A/B, 110A/B, 104A/B, and 126A/B is maintained during steps (a) to (h). Step (a), operating the first train (A) in steady state mode (402A), generally requires all lines entering and exiting the main process line to be isolated and purge media flowing to the isolation valves (118A,138A,126A) with the first and second inlet and first and second outlet isolation valves (102A, 106A, 110A, 104A) open and purge flow to bodies to allow the control valve (109A) to continuously control the hot process stream through the first train (A).

[107] Step (b), operating the second train (B) in isolated, hot standby mode (404B), generally requires media supply and return valves (118B, 126B) to be open with control valve

(128B) in automatic control to pass hot purge media through the second train to maintain the second train within 100 °C (preferably 50 °C) of the hot process stream (112,114).

[108] Step (c), opening the second inlet and second outlet isolation valves (102B, 104B) to allow the hot process stream to pass through both first and second trains simultaneously in step (412B), generally involves initially closing the control valve (109B) in manual control and closing the purge supply and return valves (118B, 126B) with purge flowing to these valves, and then manually opening the control valve (109B) followed by full automatic setting to allow the control valve (109B) to control the hot process stream to pass through both first and second trains simultaneously.

[109] Step (d), closing the first inlet valve (102A) to place the first train in semi-isolated mode (406A) and the second train in steady state mode (418A, 402B), generally involves manually closing control valve (109A) followed by closing the first inlet valve (102A) and then manually opening the control valve (109A), all while the first outlet isolation valve (104B) remains open, to place the first train in semi-isolated mode (406A) and the second train in steady state mode (418A, 402B).

[110] Step (e), opening media supply valve to pass hot purge media in step 422A through the first train in a process media removal mode (424A) to the downstream piping (114), involves introducing hot purge media into the valve 102A at the connection point 120B through the secondary upstream isolation valve (106A), manually fully opened control valve (109A), and downstream isolation valves (110A,104A) to put the first train in the process media removal mode (424A), thereby displacing black oil to the downstream piping (114).

[111] Step (h), operating the first train (A) in isolated, hot standby mode (404A), generally requires media supply and return valves (118A, 126A) to be open with control valve (128A) in automatic control to pass hot purge media through the first train to maintain the first train within 100 °C (preferably 50 °C) of the hot process stream (112,114).

[112] In a preferred embodiment, the method (400A, 400B) comprises operation of the system wherein the hot process stream comprises black oil, the redundant equipment items (108A/B) comprise control valves (109A/B), and wherein the displacement media system (300) is further adapted to continuously supply the hot purge media to a valve stem bore of the process control valve (109A/B). The control valve 109 purge details are best seen in FIG. 13. The control valve 109 has a process inlet 850, process outlet 852, and stem 854 connected to a flow control element partially shown at 856 for the purpose of clarity, which is moved into and out of the outlet 852 to effect flow control. The purge 3003/4003 introduces purge media in the bore 858 for the stem 854. If desired, the stem 854 may be provided with grooves 860 to

facilitate flow of the purge media. In general, the purge media is supplied at or near the temperature of the control valve 109 to minimize any thermal shocks.

[113] In this or any other embodiment, the hot standby mode (404A, 404B) can comprise supplying purge media from a media supply line (116A/B) to a media supply connection (120A/B) to the respective inlet valve (102A/B), e.g., via connection (840) in outlet flow passages (842) thereof as shown in FIG. 12, passing the hot purge media through the respective train, out from a media return connection (122A/B) to the respective outlet valve (104A/B), e.g., in an inlet flow passage thereof, and through a return line (124A/B) from the return connection (122A/B) to bypass the respective outlet valves (104A/B) to the downstream piping (114). Preferably, the media supply lines (116A/B) comprise respective media supply valves (118A/B) adjacent the media supply connections (120A/B), wherein the return lines (124A/B) comprise respective media return valves (126A/B) adjacent the return connections (122A/B), and the method further comprises supplying the purge media to valve bodies (816) of the flushing/purging supply valves (118A/B) and the bypass valves (126A/B), as shown in FIG. 9, for example. If desired, the method can further comprise controlling temperature of the respective trains by means of media return control valves (128A/B) located in the respective return lines (124A/B). By modulating the amount of hot purge media passing through the train, the temperature of the train can be controlled via feedback temperature from skin type thermocouples in the control valves (109A/B).

[114] The method preferably comprises:

- (1) connecting media recovery lines (130A/B) to the respective first and second trains at respective connection points (131A/B) between the process control valve (109A/B) and the downstream secondary isolation valves (110A/B) to drain media to one or more media recovery systems (142, 144, 146);
- (2) wherein the media recovery lines (130A/B) comprise respective recovery valves (138A/B) adjacent the connection points (131A/B); and
- (3) supplying purge media to valve bodies (816) of the media recovery valves (138A/B).

[115] In this or any other embodiment, the purge media can be supplied to type IV purge connections (410, 3004, 4004, 5003, 5004, 6003, 6004) (see FIGs. 2, 3, and 11) to the media supply valves (118A/B) and the media return valves (126A/B), and also to the media recovery valves (138A/B), to bleed purge media to the respective media supply, return and recovery connections (120A/B, 122A/B, 131A/B). This inhibits black oil entry and solidification in the valves (118A/B, 126A/B, 138A/B) and in the connection lines (120A/B, 122A/B, 130A/B), which are deadlegs adjacent to the connection points (120A/B, 122A/B, 131A/B) in the steady

state mode, and adjacent to the recovery connection points (131A/B) in the hot standby mode. As best seen in FIG. 11, the type IV purge connection allows purging media to flow between a back of a seat (806) and a spring (830) of the valve, between a back of the spring (830) and a spring pocket (832) of the valve (800), and into process piping.

5 **[116]** In this or any other embodiment, the method can further comprise controlling temperature and/or pressure of the respective trains in isolated mode by means of return control valves (140A/B) located in the respective return lines (130A/B).

[117] In this or any other embodiment, the automated switching between the steady state and hot standby modes (402A/B, 404A/B) shown in FIGs. 4 and 5 can further comprise:

- 10 (I) with the second train process control valve (109B) in the manual closed position, opening the second inlet and second outlet isolation valves (102B, 104B) for fluid communication between the hot process stream (112, 114) and the second processing train (410B, 412B);
 (II) then manually opening the second train process control valve (109B) (414B);
 (III) then placing the first train process control valve (109A) on manual partially open
15 (416A);
 (IV) then placing the second train process control valve (109B) on automatic control (416B), thereby placing the second train in steady state mode (402B);
 (V) closing the first inlet isolation valve (102A) (418A);
 (VI) then placing the first train process control valve (109A) on manual open (420A);
20 (VII) opening the media supply valve (118A) (422A);
 (VIII) removing black oil from the first train by supplying hot purge media into the first train adjacent the first inlet isolation valve (102A), through the first train, and out through the first outlet isolation valve (104A) into the hot process stream (114) (424A); and
 (IX) placing the first train in hot standby mode (404A) by closing the first outlet isolation
25 valve (104A) and opening the flushing media return valve (126A) (428A) and removing purge media from the first train upstream from the second outlet isolation valve (104A), wherein the black oil removal and placing the first train in hot standby mode are automated based on a cumulative volumetric flow of the flushing media through the first train exceeding a volume of the first train (426A).

30 **[118]** In this or any other embodiment, the method can further comprise interlocking the system to prevent switching between hot standby and steady state modes unless the pressure and temperature of the hot standby train is at or near (within 0.5 MPa and 100 °C (preferably 50 °C)) the pressure and temperature of the hot process stream.

[119] In this or any other embodiment, with reference to FIG. 6, the method can further

comprise:

- (A-1) circulating cooling media through the respective train in a cooldown mode (602, 606, 608);
- (A-2) draining the cooling media from the respective train in a draining mode (610); and
- 5 (A-3) closing and locking out operation of the respective inlet isolation valve (102A/B), upstream secondary isolation valve (106A/B), downstream secondary isolation valve (110A/B), and outlet isolation valve (104A/B) for a service mode (616) until service of the respective process control valve (109A/B) is completed.

[120] In this or any other embodiment, with reference to FIGs. 4 and 6, the method preferably further comprises sets of permissives comprising valve positions, temperature and/or pressure readings (408A/B, 426A/B, 603, 605, 607, 609) which must be satisfied for changing from hot standby, steady state, process media removal, cool down, depressurization, drain and service modes to another mode.

[121] FIGs. 4-6 depict the operation of the severe service module 100, 100' of FIGs. 1 and 2, respectively. When trains A/B are in steady state mode, respective valves 102A/B and 104A/B are open to receive the hot process stream from upstream piping 112 and pass it through redundant equipment item 108A/B, i.e., process control valve 109A/B in the case of FIG. 2, into downstream piping 114. In steady state mode 402A/B (FIG. 4), respective media supply valves 118A/B, bypass valves 126A/B, and main drain valves 138A/B are all closed.

20 When trains A/B are in an isolated mode, as in hot standby mode 404A/B, respective valves 102A/B and 104A/B are closed. In hot standby mode 404A/B, media supply valves 118A/B and return valves 126A/B are open. The temperature of the standby trains A/B can be controlled by preferably automatic operation of temperature/pressure control valves 128A/B.

[122] FIG. 4 shows the method whereby Train A is initially in steady state mode 402A, Train B is in hot standby mode 404B, and a switchover is initiated whereby Train A is switched to hot standby mode 404A and Train B is switched to steady state mode 402B. For the switchover process to initiate, the permissives must be satisfied in step 408B, i.e., the temperature must be higher than the hot standby required temperature, TH, and the pressure must be higher than the hot standby required pressure, PH, for this embodiment. For example,

25 the TH may be within 100 °C of the steady state train A, preferably 50 °C, and the PH may be higher than that of train A.

[123] The switchover is initiated by closing process control valve 109B in manual mode and valve 126B, in step 410B. Then, in step 412B, valves 102B and 104B are opened. Next, in steps 414B, 416A, and 416B, process control valve 109B is brought into automatic mode while

process control valve is brought into manual mode and closed. For example, valve 109B can be opened manually in 5% increments while valve A closes automatically to compensate, and the process is lined out before opening valve 109B some more. When valve 109A is almost closed, valve 109B can be placed in automatic and valve 109A manually closed.

5 **[124]** Then, in step 418A, valve 102A is closed and train A is placed in semi-isolated mode 406A with valve 104A still open. By opening valve 109A in manual mode in step 420A, and opening valve 116A in step 422A, train A is placed in process media removal mode 424A, whereby purge media from line 310A passes through valve 311A, valve 118A, line 116A, type V purge connection 120A, secondary isolation valve 106A, process control valve 109A,
10 secondary isolation valve 110A, and isolation outlet valve 104A and into downstream piping 114. By measuring the cumulative flow in mode 424A, it can be determined in step 426A when the process media has been completely displaced from train A, usually with a safety factor of say 10-20% to account for back-mixing between the process media and the purge media. Then, valve 104A is automatically closed and valve 126A is automatically opened in step 428A,
15 whereby the purge media exits out through type V purge connection 120A from valve 104A, through return valve 126A and return piping 124A, and into downstream piping 114. Train A is thus placed on hot standby mode 404A wherein the temperature of train A can be controlled via temperature feedback from control valve 126A.

20 **[125]** The converse method 400B for the switchover from Train B in steady state and train A in hot standby, is illustrated in FIG. 5.

25 **[126]** FIG. 6 shows the method of operation 600 when trains A/B are in an isolated mode such as in offline sequences for high pressure cooldown mode 602, depressurization mode 604, low pressure cooldown mode 606, final cooldown mode 608, drain/vent/sweep modes 610, 612, 614, and service mode 616. In high pressure cooldown mode 602, purge media is used as the flushing media via valves 118A/B, and the temperature of the purge media is gradually decreased by lowering the temperature of the purge media that is supplied. The rate of temperature change can be controlled by operating valves 128A/B with a temperature rate of change controller (not shown). Upon entry to cooldown mode 606, interlock system 330 prevents operation of the respective valves 102A/B and 104A/B.

30 **[127]** In high pressure to low pressure transition mode 604, valves 311A/B (see FIG. 3) and 126A/B are closed and valves 138A/B and 152 are opened to depressurize the trains A/B into high pressure/high temperature media recovery system 142. Then valves 313A/B are opened to supply Flush Media I 350 via lines 312A/B and 116A/B. Permissives in step 603 to enter the transition mode 604 are the closure of all purge oil valves in panels III/V or IV/VI

and a train A/B temperature less than or equal to T1. In some embodiments a swing elbow (not shown) is used to connect the flushing media source 350 and/or 352 (lines 312A/B, see FIG. 3) to lines 116A/B. Upon entering the low pressure status of the train 608, interlock system 330 prevents supply of purge media to the respective purge panels III-VI (FIG. 3), and also prevents operation of respective valves 102A/B and 104A/B (see FIGs. 1-2).

[128] In low pressure cooldown mode 606, valves 315, 312A/B, 118A/B, 138A/B, and 152 are open and valves 317, 126A/B and 311A/B are closed to circulate high temperature (120-180 °C) Flush Media I 350 at a progressively lower temperature through the trains A/B. Any steam tracing should preferably be turned off for the cooldown modes. In an embodiment, the trains A/B are cooled down using flushing media at two different temperatures, initially at a higher temperature, e.g., 120-180 °C, and then at a lower temperature, e.g., 50-90 °C, using low temperature Flush Media II 352 at 50-90 °C. Permissives to enter or progress in the low pressure cooldown mode 606 are the temperature of the flushing media. In embodiments, the 120-180 °C flushing media may be different than the 50-90 °C flushing media, e.g., vacuum gas oil and diesel fractions with a suitable boiling point above the temperature of use and a desirably high flash point, which is preferably above the temperature of use of the respective flushing media.

[129] In the final cooldown mode 608, low temperature flushing media (10-40 °C) is supplied to displace the medium temperature flushing media. Valves 313A/B, 118A/B, 138A/B, and 152 are open and valves 126A/B are closed, and a rate of change temperature controller (not shown) can be used.

[130] After the train is cooled down to ambient temperature and the high temperature flushing media has been displaced with the low temperature flushing media, the train can be drained in step 610, vented in step 612, and swept with nitrogen in step 614 in preparation for the service mode 616. Draining 610 is effected by closing valves 116A/B, opening valve 138A/B, pacing valves 140A/B in manual open, closing valves 152 and 154, and opening drain valve 160. Venting is accomplished by opening respective valves 160A/B and 162A/B to vent lines 164, 166. Nitrogen (or other inert gas) sweeping is accomplished by opening valve 319.

[131] After draining 610, venting 612 and sweeping 614, the trains A/B are isolated for maintenance of the redundant equipment items 108A/B by closing, de-energizing and locking out respective valves 102A/B, 104A/B, 106A/B, and 110A/B. Completion of the double-block isolation sequence preferably activates sequence interlock system 330 (FIGs. 1-3), which closes all valves 102A/B, 104A/B, 106A/B, 110A/B, 118A/B, 126A/B, and 138A/B. Control valves 128A/B and 140A/B are fail manual closed from the previous sequence. The sequence

interlock cannot be deactivated until maintenance (repair or replacement) of the redundant equipment items 108A/B (valves 109A/B) is completed. Interlock system 330 also prevents supply of purge media to the respective purge panels III/V or IV/VI.

[132] FIG. 7 shows the method of operation 700 when a train is finishing service mode 616 and is brought into hot standby mode 404, including pipe fill mode 706, initial warmup mode 710, low pressure/low temperature warmup mode 712, low pressure/high temperature warmup mode 714, pressurization mode 716, high pressure warmup mode 718, etc. In step 616, respective valves 102A/B and 104A/B are closed.

[133] After maintenance of the redundant equipment item 108A/B (e.g., control valve 109A/B), the sequence interlock 330 is de-activated in step 702, valves 104A/B and 110A/B are opened and valves 138A/B are closed in step 704, and the respective train A/B is flooded with flushing media (low temperature) and all air pockets removed in step 706. Valves 158, 118A/B, 138A/B, and 152 are open and valves 126A/B are closed, and the rate of change temperature controller (not shown) can be used to operate valves 138A/B. The initial warmup sequence will raise the temperature of the trains A/B to the medium temperature flushing media temperature. Temperature rise may only be 2-2.5 °C/h, depending on fluid usage limitations.

[134] In low pressure warmup mode, valves 158, 118A/B, 138A/B, and 152 are open and valves 126A/B are closed to circulate flushing media at a progressively higher temperature through the trains A/B. Steam tracing can be turned on for the warmup mode. In an embodiment, the trains A/B are warmed up using flushing media at two different temperatures, initially at a lower temperature, e.g., 70 °C, and then at a higher temperature, e.g., 150 °C. Permissives to enter or progress in the low pressure warmup mode are the temperature of the flushing media. In embodiments, the 150 °C flushing media may be different than the 70 °C flushing media, e.g., vacuum gas oil and diesel.

[135] In low pressure to high pressure transition mode 716, the swing elbow is aligned to the desired flushing media source (preferably purge media from supply 302), valves 138A/B and 158 are closed and valves 117 and 126A/B are opened to pressurize the trains A/B.

[136] In high pressure warmup mode 720, purge media is preferably used as the flushing media via lines 116A/B and 310, and the temperature of the trains A/B is gradually increased by increasing the temperature of the purge media. The rate of temperature change can be controlled by operating valves 128A/B with the temperature rate of change controller. At the end of the high pressure warmup sequence, the trains A/B preferably transition automatically to hot standby mode 404 if the permissives are met in step 720.

[137] FIGs. 8-12 show different types of purge media connections in a typical valve 800.

Type I connection 802 best seen in FIG. 8 supplies purge media to seat pocket 804, which is specifically designed to direct clean purge media around the perimeter of the seat 806. This type of purge connection results in practically no flow during normal operations and is generally continuously supplied in all valve positions at a pressure greater than any process media 808 in the valve 800, e.g., a delta P of equal to or greater than 0.35 MPa. The Type I
5 purge is generally continuously provided to all valves in steady state or hot bypass modes, e.g., the inlet and outlet Y-pattern valve assemblies 102, 104, double isolation valves 106A/B, 110A/B and also sometimes to control valves 109A/B depending on their design.

[138] Type II connection 810 best seen in FIG. 9 continuously supplies purge media to
10 valve body cavity 812 between flow control element 814 and valve body 816 at a pressure greater than process media 808. During cycling of the valve 800, i.e., when the valve 800 is partially open/partially closed, there is a relatively high volume of purge media flow into the process media 808 to inhibit process media from entering the valve cavity 812, and when the valve 800 is fully open or fully closed, there is practically no purge flow. The type II purge is
15 used, for example, on the double isolation valves 106A/B and 108A/B.

[139] Type III connection 820 best seen in FIG. 10 is a drain that is continuously and/or intermittently activated to remove purge media from cavity 812 to a purge media return or to another process location, e.g., downstream in the process, typically using appropriate check, block and control valves as is known to one skilled in the art. Connection 820, when activated
20 with the valve 800 generally in a fully open or fully closed position, effectively converts Type II purge connection 810 to continuous flow to flush purge media through cavity 812. The type III drain is used, for example, on the secondary isolation valves 106A/B and 108A/B.

[140] The Type IV purge connection best seen in FIG. 11 uses a Type II connection 810 in combination with a specially designed spring 830 and seat 806 with one or more leak paths
25 834 notched in the seat 806, and a high purge media-process media delta P to provide continuous purging between the back of the seat 806 and the spring, and between the back of the spring 830 and the spring pocket 832, into the upstream process piping containing or otherwise containing process media 808. The Type IV purge helps keep process media 808 out of the cavity 812, seat pocket 804 and spring pocket 832, and can also purge the upstream
30 piping containing process media 808, e.g., where this is a deadleg that might otherwise accumulate process media that is prone to solidification such as coke formation from black oil. The type IV purge connection is used on flushing media supply valves 118A/B (see FIG. 1) connected to the upstream Type V purge connections 120A/B from the downstream Y-pattern isolation valve assembly 104. The type IV purge connection can similarly be used on flushing

media return valves 138A/B and bypass valves 126A/B. This helps keep process media from entering and solidifying in the piping runs between connections 120A/B and valves 118A/B, between connections 122A/B and valves 126A/B, and in lines 130A/B, when the respective trains A/B are operated in steady state mode.

5 **[141]** The Type V purge connection 840 best seen in FIG. 12 provides a continuous or intermittent flush to (or from) upstream (not shown, cf. connections 122A/B) in FIG. 1) or downstream piping 842 for optimized purge flow (cf. connections 120A/B in FIG. 1). The Type V purge may be used in applications with vacuum process conditions, or other applications. In the instant system and process, the type V purge 840 is used in the downstream legs of inlet Y-pattern isolation valve assembly 102 and the upstream legs of outlet Y-pattern isolation valve assembly 104, to circulate purge media through the respective train during hot standby and other operational modes when isolated or semi-isolated from the steady state train.

[142] The invention thus provides the following embodiments:

1. A severe service system (100) for processing a hot process stream ($>200\text{ }^{\circ}\text{C}$) (112) from a process unit using redundant equipment, comprising:
 - an inlet primary isolation valve assembly (102) to receive the process stream and comprising first and second inlet valves (102A, 102B) to selectively divert the process stream to either or both of respective first and second parallel processing trains (A, B);
 - an outlet primary isolation valve assembly (104) comprising first and second outlet valves (104A, 104B) to selectively receive the process stream from either or both respective first and second parallel processing trains and pass the process stream into downstream piping (114);
 - the first and second parallel processing trains each comprising a redundant equipment item (108A, 108B), an upstream secondary isolation valve (106A, 106B) between the inlet primary isolation valve assembly and the redundant equipment item, and a downstream secondary isolation valve (110A, 110B) between the redundant equipment item and the outlet primary isolation valve assembly;
 - a displacement media system (300) associated with the first and second trains, the displacement media system adapted to continuously supply a hot purge media (308) to valve bodies (816) adjacent respective flow control elements (814) of the first and second inlet valves (102A, 102B) and of the first and second outlet valves (104A, 104B);
- wherein one of the first and second trains (A, B) is configured for a steady state operating mode (402A, 402B) to pass the hot process stream (112) from the respective inlet primary

- isolation valve assembly (102), through the respective redundant equipment item (108A, 108B), and through the outlet primary isolation valve assembly (104);
- wherein the other one of the first and second trains (A, B) is configured in an isolated or semi-isolated mode wherein the inlet primary isolation valve assembly (102) blocks the hot process stream (112) from entering the isolated or semi-isolated train, wherein the outlet primary isolation valve assembly (104) blocks communication between the isolated process train and the process stream in the isolated mode, and wherein the outlet primary isolation valve assembly (104) allows communication between the semi-isolated train and the downstream piping (114) in the semi-isolated mode;
- wherein the displacement media system (300) is adapted to pass the hot purge media (308) through the semi-isolated train in a process media removal mode (424) to downstream piping (114);
- wherein the displacement media system (300) is adapted to pass the hot purge media (308) through the isolated process train to maintain the isolated process train in a hot standby mode (404) within 100 °C (preferably within 50 °C) of the hot process stream (112); and
- wherein the displacement media system (300) is adapted to continuously supply the purge media (308) to valve bodies (816) adjacent respective flow control elements (814) of the upstream and downstream secondary isolation valves (106, 110) during the steady state (402), hot standby (404), and process media removal (424) modes.
2. The severe service system of Embodiment 1, wherein the redundant equipment items (108) comprise control valves (109).
 3. The severe service system of Embodiment 1 or Embodiment 2, wherein the process stream (112) comprises black oil.
 4. The severe service system of any preceding Embodiment, wherein the inlet and outlet primary isolation valve assemblies (102, 104) comprise a Y-pattern arrangement and an inlet/outlet deadleg (103'/105') of from 2 to 25 cm.
 5. The severe service system of any preceding Embodiment, wherein the displacement media system (300) comprises an insertion type heater (304) comprising a heating element (305) for heating the purge media (302), valving, and control logic to maintain a set point temperature of the hot purge media (308) within 50 °C of a temperature of the hot process stream (112).
 6. The severe service system of any preceding Embodiment, wherein the redundant equipment items (108) comprise process control valves (109), wherein the process stream (112)

comprises black oil, and wherein the displacement media system (300) is further adapted to continuously supply the hot purge media (308) to a valve stem bore (858) of the process control valve (109).

7. The severe service system of any preceding Embodiment, wherein the system (100, 100')
5 is automated for switching between the steady state and hot standby operating modes, wherein the first train (A) is initially in the steady state mode (402A) and the second train (B) is initially in the hot standby mode (404B), and wherein the first train is subsequently in the hot standby mode (404A) and the second train is subsequently in the steady state mode (402B).
- 10 8. The severe service system of any preceding Embodiment, further comprising:
media supply connections (120) to the respective first and second inlet valves (102A, 102B);
supply lines (116A, 116B) from a media supply (302, 350, 352, 354) to the respective media
supply connections (120A, 120B) comprising respective media supply valves (118A,
118B) adjacent the media supply connections; and
15 wherein the displacement media system (300) comprises lines (300A, 400A) to supply the purge
media to valve bodies (816) of the media supply valves;
media return connections (122A, 122B) from the first and second outlet valves (104A, 104B)
and return lines (124A, 124B) from the media return connections to bypass the
respective outlet valves (104A, 104B) to the downstream piping (114), wherein the
20 return lines comprise media return valves (126A, 126B) adjacent the media return
connections, and wherein the displacement media system comprises lines (500A, 600A)
to supply the purge media to valve bodies (816) of the media return valves (126A,
126B); and
return control valves (128A, 128B) located in the respective return lines (124A, 124B) to
25 control temperature and/or pressure of the respective trains (A, B) in isolated mode;
preferably wherein the purge media is supplied to type IV purge connections (410) to the media
supply valves (118A, 118B) and the media return valves (126A, 126B) to bleed purge
media to the respective supply and return connections (120A, 120B, 122A, 122B) when
the respective train (A, B) is in the steady state mode (402).
- 30 9. The severe service system of any preceding Embodiment, further comprising:
one or more media recovery lines (130A, 130B) connected to the respective first and second
parallel processing trains (A, B) at respective connection points (131A, 131B) between
the process control valves (109A, 109B) and the downstream secondary isolation valves

- (110A, 110B) to recover purge and/or flushing media to a media recovery system (142, 144, 146); and
- wherein the recovery lines (130A, 130B) comprise respective recovery valves (138A, 138B) adjacent the connection points (131A, 131B);
- 5 wherein the displacement media system (300) comprises lines (5003, 6003) to supply the purge media to valve bodies (816) of the media recovery valves (138);
- return control valves (128A, 128B) located in the respective return lines (124A, 124B) to control temperature and/or pressure of the respective trains (A, B);
- preferably type IV purge connections (410) to the media recovery valves (138A, 138B) to bleed
- 10 purge media to the respective connection points (131A, 131B), wherein the type IV purge connections allow purge media to flow between a back of a seat (806) and a spring (830) of the valve, between a back of the spring and a spring pocket (832) of the valve, and into process piping (808).
10. The severe service system of Embodiment 9, further comprising a control system to
- 15 automate switching between the steady state and hot standby modes (402, 404), wherein the switching comprises:
- with the second train process control valve (109B) in the manual closed position, opening the second inlet and second outlet valves (102B, 104B) for fluid communication between the hot process stream (112, 114) and the second train (B);
- 20 then manually opening the second train process control valve (109B);
- then placing the first train process control valve (109A) on manual partially open;
- then placing the second train process control valve (109B) on automatic control, thereby placing the second train in steady state mode (402);
- closing the first inlet valve (102A);
- 25 then placing the first train process control valve (109A) on manual open;
- removing black oil from the first train (A) by supplying hot purge media into the first train adjacent the first inlet valve (102A), through the first train (A), and out through the first outlet valve (104A) into the downstream piping (114); and
- placing the first train (A) in hot standby mode (404) by closing the first outlet valve (104A)
- 30 and removing purge media from the first train upstream from the first outlet valve (104A), wherein the black oil removal and placing the first train in hot standby mode are automated based on a cumulative volumetric flow of the purge media through the first train exceeding a volume of the first train;

- preferably wherein the control system further comprises a hot standby interlock (303) to prevent switching between hot standby (404) and steady state (402) modes unless the pressure and temperature of the hot standby train is at or near (within 0.5 MPa and 100 °C, preferably within 50°C) the pressure and temperature of the hot process stream (112).
- 5 (112).
11. The severe service system of Embodiment 10, wherein the control system further comprises a set of offline sequences:
- a train high pressure (HP) cooldown mode (602) to circulate cooling media through the respective trains;
 - 10 a train HP to low pressure (LP) transition mode (604) to reduce pressure in the respective trains;
 - an LP train cooldown sequence mode (606) for gradually decreasing temperature of the respective trains;
 - a train final cooldown sequence mode (608) for reducing temperature to ambient in the respective trains;
 - 15 a train drain/vent and nitrogen sweep sequence mode (610, 612, 614) for remaining flushing media and pressure to be evacuated from the respective trains; and
 - a train control valve removal sequence mode (615) that activates an interlock system (330) for process double isolation to prevent accidental opening of upstream or downstream double isolation for removal of the process control valve from the respective trains; and
 - 20 wherein the control system preferably further comprises:
- sets of permissives comprising valve positions, temperature and/or pressure readings which must be satisfied for changing from the hot standby, steady state, black oil removal, cool down, drain and service modes to another mode;
 - a low pressure interlock to prevent operation of the inlet and outlet valves (102A, 102B, 104A, 25 104B) and to cut off a supply of purge oil to the upstream and downstream secondary isolation valves (106A, 106B, 110A, 110B) (and preferably to the media supply, return and recovery valves (118A, 118B, 126A, 126B, 138A, 138B)) when the pressure of the isolated train is less than 0.5 MPa; and
 - a service mode (616) interlock to prevent operation of the inlet and outlet valves (102A, 102B, 30 104A, 104B), and of the upstream and downstream secondary isolation valves (106A, 106B, 110A, 110B), and to cut off a supply of purge oil to the upstream and downstream secondary isolation valves (and preferably to the media supply, return and recovery

- valves (118A, 118B, 126A, 126B, 138A, 138B)) until servicing of the respective process control valve (109A, 109B) is complete.
12. The severe service system of any preceding Embodiment, wherein the upstream and downstream secondary isolation valves (106A, 106B, 110A, 110B) are provided with seat pocket purge connections (802), body cavity purge connections (810) and a body cavity drain (820).
 13. The severe service system of any preceding Embodiment, wherein the redundant items comprise control valves (109A, 109B) provided with stem purge connections (3003, 4003).
 14. A method for operation of the severe service system of any preceding Embodiment, comprising the steps of:
 - (a) operating the first train (A) in steady state mode (402A) with the first inlet and first outlet valves (102A, 104A) open to continuously pass the hot process stream (112) through the first train;
 - (b) operating the second train (B) in isolated, hot standby mode (404B) to pass hot purge media (308) through the second train to maintain the second train within 100 °C, preferably 50 °C, of the hot process stream (112);
 - (c) opening the second inlet and second outlet valves (102B, 104B) to allow the hot process stream (112) to pass through both first and second trains (A, B) simultaneously;
 - (d) closing the first inlet valve (102A) to place the first train (A) in semi-isolated mode (424A) and the second train (B) in steady state mode (404B);
 - (e) opening the media supply valve (118A) to pass hot purge media through the first train through the open first outlet valve (104A) to the downstream piping (114) in a process media removal mode (424A);
 - (f) after displacing process media from the first train (426A), automatically closing the first outlet valve (104A) to isolate the first train from the hot process stream (114);
 - (g) automatically operating the first train (A) in isolated, hot standby mode (404A) to pass hot purge media through the first train to maintain the first train within 100 °C, preferably within 50 °C, of the hot process stream (112);
 - (h) continuously supplying purge media to valve bodies (816) adjacent respective flow control elements (814) of the respective first and second inlet valves (102A, 102B) and first and second outlet valves (104A, 104B); and
 - (i) supplying purge media to valve bodies (816) adjacent respective flow control elements (814) of the respective upstream and downstream secondary isolation valves (106A, 106B,

110A, 110B) in the steady state (402), process media removal (424), and hot standby modes (404).

15. The method of Embodiment 14, wherein the hot standby mode (404) comprises supplying hot purge media from a media supply line (116) to a media supply connection (120) to
5 the respective inlet valve (102A, 102B), passing the hot purge media through the respective train (A, B), out from a media return connection (122) from the respective outlet valve (104A, 104B), and through a return line (124) from the media return connection to bypass the respective outlet valves (104A, 104B) to the downstream process piping (114);
- 10 preferably wherein the media supply lines (116A, 116B) comprise respective media supply valves (118A, 118B) adjacent the media supply connections (120A, 120B), wherein the return lines (124A, 124B) comprise respective return valves (126A, 126B) adjacent the media return connections (122A, 122B), and further comprising supplying the purge media to valve bodies (816) of the respective media supply and return valves (118A,
15 118B, 126A, 126B) in the steady state (402), hot standby (404), and process media removal modes (424);
- preferably controlling temperature of the respective trains (A, B) by means of return control valves (128A, 128B) located in the respective return lines (124A, 124B);
- preferably wherein the purge media is supplied to type IV purge connections (410) to the media
20 supply valves (118A, 118B) and the return valves (126A, 126B) to bleed purge media to the respective media supply and return connections (120A, 120B, 122A, 122B).
16. The method of Embodiment 14 or Embodiment 15, wherein the redundant equipment items comprise control valves (109A, 109B) and further comprising:
- connecting media recovery lines (130A, 130B) to the respective first and second trains at
25 respective connection points (131A, 131B) between the process control valves (109A, 109B) and the downstream secondary isolation valves (110A, 110B) to return media to a media recovery system (142, 144, 146);
- wherein the media recovery lines (130A, 130B) comprise respective media recovery valves (138A, 138B) adjacent the connection points (131A, 131B);
- 30 supplying purge media to valve bodies (816) of the media recovery valves (138A, 138B);
- preferably wherein the purge media is supplied to type IV purge connections (410) to the media recovery valves (138A, 138B) to bleed purge media to the respective connection points (131A, 131B), wherein the type IV purge connection allows purge media to flow

- between a back of a seat (806) and a spring (830) of the valve, between a back of the spring and a spring pocket (832) of the valve, and into process piping (808); and preferably controlling temperature of the respective trains in isolated mode (404) by means of return control valves (128A, 128B) located in the respective return lines (124A, 124B).
- 5 17. The method of any of Embodiments 14 to 16, wherein the redundant equipment items comprise control valves (109A, 109B) and wherein switching between the steady state (402) and hot standby (404) modes is automated and comprises:
- with the second train process control valve (109B) in the manual closed position, opening the second inlet and second outlet valves (102B, 104B) for fluid communication between
- 10 the hot process stream (112, 114) and the second train (B);
- then manually opening the second train process control valve (109B);
- then placing the first train process control valve (109A) on manual partially open;
- then placing the second train process control valve (109B) on automatic control, thereby placing the second train in steady state mode (404B);
- 15 closing the first inlet valve (102A);
- then placing the first train process control valve (109A) on manual open;
- removing black oil from the first train by supplying purge media into the first train (A) adjacent the first inlet isolation valve (102A), through the first train (A), and out through the first outlet isolation valve (104A) into the hot process stream (114); and
- 20 placing the first train (A) in hot standby mode (404A) by closing the first outlet valve (102A) and removing purge media from the first train upstream from the first outlet valve (104A), wherein the black oil removal (424A) and placing the first train in hot standby mode (404A) are automated based on a cumulative volumetric flow of the purging media through the first train exceeding a volume of the first train; and
- 25 preferably interlocking the system (101, 101') to prevent switching between hot standby and steady state modes (402, 404) unless the pressure and temperature of the hot standby train (404) is at or near (within 0.5 MPa and 100 °C, preferably within 50 °C) the pressure and temperature of the hot process stream (112).
18. The method of any of Embodiments 14 to 17, further comprising:
- 30 circulating cooling media through the respective train in a cooldown mode (602);
- depressurizing the respective train (604) to a pressure below 0.5 MPa for operation in a low pressure mode (606);
- closing and locking out operation of the displacement media system (300) to prevent supplying purge media to the respective upstream and downstream secondary isolation valves

- (106A, 106B, 110A, 110B), to the respective media supply valve (118A, 118B), to the respective return valve (126A, 126B), and to the respective media recovery valve (138A, 138B), during operation in the low pressure mode;
- draining the cooling media from the respective train in a drain mode (610); and
- 5 closing and locking out operation of the respective inlet isolation valve (102A, 102B), upstream secondary isolation valve (106A, 106B), downstream secondary isolation valve (110A, 110B), and outlet valve (104A, 104B) for a service mode (616) until service of the respective process control valve (109A, 109B) is completed; and
- preferably further comprising sets of permissives comprising valve positions, temperature
- 10 and/or pressure readings which must be satisfied for changing from hot standby (404), steady state (402), process media removal (424), cool down (602, 606, 608), low pressure (604, 606), drain (610), and service (616) modes to another mode.
- [143]** All documents described herein are incorporated by reference herein, including any priority documents and/or testing procedures to the extent they are not inconsistent with this
- 15 text. As is apparent from the foregoing general description and the specific embodiments, while forms of this disclosure have been illustrated and described, various modifications can be made without departing from the spirit and scope of this disclosure. Accordingly, it is not intended that this disclosure be limited thereby. Likewise, the term “comprising” is considered synonymous with the term “including” for purposes of United States law. Likewise whenever
- 20 a composition, an element or a group of elements is preceded with the transitional phrase “comprising,” it is understood that we also contemplate the same composition or group of elements with transitional phrases “consisting essentially of,” “consisting of,” “selected from the group of consisting of,” or “is” preceding the recitation of the composition, element, or elements and vice versa.
- 25 **[144]** While this disclosure has been described with respect to several embodiments and examples, those skilled in the art, having benefit of this disclosure, will appreciate that other embodiments can be devised which do not depart from the scope and spirit of this disclosure.

CLAIMS

What is claimed is:

1. A severe service system (100) for processing a hot process stream ($>200\text{ }^{\circ}\text{C}$) (112) from a process unit using redundant equipment, comprising:
 - 5 an inlet primary isolation valve assembly (102) to receive the process stream and comprising first and second inlet valves (102A, 102B) to selectively divert the process stream to either or both of respective first and second parallel processing trains (A, B);
 - an outlet primary isolation valve assembly (104) comprising first and second outlet valves (104A, 104B) to selectively receive the process stream from either or both respective first and second parallel processing trains and pass the process stream into downstream piping (114);
 - 10 the first and second parallel processing trains each comprising a redundant equipment item (108A, 108B), an upstream secondary isolation valve (106A, 106B) between the inlet primary isolation valve assembly and the redundant equipment item, and a downstream secondary isolation valve (110A, 110B) between the redundant equipment item and the outlet primary isolation valve assembly;
 - 15 a displacement media system (300) associated with the first and second trains, the displacement media system adapted to continuously supply a hot purge media (308) to valve bodies (816) adjacent respective flow control elements (814) of the first and second inlet valves (102A, 102B) and of the first and second outlet valves (104A, 104B);
 - 20 wherein one of the first and second trains (A, B) is configured for a steady state operating mode (402A, 402B) to pass the hot process stream (112) from the respective inlet primary isolation valve assembly (102), through the respective redundant equipment item (108A, 108B), and through the outlet primary isolation valve assembly (104);
 - 25 wherein the other one of the first and second trains (A, B) is configured in an isolated or semi-isolated mode wherein the inlet primary isolation valve assembly (102) blocks the hot process stream (112) from entering the isolated or semi-isolated train, wherein the outlet primary isolation valve assembly (104) blocks communication between the isolated process train and the process stream in the isolated mode, and wherein the outlet primary isolation valve assembly (104) allows communication between the semi-isolated train and
 - 30 the downstream piping (114) in the semi-isolated mode;

- wherein the displacement media system (300) is adapted to pass the hot purge media (308) through the semi-isolated train in a process media removal mode (424) to downstream piping (114);
- wherein the displacement media system (300) is adapted to pass the hot purge media (308) through the isolated process train to maintain the isolated process train in a hot standby mode (404) within 100 °C (preferably within 50 °C) of the hot process stream (112); and
- wherein the displacement media system (300) is adapted to continuously supply the purge media (308) to valve bodies (816) adjacent respective flow control elements (814) of the upstream and downstream secondary isolation valves (106, 110) during the steady state (402), hot standby (404), and process media removal (424) modes.
2. The severe service system of claim 1, wherein the redundant equipment items (108) comprise control valves (109).
 3. The severe service system of claim 1, wherein the process stream (112) comprises black oil.
 4. The severe service system of claim 1, wherein the inlet and outlet primary isolation valve assemblies (102, 104) comprise a Y-pattern arrangement.
 5. The severe service system of claim 4, wherein the inlet and outlet primary isolation valve assemblies (102, 104) have an inlet/outlet deadleg (103'/105') of from 2 to 25 cm.
 6. The severe service system of claim 1, wherein the displacement media system (300) comprises an insertion type heater (304) comprising a heating element (305) for heating the purge media (302), valving, and control logic to maintain a set point temperature of the hot purge media (308) within 50 °C of a temperature of the hot process stream (112).
 7. The severe service system of any of claims 1 to 6, wherein the redundant equipment items (108) comprise process control valves (109), wherein the process stream (112) comprises black oil, and wherein the displacement media system (300) is further adapted to

continuously supply the hot purge media (308) to a valve stem bore (858) of the process control valve (109).

8. The severe service system of claim 7, wherein the system (100, 100') is automated for switching between the steady state and hot standby operating modes, wherein the first train (A) is initially in the steady state mode (402A) and the second train (B) is initially in the hot standby mode (404B), and wherein the first train is subsequently in the hot standby mode (404A) and the second train is subsequently in the steady state mode (402B).
9. The severe service system of claim 8, further comprising:
media supply connections (120) to the respective first and second inlet valves (102A, 102B);
supply lines (116) from a media supply (302, 350, 352, 354) to the respective media supply connections (120) comprising respective media supply valves (118) adjacent the media supply connections; and
wherein the displacement media system (300) comprises lines (3004, 4004) to supply the purge media to valve bodies (816) of the media supply valves;
preferably further comprising media return connections (122A, 122B) from the first and second outlet valves (104A, 104B) and return lines (124A, 124B) from the media return connections to bypass the respective outlet valves (104A, 104B) to the downstream piping (114), wherein the return lines comprise media return valves (126A, 126B) adjacent the media return connections, and wherein the displacement media system comprises lines (5004, 6004) to supply the purge media to valve bodies (816) of the media return valves (126A, 126B).
10. The severe service system of claim 9, further comprising type IV purge connections (410) to the media supply valves (118A, 118B) and the media return valves (126A, 126B) to bleed purge media to the respective supply and return connections (120A, 120B, 122A, 122B) when the respective train (A, B) is in the steady state mode (402).

11. The severe service system of claim 9, further comprising return control valves (128A, 128B) located in the respective return lines (124A, 124B) to control temperature and/or pressure of the respective trains (A, B) in isolated mode.
- 5 12. The severe service system of claim 9, further comprising:
one or more media recovery lines (130A, 130B) connected to the respective first and second parallel processing trains (A, B) at respective connection points (131A, 131B) between the process control valves (109A, 109B) and the downstream secondary isolation valves (110A, 110B) to recover purge and/or flushing media to a media recovery system (142,
10 144, 146); and
wherein the recovery lines (130A, 130B) comprise respective recovery valves (138A, 138B) adjacent the connection points (131A, 131B);
wherein the displacement media system (300) comprises lines (5003, 6003) to supply the purge media to valve bodies (816) of the media recovery valves (138).
- 15 13. The severe service system of claim 12, further comprising type IV purge connections (410) to the media recovery valves (138A, 138B) to bleed purge media to the respective connection points (131A, 131B), wherein the type IV purge connections allow purge media to flow between a back of a seat (806) and a spring (830) of the valve, between a
20 back of the spring and a spring pocket (832) of the valve, and into process piping (808).
14. The severe service system of claim 9, further comprising return control valves (128A, 128B) located in the respective return lines (124A, 124B) to control temperature and/or pressure of the respective trains (A, B).
- 25 15. The severe service system of claim 14, further comprising a control system to automate switching between the steady state and hot standby modes (402, 404), wherein the switching comprises:
with the second train process control valve (109B) in the manual closed position, opening the
30 second inlet and second outlet valves (102B, 104B) for fluid communication between the hot process stream (112, 114) and the second train (B);

- then manually opening the second train process control valve (109B);
then placing the first train process control valve (109A) on manual partially open;
then placing the second train process control valve (109B) on automatic control, thereby placing
the second train in steady state mode (402);
- 5 closing the first inlet valve (102A);
then placing the first train process control valve (109A) on manual open;
removing black oil from the first train (A) by supplying hot purge media into the first train
adjacent the first inlet valve (102A), through the first train (A), and out through the first
outlet valve (104A) into the downstream piping (114); and
- 10 placing the first train (A) in hot standby mode (404) by closing the first outlet valve (104A) and
removing purge media from the first train upstream from the first outlet valve (104A),
wherein the black oil removal and placing the first train in hot standby mode are
automated based on a cumulative volumetric flow of the purge media through the first
train exceeding a volume of the first train.
- 15
16. The severe service system of claim 15, further comprising a hot standby interlock (303) to
prevent switching between hot standby (404) and steady state (402) modes unless the
pressure and temperature of the hot standby train is at or near (within 0.5 MPa and 100
°C, preferably within 50°C) the pressure and temperature of the hot process stream (112).
- 20
17. The severe service system of claim 16, wherein the control system further comprises, a set
of offline sequences:
- a train high pressure (HP) cooldown mode (602) to circulate cooling media through the
respective trains;
- 25 a train HP to low pressure (LP) transition mode (604) to reduce pressure in the respective trains;
an LP train cooldown sequence mode (606) for gradually decreasing temperature of the
respective trains;
- a train final cooldown sequence mode (608) for reducing temperature to ambient in the
respective trains;
- 30 a train drain/vent and nitrogen sweep sequence mode (610, 612, 614) for remaining flushing
media and pressure to be evacuated from the respective trains; and

a train control valve removal sequence mode (615) that activates an interlock system (330) for process double isolation to prevent accidental opening of upstream or downstream double isolation for removal of the process control valve from the respective trains.

- 5 18. The severe service system of claim 17, further comprising sets of permissives comprising valve positions, temperature and/or pressure readings which must be satisfied for changing from the hot standby, steady state, black oil removal, cool down, drain and service modes to another mode.
- 10 19. The severe service system of claim 18, wherein the control system further comprises:
a low pressure interlock to prevent operation of the inlet and outlet valves (102A, 102B, 104A, 104B) and to cut off a supply of purge oil to the upstream and downstream secondary isolation valves (106A, 106B, 110A, 110B) (and preferably to the media supply, return and recovery valves (118A, 118B, 126A, 126B, 138A, 138B)) when the pressure of the
15 isolated train is less than 0.5 MPa; and
a service mode (616) interlock to prevent operation of the inlet and outlet valves (102A, 102B, 104A, 104B), and of the upstream and downstream secondary isolation valves (106A, 106B, 110A, 110B), and to cut off a supply of purge oil to the upstream and downstream secondary isolation valves (and preferably to the media supply, return and recovery
20 valves (118A, 118B, 126A, 126B, 138A, 138B)) until servicing of the respective process control valve (109A, 109B) is complete.
20. The severe service system of any one of claims 1 to 6, wherein the upstream and downstream secondary isolation valves (106A, 106B, 110A, 110B) are provided with seat
25 pocket purge connections (802), body cavity purge connections (810) and a body cavity drain (820).
21. The severe service system of claim 7, wherein the upstream and downstream secondary isolation valves (106A, 106B, 110A, 110B) are provided with seat pocket purge
30 connections (802), body cavity purge connections (810) and a body cavity drain (820).

22. The severe service system of claim 2, wherein the control valves (109A, 109B) are provided with stem purge connections (3003, 4003).
23. The severe service system of claim 7, wherein the control valves (109A, 109B) are provided with stem purge connections (3003, 4003).
24. A method for operation of the severe service system of claim 1, comprising the steps of:
- (a) operating the first train (A) in steady state mode (402A) with the first inlet and first outlet valves (102A, 104A) open to continuously pass the hot process stream (112) through the first train;
 - (b) operating the second train (B) in isolated, hot standby mode (404B) to pass hot purge media (308) through the second train to maintain the second train within 100 °C, preferably 50 °C, of the hot process stream (112);
 - (c) opening the second inlet and second outlet valves (102B, 104B) to allow the hot process stream (112) to pass through both first and second trains (A, B) simultaneously;
 - (d) closing the first inlet valve (102A) to place the first train (A) in semi-isolated mode (424A) and the second train (B) in steady state mode (404B);
 - (e) opening the media supply valve (118A) to pass hot purge media through the first train through the open first outlet valve (104A) to the downstream piping (114) in a process media removal mode (424A);
 - (f) after displacing process media from the first train (426A), automatically closing the first outlet valve (104A) to isolate the first train from the hot process stream (114);
 - (g) automatically operating the first train (A) in isolated, hot standby mode (404A) to pass hot purge media through the first train to maintain the first train within 100 °C, preferably within 50 °C, of the hot process stream (112);
 - (h) continuously supplying purge media to valve bodies (816) adjacent respective flow control elements (814) of the respective first and second inlet valves (102A, 102B) and first and second outlet valves (104A, 104B); and
 - (i) supplying purge media to valve bodies (816) adjacent respective flow control elements (814) of the respective upstream and downstream secondary isolation valves (106A, 106B,

110A, 110B) in the steady state (402), process media removal (424), and hot standby modes (404).

25. A method for operation of the severe service system of claim 7, comprising the steps of:
- 5 (a) operating the first train (A) in steady state mode (402A) with the first inlet and first outlet valves (102A, 104A) open to continuously pass the hot process stream (112) through the first train;
 - (b) operating the second train (B) in isolated, hot standby mode (404B) to pass hot purge media through the second train to maintain the second train within 100 °C, preferably within 50
10 °C, of the hot process stream (112);
 - (c) opening the second inlet and second outlet valves (102B, 104B) to allow the hot process stream (112) to pass through both first and second trains (A, B) simultaneously;
 - (d) closing the first inlet valve (102A) to place the first train (A) in semi-isolated mode (424A) and the second train in steady state mode (404B);
 - 15 (e) passing the hot purge media through the first train (A) through the open first outlet valve (104A) to the downstream piping (114) in the process media removal mode (424A);
 - (f) after displacing process media from the first train, automatically closing the first outlet valve (104A) to isolate the first train from the process stream (114);
 - (g) automatically operating the first train in isolated, hot standby mode (404A) to pass the hot
20 purge media through the first train to maintain the first train within 100 °C, preferably within 50 °C, of the hot process stream (112);
 - (h) continuously supplying purge media to valve bodies (816) adjacent respective flow control elements (814) of the respective first and second inlet valves (102A, 102B) and first and second outlet valves (104A, 104B); and
 - 25 (i) supplying purge media to valve bodies (816) adjacent respective flow control elements (814) of the respective upstream and downstream secondary isolation valves (106A, 106B, 110A, 110B) in the steady state (402), process media removal (424), and hot standby (404) modes.
- 30 26. The method of claim 25, wherein the hot standby mode (404) comprises supplying hot purge media from a media supply line (116) to a media supply connection (120) to the

respective inlet valve (102A, 102B), passing the hot purge media through the respective train (A, B), out from a media return connection (122) from the respective outlet valve (104A, 104B), and through a return line (124) from the media return connection to bypass the respective outlet valves (104A, 104B) to the downstream process piping (114).

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27. The method of claim 26, wherein the media supply lines (116A, 116B) comprise respective media supply valves (118A, 118B) adjacent the media supply connections (120A, 120B), wherein the return lines (124A, 124B) comprise respective return valves (126A, 126B) adjacent the media return connections (122A, 122B), and further comprising supplying the purge media to valve bodies (816) of the respective media supply and return valves (118A, 118B, 126A, 126B) in the steady state (402), hot standby (404), and process media removal modes (424).

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28. The method of claim 27, further comprising controlling temperature of the respective trains (A, B) by means of return control valves (128A, 128B) located in the respective return lines (124A, 124B).

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29. The method of claim 28, wherein the purge media is supplied to type IV purge connections (410) to the media supply valves (118A, 118B) and the return valves (126A, 126B) to bleed purge media to the respective media supply and return connections (120A, 120B, 122A, 122B).

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30. The method of claim 26, further comprising:
connecting media recovery lines (130A, 130B) to the respective first and second trains at respective connection points (131A, 131B) between the process control valves (109A, 109B) and the downstream secondary isolation valves (110A, 110B) to return media to a media recovery system (142, 144, 146);
wherein the media recovery lines (130A, 130B) comprise respective media recovery valves (138A, 138B) adjacent the connection points (131A, 131B);
supplying purge media to valve bodies (816) of the media recovery valves (138A, 138B).

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31. The method of claim 30, wherein the purge media is supplied to type IV purge connections (410) to the media recovery valves (138A, 138B) to bleed purge media to the respective connection points (131A, 131B), wherein the type IV purge connection allows purge media to flow between a back of a seat (806) and a spring (830) of the valve, between a
5 back of the spring and a spring pocket (832) of the valve, and into process piping (808).
32. The method of claim 30, further comprising controlling temperature of the respective trains in isolated mode (404) by means of return control valves (128A, 128B) located in the respective return lines (124A, 124B).
- 10 33. The method of claim 26, wherein automated switching between the steady state (402) and hot standby (404) modes further comprises:
with the second train process control valve (109B) in the manual closed position, opening the second inlet and second outlet valves (102B, 104B) for fluid communication between the
15 hot process stream (112, 114) and the second train (B);
then manually opening the second train process control valve (109B);
then placing the first train process control valve (109A) on manual partially open;
then placing the second train process control valve (109B) on automatic control, thereby placing
the second train in steady state mode (404B);
20 closing the first inlet valve (102A);
then placing the first train process control valve (109A) on manual open;
removing black oil from the first train by supplying purge media into the first train (A) adjacent the first inlet isolation valve (102A), through the first train (A), and out through the first outlet isolation valve (104A) into the hot process stream (114); and
25 placing the first train (A) in hot standby mode (404A) by closing the first outlet valve (102A) and removing purge media from the first train upstream from the first outlet valve (104A), wherein the black oil removal (424A) and placing the first train in hot standby mode (404A) are automated based on a cumulative volumetric flow of the purging media through the first train exceeding a volume of the first train.
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34. The method of claim 33, further comprising interlocking the system (101, 101') to prevent switching between hot standby and steady state modes (402, 404) unless the pressure and temperature of the hot standby train (404) is at or near (within 0.5 MPa and 100 °C, preferably within 50 °C) the pressure and temperature of the hot process stream (112).
- 5
35. The method of claim 26, further comprising:
circulating cooling media through the respective train in a cooldown mode (602);
depressurizing the respective train (604) to a pressure below 0.5 MPa for operation in a low pressure mode (606);
- 10 closing and locking out operation of the displacement media system (300) to prevent supplying purge media to the respective upstream and downstream secondary isolation valves (106A, 106B, 110A, 110B), to the respective media supply valve (118A, 118B), to the respective return valve (126A, 126B), and to the respective media recovery valve (138A, 138B), during operation in the low pressure mode;
- 15 draining the cooling media from the respective train in a drain mode (610); and
closing and locking out operation of the respective inlet isolation valve (102A, 102B), upstream secondary isolation valve (106A, 106B), downstream secondary isolation valve (110A, 110B), and outlet valve (104A, 104B) for a service mode (616) until service of the respective process control valve (109A, 109B) is completed.
- 20
36. The method of claim 24, further comprising sets of permissives comprising valve positions, temperature and/or pressure readings which must be satisfied for changing from hot standby (404), steady state (402), process media removal (424), cool down (602, 606, 608), low pressure (604, 606), drain (610), and service (616) modes to another mode.
- 25
37. The method of claim 25, further comprising sets of permissives comprising valve positions, temperature and/or pressure readings which must be satisfied for changing from hot standby (404), steady state (402), process media removal (424), cool down (602, 606, 608), low pressure (604, 606), drain (610), and service (616) modes to another mode.
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