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Volatile corrosion inhibitor detection device

Abstract

A volatile corrosion inhibitor detection device includes a coupling configured to couple to a system configured to be closed, and a housing in fluid communication with the coupling and containing an indicator element configured to visually change upon contact with volatile corrosion inhibitor. A bendable and crushable portion of the housing contains the indicator element and further contains an indicator capillary, the indicator capillary contains indicator fluid, and the indicator element and the indicator capillary are arranged such that, upon breaking of the indicator capillary by bending or crushing a portion of the housing, the indicator fluid is released from the indicator capillary and reaches the indicator element to render the indicator element sensitive to volatile corrosion inhibitor, thereby providing an indication upon contact with the volatile corrosion Inhibitor.

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Background/Summary

CROSS REFERENCE TO RELATED APPLICATION (1) This application is a divisional of U.S. application Ser. No. 17/113,192 filed on Dec. 7, 2020, which claims the benefit of U.S. Provisional Patent Application Ser. No. 63/090,965 filed on Oct. 13, 2020, the entire content of each of which is incorporated herein by reference in their entireties for all purposes.

TECHNICAL FIELD
(1) The present disclosure relates to a corrosion risk reduction apparatus, a corrosion risk reduction detection device, and corrosion risk reduction systems and methods involving the same.
BACKGROUND INFORMATION
(2) Corrosion, including oxygen-caused corrosion and/or microbiological-influenced corrosion, can lead to significant problems in various systems including, but not limited to, dry pipe or pre-action piping systems for fire sprinkler systems, heat exchangers and boiler tube assemblies, power plant equipment, steam turbine assemblies, offshore platform piping systems, refineries, double-bottom tanker hulls and above ground storage tanks, or any compressed air piping systems. Water borne microbiological entities, such as bacteria, molds and fungi, brought into a piping network of a sprinkler system with untreated water, feed on nutrients within the piping system and establish colonies in the stagnant water within the system. This may occur even in so-called “dry” sprinkler systems where significant amounts of residual water may be present in the piping network after a test or activation of the system.
(3) Over time, oxygen, and/or the biological activities of living entities can cause significant problems within piping networks. For example, both copper and steel pipes may suffer from pitting corrosion leading to pin-hole leaks. Iron oxidizing bacteria form tubercles, which are corrosion deposits on the inside walls of the pipes that can grow to occlude the pipes. Tubercles may also break free from the pipe wall and lodge in sprinkler heads, thereby blocking the flow of water from the head either partially or entirely. Even stainless steel is not immune to the adverse effects of such corrosion, as certain sulfate-reducing bacteria are known to be responsible for rapid pitting and through-wall penetration of stainless steel pipes.

(4) Other forms of corrosion may include, for example, water and oxygen-caused oxidative corrosion of ferrous materials. Such corrosion can cause leaks as well as foul a network and/or sprinkler heads with rust particles. The presence of water in a piping network having a high mineral content can cause scaling as the various dissolved minerals, such as calcium and zinc, react with the water and the pipes to form mineral deposits on the inside walls which can inhibit flow or break free and clog sprinkler heads, preventing proper discharge in the event of a fire.

SUMMARY

(5) A corrosion risk reduction method comprises introducing volatile corrosion inhibitor into a piping system, and distributing the volatile corrosion inhibitor inside the piping system.

(6) A corrosion risk reduction apparatus comprises at least one corrosion risk reduction module. Each corrosion risk reduction module comprises a housing including an inlet port and an outlet port which are each configured for fluid communication between an inside of the housing and an outside of the housing. The housing contains a volatile corrosion inhibitor. An outlet of the corrosion risk reduction apparatus is configured for fluid communication with a system, and is further configured to direct gas containing volatile corrosion inhibitor from the inside of the housing of the at least one corrosion risk reduction module into the system for distribution inside the system.

(7) A volatile corrosion inhibitor detection device comprises a coupling configured to couple to a system configured to be closed, and a housing in fluid communication with the coupling and containing an indicator element configured to visually change upon contact with volatile corrosion inhibitor.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) Other features and advantages disclosed herein will become more apparent from the following detailed description of illustrative embodiments when read in conjunction with the attached drawings.

(2) FIG. **1** is a schematic representation of a cross-sectional view of an illustrative embodiment of a corrosion risk reduction module.

(3) FIG. **2** is a schematic representation of a side view of an illustrative embodiment of a corrosion risk reduction module.

(4) FIG. **3** is a schematic representation of a perspective view of an illustrative embodiment of a corrosion risk reduction module.

(5) FIG. **4**A is a schematic representation of a perspective view of an illustrative embodiment of a corrosion risk reduction module.

(6) FIG. **4**B is a schematic representation of an exploded view of an illustrative embodiment of a corrosion risk reduction module.

(7) FIG. **5** is a schematic representation of a perspective view of an illustrative embodiment of a corrosion risk reduction module in a closed configuration.

(8) FIG. **6** is a schematic representation of a perspective view of an illustrative embodiment of a corrosion risk reduction module in an open configuration.

(9) FIG. **7**A is a schematic representation of a cross-sectional view of an illustrative embodiment of a corrosion risk reduction module.

(10) FIG. **7**B is a schematic representation of a cross-sectional view of an illustrative embodiment of a corrosion risk reduction module.

(11) FIGS. **8**A and **8**B show schematic representations of corrosion risk reduction modules including a filtering system.

(12) FIG. **9**A is a schematic representation of a perspective view of an illustrative cartridge.

(13) FIG. **9**B is a schematic representation of an exploded view of an illustrative cartridge.
(14) FIG. **9**C is a schematic representation of a cross-sectional view of an illustrative cartridge.
(15) FIG. **9**D is a schematic representation of another cross-sectional view of an illustrative cartridge.
(16) FIG. **9**E is a schematic representation of an enlargement of the cross-sectional view of FIG. **9**D.
(17) FIG. **9**F is a schematic representation of a top view of an illustrative cartridge.
(18) FIG. **9**G is a schematic representation of an enlargement of a cross-sectional view of an alternative illustrative cartridge.
(19) FIG. **10** is a schematic representation showing the connection of the rubber gasket to the center wall of a cartridge.
(20) FIG. **11** is a schematic representation showing an illustrative metal mesh configured to help secure a vapor-permeable container.
(21) FIG. **12**A is a schematic representation showing an arrangement of vapor-permeable containers inside an illustrative cartridge.
(22) FIG. **12**B is a schematic representation showing another arrangement of vapor-permeable containers inside an illustrative cartridge.
(23) FIG. **13**A is a schematic representation showing details of an end cap of an illustrative cartridge.
(24) FIG. **13**B is a schematic representation showing details of an end cap of another illustrative cartridge.
(25) FIG. **13**C is a schematic representation showing details of alignment pins and holes of another illustrative cartridge.
(26) FIGS. **14**A and **14**B are schematic representations of webbing at the end of a cartridge.
(27) FIG. **15** is a schematic representation of a perspective view of another embodiment of the cartridge.
(28) FIG. **16** is a schematic representation of a middle section of the cartridge of FIG. **15**.
(29) FIG. **17** is a schematic representation of a side perspective view of the middle section of the cartridge of FIG. **15**.
(30) FIG. **18** is a schematic representation of an overhead perspective view of the end sections of the cartridge of FIG. **15**.
(31) FIG. **19** is a schematic representation of a side view of the outside of the end section end the cartridge of FIG. **15**.
(32) FIG. **20** is a schematic representation of an overhead view of the underside of the end section of the cartridge of FIG. **15**.
(33) FIG. **21** is a schematic representation of a perspective view of a partial assembly of the cartridge of FIG. **15**.
(34) FIG. **22** is a schematic representation of a perspective view of assembly of the entire cartridge of FIG. **15** before attachment of the sections.
(35) FIG. **23** is a schematic representation of a side view of the assembly of the cartridge of FIG. **15**.
(36) FIG. **24** is a schematic representation of a perspective view showing the fully assembled cartridge of FIG. **15**.
(37) FIG. **25** is a schematic representation of an exploded view of the cartridge of FIG. **15**;
(38) FIG. **26** is a schematic representation of an overhead view of the assembled cartridge of FIG. **15**.
(39) FIG. **27** is a schematic representation of an exploded view of the module section of the housing with the cartridge of FIG. **15** inserted.
(40) FIG. **28** is a schematic representation of an exploded view of the stacking of the housings of FIG. **15** in a housing assembly.

(41) FIG. **29** is a schematic representation of a perspective view of an illustrative embodiment of a vapor-permeable container.
(42) FIG. **30** is a schematic representation of an illustrative discharge gas vent.
(43) FIG. **31**A is a schematic representation of a perspective view of an illustrative first embodiment of a detection device.
(44) FIG. **31**B is a schematic representation of a side view of an illustrative first embodiment of a detection device.
(45) FIG. **31**C is a schematic representation of a cross-sectional view of an illustrative first embodiment of a detection device.
(46) FIG. **32**A is a schematic representation of an exploded view of an illustrative second embodiment of a detection device.
(47) FIG. **32**B is a schematic representation of a perspective view of an illustrative second embodiment of a detection device.
(48) FIG. **32**C is a schematic representation of a side view of an illustrative second embodiment of a detection device.
(49) FIG. **32**D is a schematic representation of a cross-sectional view of an illustrative second embodiment of a detection device.
(50) FIG. **33**A is a schematic representation of a perspective view of an illustrative third embodiment of a detection device.
(51) FIG. **33**B is a schematic representation of an exploded view of an illustrative third embodiment of detection device.
(52) FIG. **33**C is a schematic representation of an exploded view of a replaceable indicator cartridge for an illustrative third embodiment of a detection device.
(53) FIG. **33**D is a schematic representation of a method of use of an illustrative third embodiment of a detection device.
(54) FIG. **34**A is a schematic representation of an exploded view of a replaceable indicator cartridge for an illustrative fourth embodiment of a detection device.
(55) FIG. **34**B is a schematic representation of a method of use of an illustrative fourth embodiment of a detection device.
(56) FIG. **35** is a schematic representation of a perspective view of an illustrative corrosion risk reduction system.
(57) FIG. **36** is a schematic representation of an illustrative corrosion risk reduction system.
(58) FIGS. **37**A-**37**B are schematic representations of illustrative corrosion risk reduction systems.
(59) FIGS. **38**A-**38**D are schematic representations of illustrative corrosion risk reduction apparatuses.
(60) FIG. **39**A is a schematic representation of an illustrative corrosion risk reduction system.
(61) FIG. **39**B is a schematic representation of an illustrative automatic purge valve coupled to a piping system.
(62) FIGS. **40**A-**40**C are schematic representations of an illustrative corrosion risk reduction apparatus with a cross-like configuration.
(63) FIG. **40**D is a schematic representation of a cross-sectional view of an illustrative flange arrangement for a corrosion risk reduction component with a cross-like configuration.
(64) FIG. **40**E is a schematic representation of an illustrative set of flange members for a corrosion risk reduction component with a cross-like configuration.
(65) FIGS. **41**A-**41**B are schematic representations of an illustrative corrosion risk reduction apparatus.
(66) FIG. **41**C is a schematic representation of various illustrative corrosion risk reduction modules.
(67) FIGS. **42**A-**42**B are schematic representations of an illustrative corrosion risk reduction apparatus.

(68) FIG. **43**A is a schematic representation of a cross-sectional view of an illustrative corrosion risk reduction module configured for straight flow.
(69) FIGS. **43**B-**43**C are schematic representations of an illustrative corrosion risk reduction apparatus including a corrosion risk reduction module configured for straight flow.
(70) FIGS. **44**A-**44**C are schematic representations of an illustrative corrosion risk reduction module with a clamshell configuration.
(71) FIGS. **45**A-**45**C are schematic representations of an illustrative corrosion risk reduction module with a stacked configuration of vapor-permeable containers of corrosion inhibitor.
(72) FIG. **45**D is a schematic representation of an illustrative tray for use in a corrosion risk reduction module with a stacked configuration of vapor-permeable containers.
(73) FIG. **45**E is a schematic representation of an illustrative corrosion risk reduction system including a corrosion risk reduction module with a stacked configuration of vapor-permeable containers.
(74) FIGS. **46**A-**46**C are schematic representations of illustrative corrosion risk reduction modules with various air flow entry and exit points.

DETAILED DESCRIPTION

(75) FIGS. **1-4**B show an illustrative embodiment of a corrosion risk reduction module **100**. The corrosion risk reduction module **100** comprises a housing **80** including an inlet port **93** and an outlet port **94** which are each configured for fluid communication between an inside of the housing **80** and an outside of the housing **80**. The corrosion risk reduction module **100** contains corrosion inhibitor (e.g., but not limited to, volatile corrosion inhibitor). In some illustrative embodiments, the corrosion risk reduction module **100** comprises at least one cartridge **110** located inside the housing **80** and removable from the housing **80**. The corrosion risk reduction module **100** comprises at least one vapor-permeable container **120** located inside the cartridge **110**, and containing a corrosion inhibitor. However, corrosion inhibitor can instead be contained in the corrosion risk reduction module **100** without a cartridge, and/or without a vapor-permeable container **120**.
(76) In illustrative embodiments, each cartridge **110** is arranged within the housing **80** and is configured to direct air or any other gas from the inlet port **93** or from an upstream cartridge **110**, around and/or through the vapor-permeable container **120**, and to the outlet port **94** or to a downstream cartridge **110**. While the term “air” is used throughout the present disclosure, it is to be understood that other gases can be used instead of air, without departing from the scope of the present disclosure.
(77) During operation of illustrative embodiments, the corrosion inhibitor can be dispersed from the corrosion risk reduction module **100**, so as to interact with and disperse into the surrounding atmosphere, such as the volume inside a system configured to be closed. This system can include, but is not limited to a dry piping system (e.g., but not limited to a dry pipe fire sprinkler system, pre-action fire sprinkler system, or any other piping system that does not store liquid), a heat exchanger or boiler tube assembly, power plant equipment, a steam turbine assembly, an offshore platform piping system, a refinery, a double-bottom tanker hull or an above ground storage tank, or any system containing compressed air, thus providing substantial corrosion control of an internal surface susceptible to corrosion. While the following description of illustrative embodiments may refer to the dispersion of corrosion inhibitor in piping systems, it is to be understood that any of the above-noted systems can be substituted for the piping systems without departing from the scope of the disclosure. In illustrative embodiments, the system is configured to be closed once corrosion inhibitor has been distributed inside the system. Closing the system may involve, for example, closing a valve that is in fluid communication with the system. In illustrative embodiments, volatile corrosion inhibitor can be used in conjunction with nitrogen, and/or dry air, and/or any other additional preventative measure against corrosion.
(78) The Housing

(79) In illustrative embodiments, as noted above and as shown in FIGS. **1-4**B, the corrosion risk reduction module **100** comprises a housing **80** including an inlet port **93** and an outlet port **94** which are each configured for fluid communication between an inside of the housing **80** and an outside of the housing **80**.
(80) FIGS. **5** and **6** show another illustrative embodiment of a corrosion risk reduction module **100**. In FIG. **5**, the housing **80** is closed, while in FIG. **6** it is open.
(81) In illustrative embodiments, the housing **80** includes a housing body **84**, a top housing lid **91** and a bottom cap **99**. A clamp **92** connects a housing lid or cap **91**, **99** to the housing body **84**. As such, the housing **80** can be opened to receive a cartridge **110**. Alternatively, in lieu of or in addition to a clamp **92**, any binding or sealing device, or contraption can be used for sealing a housing lid or cap **91**, **99** to the housing body **84**.
(82) In illustrative embodiments, a gasket **97** is positioned between a housing or cap **91**, **99** and the housing body **84**, and between stacked cartridges **110** (see FIGS. **3** and **5**). Cartridges **110** can also be stacked with sock or sleeve seals **112** between cartridges **110**, and between the cartridge **110** and a cap **91**, **99**.
(83) In illustrative embodiments, the housing **80** includes a longitudinal axis L, and two opposite ends along the longitudinal axis L, and the inlet port **93** and the outlet port **94** are both located at one of the two ends of the housing **80**. This configuration may be preferable if the housing **80** is to be disposed with its longitudinal axis L oriented vertically, as it may allow for condensation collection at the bottom of the housing **80**.
(84) As shown in FIG. **1**, in illustrative embodiments, the housing **80** further includes a drain port **88** at the other one of the two ends of the housing **80**. A drain port **88** may be desirable for condensation collection, and may include a moisture drain valve.
(85) FIGS. **7**A and **7**B show illustrative embodiments of a corrosion risk reduction module **100** including a drain port **88**. The housing **80** further includes a drain port **88** at the other one of the two ends of the housing **80**. A drain port **88** may be desirable for condensation collection. In FIG. **7**A, the drain port **88** is formed in a removable section **991** of the bottom housing cap **99** which is attached to the bottom housing cap **99** by a clamp **92**. Alternatively, as shown in FIG. **7**B, the drain port **88** can be formed in a section **991** of the bottom housing cap **99** which is not separable from the bottom housing cap **99**. With further reference to FIGS. **7**A and **7**B, the space above the section **991** allows for air flow between chambers of the cartridge, which are described below.
(86) In illustrative embodiments, as shown in FIGS. **8**A and **8**B, a drain baffle **79** can be configured to collect and drain away condensation from the housing **80**, and a coalescing or particulate filter **78** for filtering out impurities may be positioned between a source of compressed air and the inlet or outlet of the housing **80**. In yet another embodiment a manual valve, actuated valve, a plug, or nothing at all (by implementation of a solid cap) can be used.
(87) In illustrative embodiments, the housing **80** includes two opposite ends along the longitudinal axis L, and the inlet port and the outlet port are respectively located at the two opposite ends of the housing (as shown for example in FIG. **4**B). This configuration may be preferable if the housing **80** is to be disposed with its longitudinal axis L oriented horizontally.
(88) The Cartridge
(89) In illustrative embodiments, as noted above, the corrosion risk reduction module **100** comprises at least one cartridge **110** located inside the housing **80** and removable from the housing **80**. To “feed” or allow corrosion inhibitor to flow through pipes, a cartridge **110** can hold a vapor-permeable container **120**. Air flowing around and/or through the vapor-permeable container **120** can then carry vapor through the piping system.
(90) FIGS. **9**A-**9**G show examples of a cartridge **110**, which includes an outer wall **73** between two end caps **3**, **4**. In illustrative embodiments, the end caps **3**, **4** are made of plastic or nylon plastic. In illustrative embodiments, the outer wall **73** and/or the end caps can be sized and configured to withstand the flow of corrosive inhibiting gases. Alternatively, or in addition, the cartridge **110** can

include other materials, including, but not limited to, rubber, metals, ceramics, and/or combinations thereof. The size of the end caps **3**, **4** can be chosen based on the size of the cartridge **110**, and based on the intended application. The end caps **3**, **4** can be round (as shown for example in FIGS. **9**A and B), or be of other geometric shapes, depending on the shape of the openings at either end of the cartridge **110**. For instance, if the openings at either end of the cartridge **110** are rectangular or square, the end caps **3**, **4** can be rectangular or square.

(91) In illustrative embodiments, two openings **5**, **6** are formed in at least one of the end caps **3**, **4**. These openings **5**, **6** can allow for the circulation of air, which carries vapors to piping. In one embodiment, these openings **5**, **6** span equal approximately, but not limited to, one third to half of the surface area of each of the caps **3**, **4**. Larger openings **5**, **6** can serve to allow better airflow and reduced pressure drop. In an illustrative embodiment, the material or surface or geometric area of the material of the end caps **3**, **4** is kept to a minimum, with enough surface and material to provide sufficient support for the end caps **3**, **4**. Alternatively, a single opening at each end cap **3**, **4** can be configured for input and/or output of air, as shown for example in FIGS. **12**A-**12**B.

(92) In illustrative embodiments, the two end caps **3**, **4** are connected by a center wall **12** having outwardly-facing feet **10**, **11** configured to contact and support a vapor-permeable container **120**. Vapor-permeable containers **120** can rest on top of the outwardly-facing feet **10**, **11**.

(93) In illustrative embodiments, one or opposite sides of the center wall **12** has/have a ridge **67** which may span a portion of or the entire length of the center wall **12**. A ridge **67** can help secure a vapor-permeable container **120** while allowing for passage of air over and around the vapor-permeable container **120**.

(94) In illustrative embodiments, elongated rubber gaskets **63**, **64** fit on outside edges of the center wall **12** (as shown in FIG. **10**), for example, to help prevent rattling as well as unwanted leak paths between chambers **58**, **59** (illustrated in FIGS. **9**C-**9**D) formed on either side of the center wall **12**.

(95) In illustrative embodiments, two arms **27**, **28** also connect the top cap **3** with the bottom cap **4**. These two arms are positioned and attached at or near the edge or rim **29** of the end cap **3** and at or near the edge or rim of the end cap **4**. In an illustrative embodiment, each end of the arms **27**, **28**, those being the arm tops **33**, **34**, and the arm bottoms **35**, **36** have a flexible arrow point **39** (see FIG. **9**G) or clip **31** (see FIG. **9**E) that squeezes through a hole in the underside of the end caps **3**, **4**. In yet another illustrative embodiment, the arms **27**, **28** are glued or welded into position. In another illustrative embodiment, one or both of the caps **3**, **4** can be removably attached.

(96) In illustrative embodiments, the outer wall **73** is made of a material selected from the group consisting of metal or plastic, and can be a corrugated metal. In one embodiment the outer wall **73** is attached to the arms **27**, **28**. In another embodiment, the outer wall **73** is taped to the top and bottom caps **3**, **4**. In yet another embodiment, the outer wall **73** is glued to the arms and end caps. Any number of means of attachment may be used. In another embodiment, no outer wall **73** is used.

(97) In illustrative embodiments, there are no arms on the cartridge.

(98) In illustrative embodiments, the vapor-permeable containers **120** inside the cartridge **110** are held in place to keep from blowing around and possibly tearing when compressed air passes through the cartridge **110**, thus giving them a level of rigidity. In an illustrative embodiment, the inside walls of the arms **27**, **28** have bumpers **70**, **71** that push the vapor-permeable container **120** against the plurality of ridges **67** of the center wall **12**. In one embodiment, the bumpers **70**, **71** are integral with the arms **27**, **28**. In another embodiment, the bumpers **70**, **71** are placed inside of the cartridge **110** next to the arms **27**, **28**. In one embodiment, the bumpers **70**, **71** are firm, and made out of a rubber. In another embodiment, the bumpers **70**, **71** are soft and air permeable. In another embodiment, the bumpers **70**, **71** are not air permeable. In another embodiment, the bumpers **70**, **71** are an extension of metal or plastic arms **27**, **28**. In another embodiment, other materials can be used, or existing parts can extend, with gaps filled, thereby preventing short-circuiting of the air flow between chambers **58**, **59**.

(99) In illustrative embodiments, as shown for example in FIG. **11**, a metal or plastic webbing or mesh **72** is configured to hold a vapor-permeable container **120** in place. In one embodiment, the mesh **72** is used instead of or in conjunction with the bumpers **70**, **71**. In another embodiment, the ridges **67**, **68** also help secure the pouch or container in place. In one embodiment, the mesh **72** is wrapped around the vapor-permeable container **120** before being placed in the openings in the cartridge **110**. In another embodiment, the mesh **72** is positioned around the center wall **12** with enough room left to insert a vapor-permeable container **120** on each side of the center wall **12**. In another embodiment, a pocket formed by the mesh **72** is inserted on each side of the center wall **12**, into which the vapor-permeable container **120** is inserted.
(100) In illustrative embodiments, parts of the cartridge **110** can be snap-fit, attached to each other by screws, attached by glue, welding, snap-hooks, press-fit, or by any other suitable method.
(101) In illustrative embodiments, cartridges can be tubular, or of any polygonal or irregular shape.
(102) In illustrative embodiments, as illustrated in FIG. **1**, a plurality of cartridges **110** inside the housing **80** are adjacent to one another along the longitudinal axis L of the housing **80**.
(103) In illustrative embodiments, a plurality of cartridges **110** inside the housing **80** are adjacent to one another along a direction perpendicular to the longitudinal axis L of the housing **80**.
(104) In illustrative embodiments, there is a metal or plastic center wall **12**, as shown in FIG. **9**D previously described, or any material suitable to maintain cartridge integrity, with a securing mesh **72** securing the vapor-permeable containers **120** to the center wall **12**. In another embodiment, as shown in FIG. **12**A, there is no dividing wall, and instead there are just two vapor-permeable containers **120**, each wrapped in mesh to give them rigidity.
(105) In illustrative embodiments, to connect the cartridges **110** to one another, end to end, a clamp can be used, with gaskets on top of the ends of the housings. In illustrative embodiments, as illustrated in FIGS. **13**A-**13**C, stacking pins **102**, **103** can fit through stacking holes **104**, **105** of one cartridge, and through stacking holes **104**, **105** of the next cartridge. Once the cartridges **110** are stacked to the desired length, stacking pins **102**, **103** on each end of the stacked cartridges are withdrawn to provide a smooth sealing surface on the assembly ends. Alternatively, stacking pins may not be needed.
(106) In illustrative embodiments, the piping system being treated to prevent corrosion will need only one cartridge at a time, with the cartridge lasting weeks or months, or up to 1-2 years or more. In other situations the system being protected can be quite large and may need more than one cartridge at a time. In such a system, the cartridges **110** can be stacked.
(107) In illustrative embodiments, the cartridge **110** can use one or multiple vapor-permeable containers **120**. In another embodiment, multiple vapor-permeable containers **120** can reside on each side of the cartridge **110** with the vapor-permeable containers **120** in alignment on either side.
(108) In illustrative embodiments, once the vapor-permeable containers **120** are determined to be used up, or are used for a known period of time, the entire cartridge **110** can be returned to the manufacturer for the multiple vapor-permeable containers **120** to be replaced, or the vapor-permeable containers **120** may be replaced by the user, or the cartridge **110** with vapor-permeable containers **120** may be disposed of following all local guidelines and laws.
(109) In illustrative embodiments, the cartridges **110** are disposable by conventional means or sent to the manufacturer for replacement or reloading. In an illustrative embodiment, as shown in FIGS. **14**A and **14**B, there is a mesh end comprised of a diffuser or binding disc **330** positioned and attached at both ends of the cartridge **110**. The center area of the mesh end has a block **305** to redirect airflow to where it is desired. Caulk or epoxy **306** can attach the mesh end to the outer wall **73** of the disposable cartridge. The outer wall **73** itself may be a plastic, poly(methyl methacrylate) (PMMA), a metal wrap or a wire mesh. In illustrative embodiments, the mesh can be metal, plastic, ceramic or any other material.
(110) In other illustrative embodiments, as shown for example in FIGS. **15-28**, a cartridge **200** is comprised of sections. The middle section **201** has a plurality of fins or baffles **202** extending

inward from the circular wall **201** (as the other cartridges usually do), There is also a plurality of baffles **204** extending from both sides **205**, **206** of a center wall **203**, which is the length of the diameter of the opening of the cartridge **200**. In one embodiment, the baffles extending from the center wall **203** are positioned at different heights, such that a baffle may be positioned higher than the top of the center wall but consequently does not extend all the way down to the bottom of the center wall. There are also baffles positioned such that they extend below (or beyond) the bottom of the center wall **203**. The tops of these baffles do not extend all the way to the top of the center wall, with the space being equal to that extending below the bottom of the center wall **203**. There is a space between the baffles **204** and **202** into which the multiple vapor-permeable container **120** can fit. In one embodiment, there is one middle section **201**. In another embodiment, there are two middle sections **201**, for easier manufacturing. For larger multiple vapor-permeable containers **120**, there may be taller or shorter middle sections **201**, or there may be two or more middle sections **201**.

(111) In illustrative embodiments, a sectional cartridge **200** also has a top section and a bottom section **240**, **241**. In one embodiment, each of the end caps has baffles **209** extending inwardly from the circular wall **208**. A center wall **210** has a plurality of baffles **212** extending from both sides **213**, **214** of the central wall **210**. As in the middle section **201**, the center wall **210** runs the length of the diameter of the opening of the cartridge **200**. A plurality of arms **215** extend from the plurality of baffles **212**. As such, the arms **215** hold the multiple vapor-permeable containers **120** in place, so they do not slide around when air passes through the cartridge. As above, there is a space positioned between the baffles **212** of the central wall **210** and the baffles **209**. Additionally, the height of the baffles complements the height of the baffles **204** of the middle section such that they can fit on top of one another, allowing for placement and alignment of the sections. In another embodiment, the top section and the bottom section are identical.

(112) In illustrative embodiments, the bottom cap **206** and the first middle section **201** are first assembled. Once the middle section **201** is positioned onto the bottom cap **206**, the multiple vapor-permeable containers **120** can be inserted into the spaces described above. Next, any number of additional middle sections can be added, depending on the size of the vapor-permeable containers **120** to be used. At the end of the cartridge **200**, the top cap **205** is the added.

(113) In illustrative embodiments, the cartridge **200**, or multiple such stacked cartridges **200**, once assembled, can fit into a housing **80**. For example, the cartridge **200** fits into the open top of the housing **80**. A clamp **92** connects the top housing lid **91** to the body **84** of the housing **80**.

(114) In illustrative embodiments, on top of the top cap **205** and on the bottom of the bottom cap **206** is a sealing gasket **220**. The sealing gasket **220** fits on top of the top cap and on top of the bottom cap, and has a centered diameter **222** which corresponds to the center wall **210**. In another embodiment, there are two holes **223**, **224** in the sealing gasket **220** to allow for alignment or stacking pins when the cartridges are stacked. In another embodiment, there is a regular gasket **97** to seal the housing **80** and the top housing lid **91**.

(115) The Vapor-Permeable Container

(116) In illustrative embodiments, as noted above, the corrosion risk reduction module **100** comprises at least one vapor-permeable container **120** containing a corrosion inhibitor located inside the cartridge **110**.

(117) FIG. **29** shows an illustrative embodiment of a vapor-permeable container **120**. In illustrative embodiments, a vapor-permeable container **120** can include a sachet or pouch containing a corrosion inhibitor having the ability to protect against corrosion. The corrosion inhibitor can comprise inorganic nitrite salts, organic nitrite salts, anhydrous sodium molybdate, an anhydrous ammonia dimolybdate, or anhydrous amine molybdates, amine benzoate, amine nitrate, benzotriazole, cyclohexylamine benzoate, ethylamine benzoate, dicyclohexylamine nitrate, tolytriazole and salts thereof, or C.sub.13H.sub.26O.sub.2N, and any combination thereof. A more specific combination of substances includes ammonium benzoate and an inorganic salt. Other

possible additives or substances that may be used include but are not limited to aerogel, activated alumina, benzophenone, clay, calcium chloride, lithium bromide, lithium chloride, magnesium perchlorate, molecular sieve, or silica gel, or any combination thereof; wherein said corrosion inhibitor comprises a triazole or a derivative thereof, benzoate or a derivative therein, a salt of benzoic acid, carbamate, alkali metal molybdate, dimolybdate, an amine molybdate or a salt thereof, an organic nitrite, an alkali metal nitrite, or alkali dibasic acid salt, or any combination thereof; and wherein said soluble vapor phase corrosion inhibitor comprises an organic nitrite, borate, organic aminophosphite, phosphate, polyphosphate, silicate, potassium hydroxide, sodium hydroxide, an amine base compound, a sulfonate, zinc sulfate, or calcium bicarbonate, or any combination thereof. See U.S. Pat. No. 9,656,201, issued May 23, 2017; U.S. Pat. No. 9,556,635 issued May 23, 2017; U.S. Pat. No. 9,303,382 issued Apr. 5, 2016, and U.S. Pat. No. 8,377,531, issued Feb. 19, 2016, all incorporated herein by reference for their disclosure of volatile corrosion inhibitors. Other sublimating compounds and compound mixtures include but are not limited to morpholine, benzylamine, cyclohexylammonium carbonate, diisopropylammonium nitrite, morpholine nitrite, dicyclohexylammonium nitrite, dicyclohexylammonium caprylate, guanidine chromate, hexamethyleneimine benzoate, hexamethyleneimine nitrobenzoate, dicyclohexylammonium benzoate and combinations thereof in varying amounts (See U.S. Pat. No. 9,435,037, issued Sep. 6, 2016, herein incorporated by reference for its disclosure of volatile corrosion inhibitors). In illustrative embodiments, other compounds such as hydrogen fluoride and/or a pH detection compound can be added to the corrosion inhibitor.
(118) In illustrative embodiments, the vapor-permeable container **120** can be a flexible fine mesh screen-like container or a perforated rigid material such as a plastic or metal that contains the corrosion inhibitor. The vapor-permeable container **120** can be any number of materials that are vapor permeable.
(119) In illustrative embodiments, the corrosion inhibitor may alternatively exist by itself in the form of a solid mass, or a porous mass, or as a powder, where air can pick up inhibitor by stagnant contact, flowing around it, or flowing through it.
(120) The Discharge Gas Vent
(121) In illustrative embodiments, a corrosion risk reduction system includes a discharge gas vent **140**, shown for example in FIG. **30**, and described in U.S. Pat. No. 10,420,970, issued on Sep. 24, 2019, incorporated herein for reference for its description of a “discharge gas vent **100**.”
(122) In an illustrative embodiment, a ball valve **1410** provides isolation of the controlled discharge gas vent **140** from a sprinkler system piping, which is pressurized and provides the gas flow **1405**. A Y-strainer type filter **1420** protects a metallic orifice **1445** at the discharge of a levered float valve **1425** from plugging with pipe debris. The levered float valve **1425** or equivalent electric liquid sensing control unit allows gas discharge from the piping system but not liquid discharge; water can be prevented from flowing out of the vent **1400** location if the float activates when liquid enters the valve **1425** by sealing the discharge orifice. A gas sampling port **1430** allows for gas analysis using a manual or automatic gas sampling device. An in-line filter **1435** protects the end-of-line metallic orifice **1445** from plugging with debris. An adjustable back pressure regulator **1440** with a gauge can prevent complete depressurization of the fire sprinkler system piping by automatically closing the vent if the system pressure falls below a preset minimum pressure on the regulator **1440**. The preset minimum pressure can be set at a pressure above the trip pressure of the pipe valve by setting a minimum closing pressure that is above the trip pressure of the pipe valve. The end of line metallic orifice **1445** provides for the controlled release of gas from the pressurized piping system. An end of line muffler **1450** may be used to deaden the sound of the gas exhaust **1455**.
(123) The Detection Device
(124) In illustrative embodiments, a corrosion risk reduction system includes a detection device **150** configured to detect the presence of corrosion inhibitor. In exemplary embodiments, chemical

sensitive to corrosion inhibitor is disposed on a stem inside a housing. In use, a detection device **150** can removably connect to the end of a discharge gas vent **140**. The chemical changes color when corrosion inhibitor is present, e.g., from blue to red, where red may indicate saturation. Upon such an indication of saturation, a user may be alerted that a valve from the corrosion risk reduction module **100** may be turned off. Optionally, a photo-detector may detect such color change and automatically turn off the valve.

(125) FIGS. **31**A-**31**C show a first illustrative embodiment of a detection device **150**, including a pipe coupling **152** for coupling to a piping system, a fluid conduit **154** and a housing **156**, the fluid conduit **154** providing air flow from the pipe coupling **152** to the housing **156**. The housing **156** includes an indicator element **158** bonded to a perforated disk **159**. In illustrative embodiments, the indicator element **158** includes, but is not limited to, an indicator strip, a pH probe, a refractrometer. The indicator element **158** is configured to provide an indication of the presence of corrosion inhibitor upon contact therewith. For example, the indication could be visual, auditory and/or tactile. For example, the indicator element **158** could be a litmus strip **158** which contains chemical sensitive to corrosion inhibitor, and is configured to be pH-specific and indicate acidity or alkalinity, and thus to change color when inhibitor is detected. The indicator element **158** is located behind a filter housing portion **157** of the housing **156**. The filter housing portion **157** can include a transparent material to facilitate visibility of an indicator change when corrosion inhibitor is present.

(126) In the following descriptions of alternative illustrative embodiments of detection devices, it is to be understood that the indicator element **158** can be an indicator element which changes color upon contact with corrosion inhibitor, or any indicator element known in the art.

(127) FIGS. **32**A-**32**D show a second illustrative embodiment of a detection device **150**, including an inlet valve **251** configured to connect to a source of pressurized air including corrosion inhibitor (e.g., a compressor/corrosion risk reduction module combination), a pressure release valve **252** configured for releasing pressure to the outside, and an indicator module **258** including an indicator element **158** which slides onto a carrier and is bonded to a plug **260**. The plug **260** can be unscrewed from the housing to pull out and replace a used indicator element **158**. A lateral sight glass **262** on the housing can be used to provide a line of sight from an outside of the housing to the indicator element **158** to enable a user to observe visual changes (e.g., but not limited to color changes) on an indicator element **158**. A bottom sight glass **263** can allow a user to shine light into the housing for additional visibility. In use, the system is first pressurized using the inlet valve **251**. A change in the indicator element **158** is then observed through the lateral sight glass **262**. Optionally, a light is shone into the housing through the bottom sight glass **263** for additional visibility. If such a change is observed, the indicator element **158** is accessed by unscrewing the plug **260** and then changed. The system is then depressurized using the pressure release valve **252**.

(128) FIGS. **33**A-**33**D show a third illustrative embodiment of a detection device **150**, including a pipe coupling **351**, a valve **352**, a replaceable indicator cartridge **360**, an adapter **353** and a muffler **354**.

(129) In illustrative embodiments, the pipe coupling **351** can be a male (or female) industrial-style quick disconnect configured to connect to a female (or male) port on a piping system. The valve **352** is configured to enable/disable flow through the detection device **150**. The replaceable indicator cartridge **360** (shown in detail in FIG. **33**C) is configured to provide a one-time use indicator test which is disposable via conventional means. The adapter **353** connects the replaceable indicator cartridge **360** to the muffler **354**, which is configured to aerate/vaporize excess fluid to the atmosphere.

(130) In illustrative embodiments, as shown in FIG. **33**C, the replaceable indicator cartridge **360** includes an indicator chamber **361** which houses and allows airflow across an indicator element **158**. The indicator element **158** is configured to undergo a visual change to indicate the presence of corrosion inhibitor. The indicator element **158** is insulated from brass orifices **363** on both ends by

negative catalysts **362**, thereby preventing a false positive reaction. The brass orifices **363** control flow entering or exiting the indicator chamber **361**. Connectors **364** are configured to connect to the valve **352** or to the adapter **353** or muffler **354**, and connect to the brass orifices **363**.

(131) In illustrative embodiments, in use, and as shown in FIG. **33**D, the detection device **150** is first assembled at step S**1** and is then connected to a piping system **300** at step S**2**, for example to any industrial-type quick disconnect downstream from a compressor. The valve **352** is then open at step S**3** to allow flow across the indicator element **158**. The element **158** is then checked for visual change.

(132) FIGS. **34**A-**34**B show aspects of a fourth illustrative embodiment of a detection device **150**, which differs from the third embodiment in that it includes a different replaceable indicator cartridge **460**.

(133) In illustrative embodiments, as shown in FIG. **34**A, the replaceable indicator cartridge **460** includes an indicator chamber **461** which houses and allows airflow across an indicator element **158**. The indicator chamber **461** further includes an indicator capillary **458** holding and keeping indicator fluid **4581** wet. In the case of a litmus strip, the indicator fluid can be litmus fluid. The indicator capillary **458** is sealed by epoxy or cap seals **4582** on both ends to lock in the indicator fluid **4581**. When cracked, the indicator capillary **458** releases indicator fluid **4581**, which is then deposited onto the indicator element **158**. The indicator element **158**, once wetted by indicator fluid **4581**, is configured to provide a visual indication of the presence of corrosion inhibitor. For example, the indicator element **158** can be a litmus strip which, once wetted by litmus fluid, is configured to change color based on pH values, or some other indicator value, of the air flowing across it to determine the presence of corrosion inhibitor. The indicator element **158**, as it is stored in dry condition, does not need to be flanked by negative catalysts preventing false positive reactions. Brass orifices **463** control flow entering or exiting the indicator chamber **461**. Connectors **464** are configured to connect to the valve **352** or to the adapter **353** or muffler **354**, and connect to the brass orifices **463**.

(134) In illustrative embodiments, in use, and as shown in FIG. **34**B, the detection device **150** is first assembled at step S**1** and is then connected to a piping system **300** at step S**2**, for example to any industrial-type quick disconnect downstream from a compressor. The indicator chamber **461** is then bent and crushed (e.g., using pliers **4611**), at step S**3**, to crack the indicator capillary **458** and release the indicator fluid **4581** so that it can be collected on the indicator element **158** and so that the indicator element **158** can become sensitive to corrosion inhibitor. For example, the indicator capillary **458** can be broken by bending or crushing a portion of the housing. The valve **352** is then open at step S**4** to allow flow across the indicator element **158**. The indicator element **158** is then checked for visual change.

(135) The Corrosion Risk Reduction System

(136) FIG. **35** shows an illustrative corrosion risk reduction system **1000** installed in a dry pipe or pre-action sprinkler system, which includes a corrosion risk reduction module **100** configured for fluid communication with a piping network including one or more pipes, and a source of compressed air **96** in fluid communication with the corrosion risk reduction module **100** and positioned downstream of the source of compressed air **96**. The source of compressed air **96** can be a compressor or any other suitable source of compressed air, and is configured to provide compressed air to the inlet **93** of the corrosion risk reduction module **100** through an inflow pipe **95**, to drive corrosion inhibitor out through the outlet **94** of the corrosion risk reduction module **100**, though an output pipe **85**, and into the piping network. The corrosion risk reduction system **1000** further includes an air maintenance device **130** connected to the output pipe **85**. The air maintenance device **130** can be configured to regulate pressure and compensate for fluctuations in air pressure generated by the source of compressed air. The beginning of a piping network is shown as a pipe end downstream of the air maintenance device **130**.

(137) FIG. **36** shows an alternative illustrative corrosion risk reduction system **1000**, in which the

source of compressed air **96** is positioned downstream of the corrosion risk reduction module **100**, and configured to pull corrosion treated air from the outlet **94** of the corrosion risk reduction module **100**, to drive corrosion inhibitor treated air through the compressed air source **96** and into the piping network. FIG. **45**A-D show an illustrative corrosion risk apparatus integrated into the air source intake filter.

(138) FIG. **37**A shows an illustrative corrosion risk reduction system **1000** including a source of compressed air **96**, a corrosion risk reduction module **100** (or a combination of corrosion risk reduction modules **100** connected in series or in parallel), a discharge gas vent **140**, a detection device **150**, and a piping system **300**, in fluid communication with one another. In illustrative embodiments, the order of elements may be varied. Furthermore, an air maintenance device **130** may be included to regulate pressure from the source of compressed air **96**. In illustrative embodiments, either one or both of the discharge gas vent **140** and the detection device **150** may be omitted from the corrosion risk reduction system **1000**.

(139) FIG. **37**B shows an illustrative corrosion risk reduction system **1000** including a three-way valve **170** between the source of compressed air **96**, the corrosion risk reduction module **100**, and the rest of the system. A check valve **172** also separates the corrosion risk reduction module **100** from the rest of the system. As such, the corrosion risk reduction module **100** can be serviced (e.g., corrosion inhibitor can be replaced) while keeping the piping system **300** under pressure.

Additional Illustrative Embodiments

(140) FIGS. **38**A-**38**D show illustrative corrosion risk reduction apparatuses **2000** including one or more corrosion risk reduction modules **100**. In particular, a corrosion risk reduction apparatus **2000** includes a single corrosion risk reduction module in FIG. **38**A, two corrosion risk reduction modules in FIGS. **38**B and **38**D, and four corrosion risk reduction modules in FIG. **38**C, in fluid communication with coalescing or particulate filters **78** upstream and downstream of the corrosion risk reduction module(s) **100**, a coalescing mist separator **182** upstream of the corrosion risk reduction module(s) **100**, and a drain baffle **79** at the bottom end of a lowermost corrosion risk reduction module **100**. The cross-sectional view depicted in FIG. **38**D shows an illustrative air flow pattern through a corrosion risk reduction apparatus **2000**. Multiple modules of the apparatus may be positioned in series or in parallel without departing from the scope of the disclosure. It is to be understood that the coalescing or particulate filters **78** and the separator **182** need not be arranged in the manner illustrated in the exemplary figures of the present disclosure. These elements can be replaced with any number of separating or filtering components, and/or can be omitted, without departing from the present disclosure.

(141) FIG. **39**A shows an illustrative corrosion risk reduction system **1000** including a source of compressed air **96**, a corrosion risk reduction apparatus **2000**, an air maintenance device **130**, branch line detection devices **150**, and a purge valve **190**. In illustrative embodiments, the purge valve **190** can be an automatic purge valve (as shown in FIG. **39**B) configured to automatically open at preset time intervals (e.g., a two-week purge valve). The purge valve **190** may be coupled to any connection to the piping system **300** that is downstream of the source of compressed air **96**, and may be coupled to a detection device **150** as well. Alternatively, a manual operation of a purge valve may also be used without departing from the present disclosure.

(142) FIGS. **40**A-**40**C show an illustrative corrosion risk reduction apparatus **2000** including plural (in the illustrated embodiment, four) corrosion risk reduction modules **100** arranged in a cross-like pattern, and in fluid communication with coalescing or particulate filters **78** upstream and downstream of the corrosion risk reduction modules **100**, a coalescing mist separator **182** upstream of the corrosion risk reduction modules **100**, and a drain baffle **79** at the bottom end of a lowermost corrosion risk reduction module **100**. The cross-sectional view depicted in FIG. **40**B shows an illustrative air flow pattern through the corrosion risk reduction apparatus **2000**. FIG. **40**C shows an exploded view of the corrosion risk reduction apparatus **2000**. The corrosion risk reduction modules **100** arranged in a cross-like pattern are connected to one another via a flange arrangement

180. The flange arrangement **180** includes plural (in the illustrated embodiment, four) flange members **185** configured to fit into a cross-shaped pipe element **186** to form a cross-like pattern. FIGS. **40**D-**40**E show that each flange member **185** includes a partition **187** for separating inflow and outflow passageways in and out of a corrosion risk reduction module **100**.
(143) FIGS. **41**A-**41**C show an illustrative corrosion risk reduction apparatus **2000** including one or more (in the illustrated embodiment, three) corrosion risk reduction modules **100** in fluid communication with a central housing **195**. The central housing **195** is in fluid communication with coalescing or particulate filters **78** upstream and downstream of the central housing **195**, and a coalescing mist separator **182** upstream of the central housing **195**. One or more corrosion risk reduction modules **100** can house corrosion inhibitor in various forms. For example, corrosion inhibitor can be housed in the form of a container **120** (e.g., a sachet or pouch containing a corrosion inhibitor), and/or raw powder **121** including corrosion inhibitor, and/or a porous solid mass or block **122** of corrosion inhibitor (e.g., but not limited to, a wafer or a brick). These are visible in the cross-sectional view of the illustrative corrosion risk reduction apparatus **2000** shown in FIG. **41**B and the exploded view of corrosion risk reduction modules **100** in FIG. **41**C. The cross-sectional view depicted in FIG. **41**B also shows an illustrative air flow pattern through the corrosion risk reduction apparatus **2000**. In the illustrative embodiments of FIGS. **41**A-**41**C, the corrosion risk reduction modules **100** are open only at one end, and the corrosion inhibitor can be drawn into the central housing **195** by the air flowing through the central housing **195**.
(144) FIGS. **42**A-**42**B show an illustrative corrosion risk reduction apparatus **2000** including a corrosion risk reduction module **100** in fluid communication with coalescing or particulate filters **78** upstream and downstream of the corrosion risk reduction module **100**, and a coalescing mist separator **182** upstream of the corrosion risk reduction module **100**. The cross-sectional view depicted in FIG. **42**B shows that the corrosion risk reduction module **100** includes raw powder **121** including corrosion inhibitor, and also shows an illustrative air flow pattern through the corrosion risk reduction apparatus **2000** (including air flow through the raw powder **121**). In the illustrative embodiments of FIGS. **42**A-**42**B, the corrosion risk reduction module **100** has inlet and outlet openings at opposite longitudinal ends.
(145) FIGS. **43**A-**43**C show a straight flow configuration. As illustrated in FIGS. **43**A and **43**C, air flow can occur at least around containers **120** of corrosion inhibitor in a corrosion risk reduction module **100**. FIGS. **43**B and **43**C show an illustrative corrosion risk reduction apparatus **2000** including a corrosion risk reduction module **100** configured for straight flow, in fluid communication with coalescing or particulate filters **78** upstream and downstream of the corrosion risk reduction module **100**, and a coalescing mist separator **182** upstream of the corrosion risk reduction module **100**.
(146) FIGS. **44**A-**44**C show a corrosion risk reduction module **100′** with a clamshell housing **80**, in which containers **120** of corrosion inhibitor are held by a metal or plastic webbing or mesh **72**. The metal or plastic webbing or mesh **72** is visible in the cross-sectional view shown in FIG. **44**B and the exploded view shown in FIG. **44**C. FIG. **44**B also shows the air flow pattern through the corrosion risk reduction module **100′**, from an inlet port **93** to an outlet port **94**.
(147) FIGS. **45**A-**45**C show an illustrative corrosion risk reduction module **100″** with a stacked configuration of vapor-permeable containers **120** of corrosion inhibitor. The top of the housing **80** can be louvered, and can be perforated or vented to facilitate vertical air flow through the corrosion risk reduction module **100″**, as illustrated in the cross-sectional view shown in FIG. **45**B. Vapor-permeable containers **120** are arranged in a stacked configuration in a plurality of trays **123**. An example of a tray **123** is illustrated in FIG. **45**D, and includes openings **1231** at the bottom thereof to facilitate air flow through the stack. As shown in FIG. **45**E, an illustrative corrosion risk reduction system **1000** can include a source of compressed air **96**, the air inlet of which is fitted with, integrated into, or otherwise in fluid communication with, a corrosion risk reduction module **100″** with a stacked configuration of vapor-permeable containers **120**. The corrosion risk reduction

system **1000** can further include an air maintenance device **130**, branch line detection devices **150**, and a purge valve **190**.
(148) FIGS. **46**A-**46**C show illustrative corrosion risk reduction modules **100** with various air flow entry and exit points. In FIG. **46**A, the inlet port **93** and the outlet port **94** are located at opposite longitudinal ends of the corrosion risk reduction module **100**. In FIG. **46**B, the inlet port **93** and the outlet port **94** are located at the same longitudinal end of the corrosion risk reduction module **100**, and are disposed at an angle relative to one another. In FIG. **46**A, the inlet port **93** and the outlet port **94** are located at opposite lateral ends of the corrosion risk reduction module **100**.
(149) It will be appreciated by those skilled in the art that the disclosure herein can be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The presently-disclosed embodiments are therefore considered in all respects to be illustrative and not restricted. The scope of the invention is indicated by the appended claims rather than the foregoing description and all changes that come within the meaning and range and equivalence thereof are intended to be embraced therein.

Claims

1. A corrosion risk reduction system comprising: at least one corrosion risk reduction module, each corrosion risk reduction module comprising a housing including an inlet port and an outlet port which are each configured for fluid communication between an inside of the housing and an outside of the housing, the housing containing a replaceable cartridge in which are disposed a plurality of containers of volatile corrosion inhibitor, wherein the outlet port is configured for fluid communication with a piping system, and the outlet is configured to direct a gas from an air compressor, and the volatile corrosion inhibitor from the inside of the housing of the at least one corrosion risk reduction module, into the piping system; and at least one corrosion risk reduction module, the corrosion inhibitor detection device comprising: a coupling configured to couple the corrosion inhibitor detection device to the piping system; a coupling configured to couple to the corrosion inhibitor detection device to the piping system; and a housing in fluid communication with the coupling and containing an indicator element configured to visually change upon contact with the volatile corrosion inhibitor; wherein a bendable and crushable portion of the housing of the corrosion inhibitor detection device contains the indicator element and further contains an indicator capillary, wherein the indicator capillary contains indicator fluid, and wherein the indicator element and the indicator capillary are arranged such that, upon breaking of the indicator capillary by bending or crushing the bendable and crushable portion of the housing of the corrosion inhibitor detection device, the indicator fluid is released from the indicator capillary and reaches the indicator element to render the indicator element sensitive to the volatile corrosion inhibitor, thereby providing an indication upon contact with the volatile corrosion inhibitor.
2. The corrosion risk reduction system of claim 1, wherein the indicator element is in a form of an indicator strip.
3. The corrosion risk reduction system of claim 1, wherein the coupling is a pipe coupling.
4. The corrosion risk reduction system of claim 1, further comprising: a sight glass on the housing of the corrosion inhibitor detection device configured to provide a line of sight from an outside environment of the housing of the corrosion inhibitor detection device to the indicator element located inside the housing of the corrosion inhibitor detection device for observing a visual change of the indicator element when the volatile corrosion inhibitor is present in the housing of the corrosion inhibitor detection device.
5. The corrosion risk reduction system of claim 1, further comprising: an inlet valve configured to connect to the piping system containing the gas to pressurize the housing of the corrosion inhibitor detection device; and a pressure release valve configured for releasing pressure from the housing of the corrosion inhibitor detection device.

6. The corrosion risk reduction system of claim 1, wherein the replaceable cartridge comprises a plurality of stacked sections, each section defining a portion of an internal wall or a series of walls of the replaceable cartridge.
7. The corrosion risk reduction system of claim 1, wherein the replaceable cartridge is configured to be stacked and fluidly connected with an identical replaceable cartridge such that the airflow is directed around and through volatile corrosion inhibitor within the identical replaceable cartridge.
8. The corrosion risk reduction system of claim 1, wherein the replaceable cartridge includes a plurality of baffles configured to position the plurality of containers of volatile corrosion inhibitor within the replaceable cartridge.
9. A volatile corrosion inhibitor detection device comprising: a coupling configured to couple to a system configured to be closed; and a housing in fluid communication with the coupling and containing an indicator element configured to visually change upon contact with volatile corrosion inhibitor, wherein a bendable and crushable portion of the housing contains the indicator element and further contains an indicator capillary, wherein the indicator capillary contains indicator fluid, and wherein the indicator element and the indicator capillary are arranged such that, upon breaking of the indicator capillary by bending or crushing the bendable and crushable portion of the housing, the indicator fluid is released from the indicator capillary and reaches the indicator element to render the indicator element sensitive to the volatile corrosion inhibitor, thereby providing an indication upon contact with the volatile corrosion inhibitor.
10. The volatile corrosion inhibitor detection device of claim 9, wherein the indicator element is in a form of an indicator strip.
11. The volatile corrosion inhibitor detection device of claim 9, wherein the coupling is a pipe coupling and the system is a piping system.
12. The volatile corrosion inhibitor detection device of claim 9, further comprising: a sight glass on the housing configured to provide a line of sight from an outside environment of the housing to the indicator element located inside the housing for observing a visual change of the indicator element when the volatile corrosion inhibitor is present in the housing.
13. The volatile corrosion inhibitor detection device of claim 9, further comprising: an inlet valve configured to connect to the system containing gas to pressurize the housing; and a pressure release valve configured for releasing pressure from the housing.
14. The volatile corrosion inhibitor detection device of claim 9, wherein a disposable housing portion contains the indicator element and is removable from the system.
15. A volatile corrosion inhibitor detection device comprising: a coupling configured to couple to a system configured to be closed; a housing in fluid communication with the coupling, the housing including an indicator chamber that contains an indicator element configured to visually change upon contact with volatile corrosion inhibitor, the indicator chamber having a proximal end and a distal end, wherein the proximal end and the distal end each include a brass orifice configured to control flow across the indicator element, and wherein each brass orifice is insulated from the indicator element by a negative catalyst.