

## **PIPE REPLACEMENT SYSTEM**

### **CROSS-REFERENCE TO RELATED APPLICATIONS**

**[0001]** This application claims priority to U.S. Provisional Patent Application Serial No. 62/836,971, filed April 22, 2019, entitled "ONLINE PIPE REPLACEMENT SYSTEM," which is incorporated herein by reference.

### **FIELD OF DISCLOSURE**

**[0002]** In general, this invention relates to repairing leaks in a pipe and, more particularly, to a pressure containing sleeve for sealing leaks through the exterior of a pipe wall.

### **BACKGROUND**

**[0003]** Pipes often develop leaks along pipe and pipe fitting connections. Leaks can occur due to factors such as pipe deterioration over time, impact structural damage, or use in harsh environments.

**[0004]** Composite repairs for pipes are seeing marked growth in the industry because they reduce the costs incurred by operators in extending the life of their systems whilst maintaining integrity. Extended repair lengths are relatively common, exceeding ninety-one meters (three-hundred feet) in length. The technology is now standardized with ISO 24817 and ASME PCC-2 Article 401 being the most common references used to support the repairs.

**[0005]** Impaired and leaking pipes (and other pressure equipment) can be repaired using composite materials to form a composite repair. Impaired and leaking pipes may be classified as having a "Type A Defect" or a "Type B Defect" in accordance with industry and/or governmental standards applying to pipes used in different industries, including the energy industry. Pipes without holes and meeting other criteria may be classified as having a pipe defect termed a Type A Defect. Where there is a hole (or might be a hole during the intended life of the repair) then the pipe defect is termed a Type B Defect. However, the capability of these repairs is limited with regard to providing containment for leaks in the case the pipe becomes perforated and is a Type B Defect. When the capability of the repair is exceeded, the pipe fluid can be driven under or through the composite repair resulting in an external leak. Many of these failures result in fluid escaping from the termination of the repair.

[0006] What is needed, therefore, is an improved method of pipe repair that addresses containment for leaks through perforations in the pipe.

### SUMMARY

[0007] This summary is provided to introduce a selection of concepts that are further described below in the detailed description. However, many modifications are possible without materially departing from the teachings of this disclosure. Accordingly, such modifications are intended to be included within the scope of this disclosure as defined in the claims. This summary is not intended to identify key or essential features of the claimed subject matter, nor is it intended to be used as an aid in limited the scope of the claimed subject matter.

[0008] An embodiment of the present disclosure provides a pipe replacement system for repairing a pipe. The pipe replacement system includes a wrap wrapped around a pipe outer surface to form a repair sleeve having a first termination section and a second termination section. The first termination enclosure encloses the first termination section to form a first pressure containing connection with the repair sleeve. The first termination enclosure includes a first outer seal disposed around the pipe on a pipe outer surface. The first outer seal is outwardly spaced from the first termination section to annularly seal on the pipe outer surface. The first termination enclosure further includes a first inner seal disposed around the repair sleeve on a repair sleeve outer surface. The first inner seal is inwardly spaced from the first outer seal to annularly seal on the repair sleeve outer surface.

[0009] An embodiment of the present disclosure provides a pipe replacement method for repairing a pipe. The method includes wrapping a wrap around the pipe to form a repair sleeve having a first termination section and a second termination section, enclosing a first termination enclosure over the first termination section to form a first pressure containing connection with the repair sleeve. Enclosing the first termination enclosure over the first termination section includes disposing a first outer seal around the pipe on a pipe outer surface. The first outer seal is outwardly spaced from the first termination section to annularly seal on the pipe outer surface. Enclosing the first termination enclosure over the first termination section further includes disposing a first inner seal around the repair sleeve on a repair sleeve outer surface. The first inner seal is inwardly spaced from the first outer seal to annularly seal on the repair sleeve outer surface.

[0010] An embodiment of the present disclosure provides a pipe replacement method for repairing a pipe. The method includes wrapping a fiber wrap around the repair section of the pipe to form a repair sleeve having a first termination section and a second termination section, and enclosing a first termination enclosure over the first termination section to form a first pressure containing connection with the repair sleeve. Enclosing the first termination enclosure over the first termination section includes disposing a first outer seal around the pipe on a pipe outer surface. The first outer seal is outwardly spaced from the first termination section to annularly seal on the pipe outer surface. Enclosing the first termination enclosure over the first termination section further includes disposing a first inner seal around the repair sleeve on a repair sleeve outer surface. The first inner seal is inwardly spaced from the first outer seal to annularly seal on the repair sleeve outer surface. The method further includes enclosing a second termination enclosure over the second termination section to form a second pressure containing connection with the repair sleeve. Enclosing the second termination enclosure over the second termination section includes disposing a second outer seal around the pipe on the pipe outer surface. The second outer seal is outwardly spaced from the second termination section to annularly seal on the pipe outer surface. Enclosing the second termination enclosure over the second termination section further includes disposing a second inner seal around the repair sleeve on a repair sleeve outer surface. The second inner seal is inwardly spaced from the second outer seal to annularly seal on the repair sleeve outer surface. The repair sleeve is configurable in a leak path configuration where the repair sleeve forms a leak flow path extending from a pipe defect covered by the repair sleeve to the first termination enclosure and the second termination enclosure. The leak flow path is sealed from an external atmosphere by the first termination enclosure and the second termination enclosure.

#### BRIEF DESCRIPTION OF THE FIGURES

[0011] Certain embodiments of the disclosure will hereafter be described with reference to the accompanying drawings, wherein like reference numerals denote like elements. It is emphasized that, in accordance with standard practice in the industry, various features are not drawn to scale. In fact, the dimensions of various features may be arbitrarily increased or reduced for clarity of discussion. It should be understood, however, that the accompanying

figures illustrate the various implementations described herein and are not meant to limit the scope of various technologies described herein, and:

[0012] Figure 1 is a perspective view of a pipe replacement system assembled on a pipe in accordance with embodiments of the present disclosure;

[0013] Figure 2 is a top perspective view of the pipe replacement system assembled on the pipe in accordance with embodiments of the present disclosure;

[0014] Figure 3 is a side view of the pipe replacement system of Figure 2 taken along the line 3-3 in accordance with embodiments of the present disclosure;

[0015] Figure 4A is an enlarged view of a section of Figure 3 showing a portion of a first termination enclosure for sealing a first termination section of a repair sleeve in accordance with embodiments of the present disclosure;

[0016] Figure 4B is an enlarged view of the section of Figure 3 showing a portion of the first termination enclosure for sealing the first termination section of the repair sleeve in accordance with embodiments of the present disclosure;

[0017] Figure 5 is a front view of the first termination enclosure in accordance with embodiments of the present disclosure;

[0018] Figures 6-8 is a series of figures showing an assembly of the pipe replacement system on the pipe in accordance with embodiments of the present disclosure;

[0019] Figure 9 is a schematic of the pipe replacement system assembled on the pipe in a non-leak path configuration in accordance with embodiments of the present disclosure;

[0020] Figure 10 is a schematic of the pipe replacement system assembled on the pipe in a leak path configuration in accordance with embodiments of the present disclosure; and

[0021] Figure 11 is a flowchart of a method of repairing a pipe with the pipe replacement system in accordance with embodiments of the present disclosure.

### DETAILED DESCRIPTION

**[0022]** In the following description, numerous details are set forth to provide an understanding of some embodiments of the present disclosure. It is to be understood that the following disclosure provides many different embodiments, or examples, for implementing different features of various embodiments. Specific examples of components and arrangements are described below to simplify the disclosure. These are, of course, merely examples and are not intended to be limiting. In addition, the disclosure may repeat reference numerals and/or letters in the various examples. This repetition is for the purpose of simplicity and clarity and does not in itself dictate a relationship between the various embodiments and/or configurations discussed. However, it will be understood by those of ordinary skill in the art that the system and/or methodology may be practiced without these details and that numerous variations or modifications from the described embodiments are possible. This description is not to be taken in a limiting sense, but rather made merely for the purpose of describing general principles of the implementations. The scope of the described implementations should be ascertained with reference to the issued claims.

**[0023]** As used herein, the terms “connect”, “connection”, “connected”, “in connection with”, and “connecting” are used to mean “in direct connection with” or “in connection with via one or more elements”; and the term “set” is used to mean “one element” or “more than one element”. Further, the terms “couple”, “coupling”, “coupled”, “coupled together”, and “coupled with” are used to mean “directly coupled together” or “coupled together via one or more elements”. As used herein, the terms “up” and “down”; “upper” and “lower”; “top” and “bottom”; and other like terms indicating relative positions to a given point or element are utilized to more clearly describe some elements.

**[0024]** In general, the present disclosure relates to repairing leaks in pipes and, more particularly, to a system and method that prevents such a leak escaping to atmosphere resulting in the repair continuing to successfully contain the pipe pressure.

**[0025]** The present disclosure provides embodiments of a pipe replacement system that renovates pipes by forming a repair sleeve over the pipe to provide an entirely new means of enclosing the fluid at pressure and a new pressure boundary. Termination enclosures form a pressurized seal connections to termination sections of the repair sleeve. By forming

pressurized seal connections at the termination sections, the termination enclosures prevent fluid from the pipe from leaking underneath the repair sleeve to the external atmosphere. Embodiments of the repair sleeve of the present disclosure may be formed on the pipe without requiring extensive grit blasting or other preparations to provide a clean pipe surface along a whole length of the repair section of the pipe to be covered by the repair sleeve. Abrasive techniques to prepare a clean pipe surface help improve the bond between the repair sleeve and the pipe outer surface but also has the potential of damaging a pipe that may be online. Embodiments of the present invention enclose the fluid pressure where there is a leak out of one or more termination sections of the repair sleeve because of pressure seals provided by the termination enclosures so that the pressure capability of the pipe replacement system is not determined by adhesion of the repair sleeve to the pipe. Pressure capability of the repair sleeve, without use of the termination enclosures, is limited by adhesion of the repair sleeve to the pipe – which is in turn governed by the surface preparation. Higher performance of a pipe repair and simpler installation can be achieved by removing reliance on adhesion between the repair sleeve and the pipe by using embodiments of the pipe replacement system having termination enclosures providing pressurized seal connection to the termination sections of the repair sleeve.

[0026] The repair sleeve of the disclosed embodiments forms a new pipe on top of and surrounding the repair section of the original pipe. The termination enclosures form a pressure seal at opposite termination sections to prevent fluid leaking underneath the repair sleeve from leaking from the termination ends. The repair sleeve may also adhere to the outer pipe surface when a wrap having an adhesive is wrapped around the pipe to the form the repair sleeve on the pipe. The repair sleeve bonded to the outer surface of the pipe may help block fluid from leaking from a through-hole defect, i.e. puncture in the pipe wall, underneath the repair sleeve, and from the termination sections to the atmosphere. The repair sleeve bonded to the outer surface of the pipe may only block fluid from leaking at the termination sections when the fluid pressure in the pipe is low and where the through-hole defects are limited. The termination enclosures operate to seal the repair sleeve to prevent a fluid leak to atmosphere at higher fluid pressures in the pipe and where the through hole defects are more substantial.

[0027] Figures 1-3 show an embodiment of the pipe replacement system, referred to generally as **100**, of the present disclosure assembled on a pipe **12**. Pipe replacement system **100** includes

a repair sleeve **102** disposed on a pipe outer surface **14**, a first sealing enclosure **104**, and a second sealing enclosure **106**. Repair sleeve **102** forms a repair sleeve bore through which the pipe **12** extends. Repair sleeve **102** may be formed by wrapping the pipe **10** with a wrap to form at least one layer over the pipe outer surface **14**. The wrap is pliable and may be wrapped around the pipe **12** so that the repair sleeve **102** is formed to abut against the pipe out surface **14** and have an inner diameter approximately equal to the outer diameter of the pipe **12**. The wrap may be a reinforcing material that has a fiber structure. The wrap may be made using materials including glass, carbon, and aramid reinforced polymers, typically epoxies and polyurethanes. The wrap may be non-metallic in some embodiments. The repair sleeve **102** typically, but not exclusively, comprises a composite material. Repair sleeve **102** may include multiple layers of the wrap wrapped circumferentially around the pipe **12**.

[0028] Repair sleeve **102** extends axially along the pipe **12** and has a first termination section **107** and a second termination section **108** axially spaced from one another, as shown in Figure 3. Repair sleeve **102** may have multiple layers and each layer may be formed by a different wrap layer. In some embodiments, the repair sleeve **102** may have one wrap layer, two wrap layers, or more than two wrap layers.

[0029] First sealing enclosure **104** and the second sealing enclosure **106** have a similar construction and are assembled at opposite ends of the repair sleeve **102**. In some embodiments, a repair sleeve may use a first termination enclosure to enclose a first termination section, and a second termination enclosure is not used to enclose a second termination section. In some embodiments, more than two termination enclosures may be used to enclose a repair sleeve, such as a repair sleeve that has multiple sections. For example, a pipe may have a main line and a branch line extending from the main line to form a T-joint, and a repair sleeve is applied to cover the T-joint with the repair sleeve having opposing termination sections on the main line and a branch termination section the branch line. The opposing termination sections and the branch termination section may each have a termination enclosure to provide a pressure connection at each of the three different termination sections. In some embodiments, a repair sleeve may cover a portion of the main line and a portion of multiple branch lines with more than three termination sections and a termination enclosure providing pressure connection for each of the termination sections. Figure 1 shows the pipe **12** with a pipe flange at each end. The pipe flanges may be used to connect to other pipe sections forming a longer pipe. The

repair sleeve **102** may be configured to extend over pipe flanges to form an extended repair sleeve.

[0030] First termination enclosure **104** includes a first upper half **110** and a first lower half **112** that connect to form the first sealing enclosure **104**. Second sealing enclosure **106** includes a second upper half **114** and a second lower half **116** that connect to form the second sealing enclosure **106**. First upper half **110** and the first lower half **112** each have an enclosure flange **120** that mate to connect the first upper half **110** and the first lower half **112** together. Second upper half **114** and the second lower half **116** each have a second flange **122** that mate to connect the second upper half **114** and the second lower half **116** together. Mechanical fasteners formed by enclosure bolts **124** and enclosure nuts **126** connect the first upper half **110** to the first lower half **112** and connect the second upper half **114** to the second lower half **116**. In some embodiments, the first termination enclosure **104** may have a non-split structure. In some assemblies of the pipe replacement system, the first termination enclosure **104** may be slid over the pipe **12** and the repair sleeve **102** to assemble the first termination enclosure **104** to pressure contain the first termination section **107**.

[0031] Termination enclosures **104**, **106** are assembled on the pipe **12** and are axially spaced from one another along a first axis **130**. First axis **130** extends through the termination enclosures **104**, **106** and through the repair sleeve **102** and the pipe **12**, as shown in Figures 1-3. First axis **130** may be a central axis of the termination enclosures **104**, **106** and the repair sleeve **102** and the pipe **12**.

[0032] Referring to Figure 3 and Figure 4A, the first termination enclosure **104** has a first main body **132** having a first outer extension **134** and a first inner extension **136**. First outer extension **134** and the first inner extension **136** extend radially inward from the first main body **132** and are spaced from one another. First outer extension **134** and the first inner extension **136** extend around the circumference of the pipe **12** to form annular extensions extending from the first main body **132**. A first outer gland assembly formed by a first outer seal **140** is connected in the first outer extension **134**. First outer seal **140** may be an annular seal that extends around an inner surface of the first outer extension **134** and around the pipe outer surface **14**. A first inner gland assembly formed by a first inner seal **142** is disposed in the first inner extension **136**. First inner seal **142** may be an annular seal that extends around an inner surface of the first inner extension **136** and around a sleeve outer surface **144**. In some

embodiments, the first outer seal **140** may be disposed in an outer seal slot **146**, see Figure **4A**, forming an annular groove in the first annular extension and the first inner seal **142** may be disposed in an inner seal slot **148**, see Figure **4A**, forming an annular groove in the first inner extension **136**.

[0033] First termination enclosure **104** has a first enclosure cavity **152**. First enclosure cavity **152** may be formed by the first main body **132**. First enclosure cavity **152** is enclosed by a first cavity surface **154**. First outer seal **140** and the first inner seal **142** seal the first enclosure cavity **152**. A pressurized fluid leaking from a pipe hole in the pipe **12** may result in a pipe fluid flowing between the repair sleeve **102** and the pipe outer surface **14**. The pipe fluid may flow in the first enclosure cavity **152** from a leak beneath the first termination section **107**. First outer seal **140** is disposed adjacent and abuts against the pipe outer surface **114** to form an annular seal between the first enclosure **104** and the pipe outer surface **114**. First inner seal **142** is disposed adjacent and abuts against the sleeve outer surface **144** to form an annular seal between the first termination enclosure **104** and the sleeve outer surface **144**, as shown in Figure **4A**. First outer seal **140** and the first inner seal **142** seal the first enclosure cavity **152** to seal the repair sleeve **102** at the first termination section **107**. First outer seal **140** and the first inner seal **142** may have an annular structure and be secured in the seal slots **146**, **148**. In some embodiments, the first outer seal **140** and the first inner seal **142** may be made of an elastomer.

[0034] Second termination enclosure **106** is constructed in a similar manner as the first termination enclosure **104** and seals the second termination section **108** of the repair sleeve **102**. Second termination enclosure **106** has a second main body **162** having a second outer extension **164** and a second inner extension **166**. Second outer extension **164** and the second inner extension **166** extend radially inward from the second main body **162** and are spaced from one another. Second outer extension **164** and the second inner extension **166** extend around the circumference of the pipe **12** to form annular extensions extending from the second main body **162**. A second outer gland assembly formed by a second outer seal **170** is connected to the second outer extension **164**. Second outer seal **170** may be an annular seal that extends around an inner surface of the second outer extension **164** and around the pipe outer surface **14**. A second inner gland assembly formed by a second inner seal **172** is connected to the second inner extension **166**. Second inner seal **172** may be an annular seal that extends around an inner surface of the second inner extension **166** and around the sleeve outer surface **144**. In

some embodiments, the second outer seal **170** may be disposed in an outer seal slot **146** forming an annular slot in the second outer extension **164** and the second inner seal **172** may be disposed in an inner seal slot **148** forming an annular slot in the second inner extension **166**. In some embodiments, second outer seal **170** and the second inner seal **172** may have an annular structure and be secured in the seal slots **146**, **148**.

**[0035]** Second termination enclosure **106** forms a second enclosure cavity **182**. Second enclosure cavity **182** may be formed in the second main body **162**. Second enclosure cavity **182** is enclosed by a second cavity surface **184**. Second outer seal **170** and the second inner seal **172** seal the second enclosure cavity **182**. A pressurized fluid leaking from a pipe hole in the pipe **12** may result in a pipe fluid flowing between the repair sleeve **102** and the pipe outer surface **14**. The pipe fluid may flow in the second enclosure cavity **182** from second termination section **108**. Second outer seal **170** is disposed adjacent and abuts against the pipe outer surface **114** to form an annular seal between the second termination enclosure **106** and the pipe outer surface **114**. Second inner seal **172** is disposed adjacent and abuts against the sleeve outer surface **144** to form an annular seal between the second termination enclosure **106** and the sleeve outer surface **144**. Second outer seal **170** and the second inner seal **172** seal the second enclosure cavity **182** to seal the repair sleeve **102** at the second termination section **108**.

**[0036]** In some embodiments, pipe replacement system **110** further includes a first ring restraint **190** and a second ring restraint **192**, as shown in Figures **1-3**, that are constructed in a similar manner. First ring restraint **190** includes a first restraint upper half **194** and a first restraint lower half **196**. First restraint upper half **194** and first restraint lower half **196** each have a first restraint flange **198** that mate to connect the first restraint upper half **194** and the first restraint lower half **196** together. Mechanical fasteners formed by first restraint bolts **206** and restraint nuts **204** connect the first restraint upper half **194** to the first restraint lower half **196**. First ring restraint **190** has a first restraint main body that forms a bore configured for the pipe **12** to extend therethrough. First ring restraint **190** may be tightened using the first restraint bolts **206** and the restraint nuts **204** to clamp the first ring restraint **192** to the pipe **12** to secure the first ring restraint **192** to the pipe **12**. A first connector member formed by a first restraint bolts **206** and nuts **208** may be used to connect the first ring restraint **190** to the first termination enclosure **104**. First ring restraint **190** may be used to secure the first termination enclosure

**104** in first axial position on the pipe **12**. First restraint bolts **206** may extend through the first restraint ring **190** and extend at least partially in the first termination enclosure **104**.

[0037] Second ring restraint **192** includes a second restraint upper half **214** and a second restraint lower half **216**. Second restraint upper half **214** and second restraint lower half **216** each have a second restraint flange **218** that mate to connect the second restraint upper half **214** and the second restraint lower half **216** together. Mechanical fasteners formed by first restraint bolts and restraint nuts connect the second restraint upper half **214** to the second restraint lower half **216**. Second ring restraint **194** has a second restraint main body that forms a bore configured for the pipe **12** to extend therethrough. Second ring restraint **192** may be tightened using the first restraint bolts and the restraint nuts to clamp the second ring restraint **194** to the pipe **12** to secure the second ring restraint **194** to the pipe **12**. A second connector member formed by a second restraint bolts **226** and nuts may be used to connect the second ring restraint **194** to the second termination enclosure **106**. Second ring restraint **192** may be used to secure the second termination enclosure **106** in a second axial position on the pipe **12**. Second restraint bolts **226** may extend through the second restraint ring **192** and extend at least partially in the second termination enclosure **106**.

[0038] In some embodiments, a structural restraint between the repair sleeve **102** and the termination enclosures **104**, **106** may be used to secure the termination enclosures **104**, **106** to the repair sleeve **102**. The structural restraint may be formed by mechanical fasteners that extend from the termination enclosures **104**, **106** and in the repair sleeve **102**.

[0039] In some embodiments, a structural restraint between the termination enclosures **104**, **106** and the pipe **12** may be formed using an adhesive that bonds the termination enclosures **104**, **106** to the pipe **12**. For example, the adhesive may be applied to an inner surface of the first outer extension **134**, shown in Figure **4A**, to adhesively secure the first termination enclosure **104** to the pipe outer surface **14**.

[0040] Referring to Figure **4B**, the first outer seal **140** and the first inner seal **142** may be an injected seal in some embodiments. In this embodiment, a first injection port **224** extends from an outer surface of the first termination enclosure **104** to the outer seal slot **146**. There may be multiple spaced apart first injection ports **224** extending from the outer surface of the first termination enclosure **104** to the outer seal slot **146**. A second injection port **225** extends from

the outer surface of the first termination enclosure **104** to the inner seal slot **148**. There may be multiple spaced second injection ports **225** extending from the outer surface of the first termination enclosure **104** to the inner seal slot **148**. A fluid may be injected in the injection ports **224**, **225** to form the first outer seal **140** and the first inner seal **142**. The first outer seal **140** and the first inner seal **142** may form a continuous seal pipe outer surface **14** and the sleeve outer surface **144**. The injected seal may cure or remain in its injected state sealing through adhesion compression or compaction.

[0041] In some embodiments, a first cavity seal **238** may be formed in the first enclosure cavity **152**. An enclosure cavity injection port **223** extends from an outer surface of the first termination enclosure **104** to the enclosure cavity **152**. There may be multiple spaced enclosure cavity injection ports **223** extending from the outer surface of the first termination enclosure **104** to the enclosure cavity **152**. A fluid may be injected in the cavity injection port **223** and in the enclosure cavity **152** to form the first cavity seal **238**. The first cavity seal **238** may form a continuous seal with the pipe outer surface **14** and the sleeve outer surface **144**. The injected first cavity seal **238** may cure or remain in its injected state sealing through adhesion compression or compaction. In some embodiments, first cavity seal **238** may have an annular structure and be secured in the first enclosure cavity **152**. In some embodiments, the injected first cavity seal **238** may be made of an elastomer.

[0042] First cavity seal **238** may seal the first enclosure cavity **152** to provide a pressure containment seal for the repair sleeve **102** at the first termination section **107**. In some embodiments, the first cavity seal **238**, the first outer seal **140**, and the first inner seal **142** may be used in combination to provide a pressure containment seal for the repair sleeve **102** at the first termination section **107**. Second termination enclosure **106** may be constructed in a similar manner as the first termination enclosure **104** and have a cavity seal **238**.

[0043] Referring to Figure **5**, a front view of the first termination enclosure **104** is shown. Termination enclosures **104**, **106** have a similar construction and the description of the first termination enclosure **104** may apply to the second termination enclosure **106**. First termination enclosure **104** has a cylindrical shape and forms an enclosure bore configured for a cylindrical pipe, not shown in Figure **4**, to pass through. In some embodiments, first termination enclosure **104** may have non-cylindrical shapes to accommodate a non-cylindrical pipe. First outer seal **140** is depicted in Figure **5** with a dashed line and extends around the

enclosure bore and the first axis **130**. First outer seal **140** may have a ring or cylindrical shape, as shown in Figure 5. A split-line seal formed by a flange gasket **222** extends between mating faces of the enclosure flanges **120**, as shown in Figure 5. Flange gasket **222** may intersect the first outer seal **140**. Flange gasket **222** may extend axially between the enclosure flanges **120**. Flange gasket **222** may be generally parallel to the first axis **130**. Flange gasket **222** may seal the interface between the enclosure flanges **120**. Flange gasket **222** may extend axially between the first outer seal **140** and the first inner seal **142**. In some embodiments, flange gasket **222** may intersect both the first outer seal **140** and the first inner seal **142**.

[0044] In some embodiments, seal activation holes **220** may be positioned through a front face of the first termination enclosure **104** and are spaced from one another around the enclosure bore and the first axis **130**, as shown in Figure 5. Seal activation members formed by seal activation screws **232**, shown in Figure 8, may be inserted in the seal activation holes **220** to mechanically energize the first outer seal **140** to form a pressure seal around the pipe outer surface **14**. In some embodiments, the seal activation screws **232** may mechanically compress the first outer seal **140** to energize the first outer seal **140**. First outer seal **140** and first inner seal **142** may be energized to form pressure seals, in some embodiments, in any number of different conventional manners to energize the seals formed by the first outer seal **140** and the first inner seal **142**. First bolt hole **210** and a second bolt hole **212** are shown formed through the first face of the first termination enclosure **104** and are used to connect the first termination enclosure **104** to the first restraint bolts **206**, shown in Figure 3.

[0045] Referring to Figures 6-8, assembling the pipe replacement system **100** to repair a pipe **12** is shown. A repair is performed on the pipe **12** by wrapping a wrap **232** around a repair section of the pipe **12**. Multiple layers of wrap **232** may be wrapped around the repair section of the pipe **12**. Figure 6 shows a layer of wrap **232** in the process of being wrapped over one or more previously wrapped layers of the wrap **232**. In some embodiments, different layers of the wrap **232** may be made of different materials. In some embodiments, the wrap may include an adhesive to bond one or more wrap layers **232** to the pipe outer surface **14** and to bond multiple layers of the wrap together. In some embodiments, the adhesive may be a resin. The wraps **232** used to form the repair sleeve **102** may have different widths. In some embodiments, a first wrap layer may be formed by overlapping the wrap **232** over the pipe **12** to form the first wrap layer. Additional wrap layers may be formed in a similar manner. Wrap **232** may be

wrapped over a through-wall defect **20** of the pipe **12**. Through-wall defect **20** may be a pipe hole or perforation in the pipe wall of the pipe **12**.

[0046] Referring to Figure 7, wrapping the wrap **232** over a repair section of the pipe **12** forms a repair sleeve **102** covering the through-wall defect **20** in the pipe **12**. Referring to Figure 8, after the repair sleeve **102** has been formed over the repair section **230**, the termination enclosures **104**, **106** may be connected on opposite ends of the repair sleeve **102**. In addition, the first restraint ring **190** may be connected to the pipe **12** outwardly from the first termination enclosure **104** and the second restraint ring **192** may be connected to the pipe **12** outwardly from the second termination enclosure **106**. First restraint bolts **206** may be connected to the first restraint ring **190** and the first termination enclosure **104** to secure the first termination enclosure **104** to the pipe **12**. First restraint bolts **206** may be connected to the restraint ring **190** and the first termination enclosure **104** to secure the first termination enclosure **104** to the pipe **12**. Second restraint bolts **226** may be connected to the second restraint ring **192** and the second termination enclosure **106** to secure the second termination enclosure **106** to the pipe **12**.

[0047] Referring to Figure 9, a schematic of the pipe replacement system **100** is shown assembled on the pipe **12** in a non-leak path configuration. Pipe **12** is online with fluid flowing in the pipe **12**, as depicted by arrows **240**. Pipe **12** may have fluid in the pipe **12** with the fluid applying pressure to the pipe walls. Operating conditions of the pipe **12** may cause the pipe walls to deteriorate over time such that the pipe **12** forms a pipe defect. For example, a pipe defect may include a through-wall defect **20** in the pipe wall of pipe **12**, as shown in Figure 9. Repair sleeve **102** is wrapped over the pipe **12** and over the through-wall defect **20**. Repair sleeve **102** may be bonded to the pipe outer surface **14** such that through-wall defect is blocked by the repair sleeve **102** and the pipe fluid is blocked from flowing underneath the repair sleeve **102** to the termination enclosures **104**, **106**.

[0048] Referring to Figure 10, a schematic of the pipe replacement system **100** is shown assembled on the pipe **12** in a leak path configuration. Fluid pressure from the pipe **12** may exert fluid pressure through the through-hole defect **20** on the portion of the pipe sleeve **102** overlying the through-hole defect **20**. The fluid pressure on the repair sleeve **102** may result in the adhesive bond between the repair sleeve **102** and the pipe outer surface **14** failing and a leak flow path **234** forming under the repair sleeve **102**. Leak flow path **234** extends from the

through-hole defect **20** to either the first enclosure housing **104**, the second enclosure housing **106**, or both enclosure housings **104**, **106**. Leak flow path **234** is depicted in Figure **10** as extending from the through-hole defect **20** to the termination enclosures **104**, **106**. Pipe fluid flows from the through-hole defect to the enclosure cavities **152**, **182**, as depicted by arrows **236**, **244**. Termination enclosures **104**, **106** form a pressure containing connection at the termination sections **107**, **108** of the repair sleeve **102** to block pipe fluid in the leak flow path from flowing to an external atmosphere outside of the termination enclosures **104**, **106**. In other words, the first outer seal **140** and the first inner seal **142** seal with the pipe outer wall **14** and the outer surface of the repair sleeve **102**, respectively, to block pipe fluid from exiting from the first enclosure cavity **152**, and the second outer seal **170** and the second inner seal **172** seal with the pipe outer wall **14** and the outer surface of the repair sleeve **102**, respectively, to block pipe fluid from exiting from the second enclosure cavity **182**.

[0049] In operation, a pipe replacement method **1100** may be performed for repairing a pipe containing a pipe fluid. A pipe defect may be identified in a repair section of the pipe. The pipe defect may be a through-wall defect. In some embodiments, the pipe defect may be determined based on the condition of the pipe. For example, wall thickness of the pipe may be one factor in a determination that there might be a hole during the intended life of the repair of the pipe.

[0050] A wrap is wrapped around the repair section of the pipe to form a repair sleeve having a first termination section and a second termination section [block **1102**]. The repair sleeve may cover a pipe defect, such as a through-hole defect in the pipe wall. The repair sleeve may have an adhesive configured to bond the repair sleeve to the pipe outer surface. Wrapping the wrap around the pipe outer surface includes bonding the repair sleeve to the pipe outer surface with the adhesive.

[0051] In some embodiments, the first termination section of the repair sleeve may be abrasively cleaned to form a first outer diameter for the first termination section. The repair sleeve may be abrasively cleaned using hand tools or other abrasive techniques. The first termination section may be abrasively cleaned to configure an outer diameter for the first termination section to conform to an inner diameter of the first inner seal of the first termination enclosure so that the first inner seal forms a seal on the abrasively cleaned first termination section. In some embodiments, the second termination section may be abrasively cleaned to

adjust a second outer diameter of the second termination section. The second termination section may be abrasively cleaned to configure an outer diameter of the second termination section to conform to an inner diameter of the second inner seal of the second termination enclosure so that the second inner seal forms a seal on the abrasively cleaned second termination section.

**[0052]** A first termination enclosure is enclosed over the first termination section to form a first pressure containing connection with the repair sleeve. Enclosing the first termination section includes disposing a first outer seal around the pipe on a pipe outer surface where the first outer seal is outwardly spaced from the first termination section to annularly seal on the pipe outer surface. Enclosing the first termination section further includes disposing a first inner seal around the repair sleeve on a repair sleeve outer surface where the first inner seal is inwardly spaced from the first outer seal to annularly seal on the repair sleeve outer surface [block 1104]. The first termination is enclosed over the repair section of the pipe by connecting the first upper half of the first termination enclosure with the first lower half of the first termination enclosure.

**[0053]** A second termination enclosure encloses over the second termination section to form a second pressure containing connection with the repair sleeve. Enclosing the second termination section includes disposing a second outer seal around the pipe on the pipe outer surface where the second outer seal is outwardly spaced from the second termination section to annularly seal on the pipe outer surface. Enclosing the second termination section further includes disposing a second inner seal around the repair sleeve on a repair sleeve outer surface where the second inner seal inwardly spaced from the second outer seal to annularly seal on the repair sleeve outer surface [block 1106].

**[0054]** The repair sleeve is configurable in a leak path configuration where the repair sleeve forms a leak flow path from a pipe leak section covered by the repair sleeve to the first termination enclosure or the second termination enclosure and the leak flow path is configured to be sealed from an external atmosphere by the first termination enclosure and the second termination enclosure. In some embodiments, the repair sleeve has an adhesive configured to bond the repair sleeve to the pipe outer surface. The repair sleeve, in some embodiments, is configurable in a non-leak path configuration where the repair sleeve is bonded to the pipe

outer surface to block pipe fluid flow from a pipe defect section covered by the repair sleeve from flowing to either the first termination enclosure or the second termination enclosure.

[0055] Embodiments of the present disclosure provide the benefits such as, but not limited to, the following: (a) allowing the repair sleeve to perform at higher pressure in comparison to repairs designed to the industry and governmental standards, such as standards described in ISO 24817 and ASME PCC-2 Article 401; (b) removes the need for surface preparation on the original pipe before wrapping a wrap over the pipe to form the repair sleeve; and (c) allows the repair sleeve thickness to be reduced.

[0056] For example, embodiments of the pipe repair system assembled on a pipe may have a repair sleeve that moves from a non-leak path configuration to a leak path configuration when the bond between the repair sleeve and the pipe outer surface fails. Because the leak path configuration typically can handle higher fluid pressures compared to the non-leak path configuration, a failure of the adhesive bond will not necessarily result in fluid leak to the atmosphere. In contrast, composite repairs not using termination enclosures may have to be designed with thicker walls or may not be suitable for repairing pipes containing fluids at higher fluid pressures. Embodiments of the pipe replacement system may have repair sleeves having thicknesses configured for Type A Defects according to industry or governmental standards (no through-hole defect or expected through-hole defect during the intended life of the repair) when the repair sleeve will be used for a pipe having a Type B defect (through-hole defect or expected through-hole defect during the intended life of the repair).

[0057] The pressure capability of a composite repair may be governed by the adhesive, such as a resin, bonding the composite repair to the pipe. Composite repairs, without use of embodiments of the termination enclosures, may be limited for pipes having a through-hole defect or perforation – performance is typically an order of magnitude lower than when the composite repair simply has to provide structural reinforcement where there is no perforation and where the pipe is identified as a pipe that will not have a perforation during the life of the pipe. A composite repair, without use of embodiments of the termination enclosures, has a capability that relies on the repair bonding strongly to the pipe (specifically, achieving a high bond toughness rather than strength) and this is governed by the quality of surface preparation completed, such as abrasive techniques. Abrasive techniques include abrasively cleaning the pipe outer surface using grit blasting or other abrasive cleaning using hand tools. The pipe

replacement system in accordance with embodiments of the present disclosure reduces or eliminates the requirement of abrasively cleaning the pipe outer surface before forming the repair sleeve on the pipe.

**[0058]** Although a few embodiments of the disclosure have been described in detail above, those of ordinary skill in the art will readily appreciate that many modifications are possible without materially departing from the teachings of this disclosure. Accordingly, such modifications are intended to be included within the scope of this disclosure as defined in the claims. The scope of the invention should be determined only by the language of the claims that follow. The term "comprising" within the claims is intended to mean "including at least" such that the recited listing of elements in a claim are an open group. The terms "a," "an" and other singular terms are intended to include the plural forms thereof unless specifically excluded. In the claims, means-plus-function clauses are intended to cover the structures described herein as performing the recited function and not only structural equivalents, but also equivalent structures. It is the express intention of the applicant not to invoke 35 U.S.C. § 112, paragraph 6 for any limitations of any of the claims herein, except for those in which the claim expressly uses the words "means for" together with an associated function.

### **CLAIMS**

What is claimed is:

1. A pipe replacement system for repairing a pipe, comprising:
  - a wrap wrapped around a pipe outer surface to form a repair sleeve having a first termination section and a second termination section; and
  - a first termination enclosure enclosing the first termination section to form a first pressure containing connection with the repair sleeve, the first termination enclosure including:
    - a first outer seal disposed around the pipe on a pipe outer surface, the first outer seal outwardly spaced from the first termination section to annularly seal on the pipe outer surface; and
    - a first inner seal disposed around the repair sleeve on a repair sleeve outer surface, the first inner seal inwardly spaced from the first outer seal to annularly seal on the repair sleeve outer surface.
2. The pipe replacement system of claim 1, wherein the first termination enclosure further includes a first upper half and a first lower half configured to be connected to form the first termination enclosure.
3. The pipe replacement system of claim 2, wherein the first termination enclosure forms a first cavity containing the first termination section where the cavity is pressure sealed by the first outer seal and the first inner seal to seal a pipe leak having a leak flow path from under the first termination section to the first cavity.
4. The pipe replacement system of claim 1, wherein the first outer seal has a first seal diameter and the first inner seal has a second seal diameter where the first seal diameter is less than the second seal diameter and wherein the wrap is made of a composite material.
5. The pipe replacement system of claim 1, wherein the repair sleeve is configurable in a leak path configuration where the repair sleeve forms a leak flow path extending from a pipe defect covered by the repair sleeve to the first termination enclosure and sealed from an external atmosphere by the first termination enclosure.
6. The pipe replacement system of claim 5, wherein the repair sleeve has an adhesive configured to bond the repair sleeve to the pipe outer surface, wherein the repair sleeve is configurable in a non-leak path configuration where the repair sleeve blocks pipe fluid flow from a pipe defect section covered by the repair sleeve from flowing to the first termination enclosure and to seal the pipe defect from the external atmosphere with the repair sleeve, and

wherein the repair sleeve is configured to move from the non-leak path configuration to the leak path configuration.

7. The pipe replacement system of claim 1, further comprising:

- a first ring restraint disposed around the pipe and spaced outwardly from the first termination enclosure, the first ring restraint including a first restraint upper half connected to a first restraint lower half to connect the first ring restraint to the pipe; and

- a first restraint bolt connected between the first ring restraint and the first termination enclosure to secure the first termination enclosure in a first axial position on the pipe;

8. The pipe replacement system of claim 1, further comprising:

- a second termination enclosure enclosing the second termination section to form a second pressure containing connection with the repair sleeve, the second termination enclosure including:

- a second outer seal disposed around the pipe on the pipe outer surface, the second outer seal outwardly spaced from the second termination section to annularly seal on the pipe outer surface; and

- a second inner seal disposed around the repair sleeve on the repair sleeve outer surface, the second inner seal inwardly spaced from the second outer seal to annularly seal on the repair sleeve outer surface.

9. The pipe replacement system of claim 8, wherein the first termination enclosure is axially spaced from the second termination enclosure.

10. A pipe replacement method for repairing a pipe, the method comprising:

- wrapping a wrap around the pipe to form a repair sleeve having a first termination section and a second termination section;

- enclosing a first termination enclosure over the first termination section to form a first pressure containing connection with the repair sleeve, the enclosing the first termination enclosure over the first termination section including:

- disposing a first outer seal around the pipe on a pipe outer surface, the first outer seal outwardly spaced from the first termination section to annularly seal on the pipe outer surface; and

- disposing a first inner seal around the repair sleeve on a repair sleeve outer surface, the first inner seal inwardly spaced from the first outer seal to annularly seal on the repair sleeve outer surface.

11. The method of claim 10, wherein the wrap is wrapped around a pipe in an online condition where pipe has fluid pressure and the repair sleeve is formed on the pipe with the pipe in the online condition.
12. The method of claim 10, further comprising identifying a pipe defect in the pipe based on the condition of the pipe, and wherein the repair sleeve covers the pipe defect and a pipe repair section.
13. The method of claim 12, wherein the pipe defect is a through-wall defect in the pipe repair section.
14. The method of claim 10, wherein the repair sleeve has an adhesive configured to bond the repair sleeve to the pipe outer surface.
15. The method of claim 10, wherein wrapping the wrap around the pipe outer surface includes bonding the repair sleeve to the pipe outer surface with the adhesive.
16. The method of claim 10, further comprising:
  - abrasively cleaning the first termination section to form a first outer diameter for the first termination section, and wherein the first inner seal forms a seal on the abrasively cleaned first termination section.
17. The method of claim 10, wherein the repair sleeve is configurable in a leak path configuration where the repair sleeve forms a leak flow path from a pipe leak section covered by the repair sleeve to the first termination enclosure and the leak flow path is sealed from an external atmosphere by the first termination enclosure, and wherein the repair sleeve has an adhesive configured to bond the repair sleeve to the pipe outer surface and the repair sleeve is configurable in a non-leak path configuration where the repair sleeve is bonded to the pipe outer surface to block pipe fluid flow from a pipe defect section covered by the repair sleeve from flowing to the first termination enclosure and the second termination enclosure.
18. The method of claim 10, further comprising:
  - enclosing a second termination enclosure over the second termination section to form a second pressure containing connection with the repair sleeve, the second termination enclosure including:
    - disposing a second outer seal around the pipe on the pipe outer surface, the second outer seal outwardly spaced from the second termination section to annularly seal on the pipe outer surface; and

disposing a second inner seal around the repair sleeve on a repair sleeve outer surface, the second inner seal inwardly spaced from the second outer seal to annularly seal on the repair sleeve outer surface.

19. A pipe replacement method for repairing a pipe, the method comprising:

wrapping a fiber wrap around the repair section of the pipe to form a repair sleeve having a first termination section and a second termination section;

enclosing a first termination enclosure over the first termination section to form a first pressure containing connection with the repair sleeve, the enclosing the first termination enclosure over the first termination section including:

disposing a first outer seal around the pipe on a pipe outer surface, the first outer seal outwardly spaced from the first termination section to annularly seal on the pipe outer surface; and

disposing a first inner seal around the repair sleeve on a repair sleeve outer surface, the first inner seal inwardly spaced from the first outer seal to annularly seal on the repair sleeve outer surface;

enclosing a second termination enclosure over the second termination section to form a second pressure containing connection with the repair sleeve, the second termination enclosure including:

disposing a second outer seal around the pipe on the pipe outer surface, the second outer seal outwardly spaced from the second termination section to annularly seal on the pipe outer surface; and

disposing a second inner seal around the repair sleeve on a repair sleeve outer surface, the second inner seal inwardly spaced from the second outer seal to annularly seal on the repair sleeve outer surface; and

wherein the repair sleeve is configurable in a leak path configuration where the repair sleeve forms a leak flow path extending from a pipe defect covered by the repair sleeve to the first termination enclosure and the second termination enclosure with the leak flow path sealed from an external atmosphere by the first termination enclosure and the second termination enclosure.

20. The method of claim 19, wherein the repair sleeve has an adhesive configured to bond the repair sleeve to the pipe outer surface, and wherein the repair sleeve is configurable in a non-leak path configuration where the repair sleeve blocks pipe fluid flow from a pipe defect section covered by the repair sleeve from flowing to the first termination enclosure and the second

termination enclosure to seal the pipe defect from the external atmosphere with the repair sleeve, and wherein the repair sleeve is configured to move from the non-leak path configuration to the leak path configuration.