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Adjustable molding system for forming material on pipe

Abstract

A molding system for applying insulation to a pipe employs an elongate mold in which to receive the pipe. A mold adjustment mechanism can adjust a shape of the mold to correspond to a shape of the pipe as the pipe sags in the mold cavity. In a method of insulating the pipe, the shape of the mold is adjusted to correspond to the shape of the sagging pipe and curable material is imparted into the mold while maintaining the adjusted shape of the mold. The elongate mold can include at least one double-walled mold member with an inner form wall, an outer jacket, and a plurality of radial supports that support the outer jacket on the inner form wall in radially spaced apart relation therewith.

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References Cited

U.S. PATENT DOCUMENTS

Patent No.	Issued Date	Patentee Name	U.S. Cl.	CPC
6644905	12/2002	Peterson	198/317	A01D 46/26
10316993	12/2018	Mueller et al.	N/A	N/A
2013/0129570	12/2012	Jung	422/119	B01J 8/1809
2017/0355112	12/2016	Perkins	N/A	B29C 45/14073
2017/0355114	12/2016	Perkins	N/A	B29C 45/80

FOREIGN PATENT DOCUMENTS

Patent No.	Application Date	Country	CPC
203858162	12/2013	CN	N/A
205192869	12/2015	CN	N/A
104502089	12/2016	CN	N/A
106113474	12/2017	CN	N/A
207197911	12/2017	CN	N/A
106500900	12/2017	CN	N/A
109848329	12/2018	CN	N/A
208936940	12/2018	CN	N/A
106840913	12/2018	CN	N/A
107610926	12/2018	CN	N/A
110961497	12/2019	CN	N/A

OTHER PUBLICATIONS

Meiwes, Karl et al., Full-Scale Reeling Tests of HFI Welded Pipe for Offshore Reel-Laying Installation, Proceedings of the 2014 10th International Pipeline Conference, Sep. 29-Oct. 3, 2014, 7 pages, Calgary, Alberta, Canada. cited by applicant

Flexure Test of Insulation Materials—Four Point Blend, Testresources.com, Jun. 30, 2020, 7 pages. cited by applicant

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION (1) This application claims priority to U.S. Provisional Patent Application No. 63/132,698, filed Dec. 31, 2021, which is hereby incorporated by reference in its entirety for all purposes.

FIELD

(1) This invention generally pertains to a molding system for applying insulation to the exterior of long lengths of pipe. Such insulated pipes are used, for example, in oil and gas exploration and extraction.

BACKGROUND

(2) As explained in U.S. Patent Application Publication No. 2017/0355112, which is hereby incorporated by reference in its entirety, it is desirable to form individual insulated pipes for the oil and gas industry in very long lengths, for example, such that each individual insulated pipe has a length in excess of 35 feet, e.g., a length of 40 feet or more.

(3) As shown in FIG. **1**, a known challenge in the field of molding systems for applying pipe insulation to long lengths of pipe is that the middle portion of a pipe P will sag within a mold M. If only the ends of the pipe P are held in place, the middle portion will sag under its own weight. The most common pipe sizes for the deep water oil production industry (a possible end user of long insulated pipes) are 6.625, 8.625, 10.750, and 12.750 inch OD. Pipe wall thickness typically ranges from 0.750 inches to 2 inches. The vertical sag of the middle portion of these types of steel pipes ranges from 0.4 to 3 inches for a 40-foot pipe simply supported at its ends. Greater pipe wall thicknesses, due to an increase in linear weight, increases sag for a given pipe diameter. Thus, pipes of the same length can sag by different amounts. Sagging of the pipe causes a loss of concentricity of the pipe and the mold. If not compensated for, sagging would cause significant variance in insulation thickness along the pipe, and in some instances, of portions of the pipe could be bare of insulation.

(4) As shown in FIG. **2**, the conventional remedy for sagging of the pipe is to place supports S along the length of the mold M to prop the middle portion of the pipe P up within the mold and prevent it from sagging. But regardless of how these supports S are deployed, the use of the supports will inherently introduce discontinuity into the insulation material, requiring insulation to be added later to fill the voids left by the intermediate supports S. However, the later applied insulation is still a discontinuity and creates an eventual source for material failure. That is, the insulation material that fills the space where the pipe P was supported by a peg S or the like during molding will be stressed differently than the remainder of the insulation material, and the boundaries between the differently stressed materials will form weak points where the insulation will eventually fail.

SUMMARY

(5) In one aspect, a molding system for applying insulation to a pipe comprises an elongate mold having a length along a longitudinal axis extending from a first end portion to a second end portion. The elongate mold defines a mold cavity in which to receive the pipe such that the pipe is supported at the first end portion and the second end portion of the elongate mold and is allowed to sag in the mold cavity between the first end portion and the second end portion of the elongate mold. A mold adjustment mechanism is configured to adjust a shape of the mold to correspond to a shape of the pipe as the pipe sags in the mold cavity.

(6) In another aspect, a method of insulating the pipe comprises positioning the pipe in a mold cavity of an elongate mold such that the pipe is supported at a first end portion and a second end portion of the elongate mold and sags in the mold cavity between the first end portion and the second end portion of the elongate mold. A shape of the elongate mold is adjusted to correspond to a shape of the pipe as the pipe sags in the mold cavity. Curable material is imparted into the elongate mold while maintaining the shape of the elongate mold to correspond to the shape of the pipe as the pipe sags in the mold cavity.

(7) In another aspect, a molding system for applying insulation to a pipe comprises an elongate mold having a length along a longitudinal axis extending from a first end portion to a second end portion. The elongate mold defines a mold cavity in which to receive the pipe such that the pipe is supported at the first end portion and the second end portion of the elongate mold. The elongate mold comprises at least one double-walled elongate mold member extending along the length of the elongate mold and defining at least a portion of the mold cavity. The double-walled elongate mold member comprises an inner form wall and an outer jacket wall spaced apart radially outward of the inner form wall with respect to the longitudinal axis such that the inner form wall and the outer jacket wall define a fluid annulus section therebetween. The outer jacket wall is supported on the inner form wall in radially spaced apart relation therewith without internal bulkheads in the fluid annulus section.
(8) In another aspect, a molding system for applying insulation to a pipe comprises an elongate mold having a length along a longitudinal axis extending from a first end portion to a second end portion. The elongate mold defines a mold cavity in which to receive the pipe such that the pipe is supported at the first end portion and the second end portion of the elongate mold. The elongate mold comprises at least one double-walled elongate mold member extending along the length of the elongate mold and defining at least a portion of the mold cavity. The double-walled elongate mold member comprises an inner form wall having a perimeter edge margin. An outer jacket wall has a perimeter edge margin. The outer jacket wall is spaced apart radially outward of the inner form wall with respect to the longitudinal axis such that the inner form wall and the outer jacket wall define a fluid annulus section therebetween. A seal is sealingly engaged with the perimeter edge margin of the inner form wall and the perimeter edge margin of the outer jacket wall to seal the fluid annulus section. A plurality of radial supports at spaced apart locations along the length of the mold each have an inner end region and an outer end region spaced apart along a respective support axis. Each support axis extends generally radially with respect to the longitudinal axis. The inner end region of each radial support is joined to the inner form wall, and the outer end region of the radial support is joined to the outer jacket wall whereby the radial supports support the inner form wall and the outer jacket wall in radially spaced apart relation. Each of the plurality of radial supports is spaced apart from the seal such that the fluid annulus section extends 360° about each radial support with respect to the respective support axis.
(9) In another aspect, a molding system for applying insulation to a pipe comprises an elongate mold having a length along a longitudinal axis extending from a first end portion to a second end portion. The elongate mold defines a mold cavity in which to receive the pipe such that the pipe is supported at the first end portion and the second end portion of the elongate mold. The elongate mold comprises at least one double-walled elongate mold member extending along the length of the elongate mold and defining at least a portion of the mold cavity. The double-walled elongate mold member comprises an inner form wall and an outer jacket wall spaced apart radially outward of the inner form wall with respect to the longitudinal axis such that the inner form wall and the outer jacket wall define a fluid annulus section therebetween. The double-walled elongate mold further comprises a plurality of radial supports at spaced apart locations along the length of the mold. Each radial support has an inner end region and an outer end region spaced apart along a support axis extending generally radially with respect to the longitudinal axis. Each radial support comprises an annular component with an interior portion extending circumferentially about the support axis and an exterior portion extending circumferentially about the support axis. Each radial support is joined to the inner form wall at the inner end region along the interior portion and being joined to the outer jacket wall at the outer end region along the exterior portion.
(10) In another aspect, a molding system for applying insulation to a pipe comprises an elongate mold having a length along a longitudinal axis extending from a first end portion to a second end portion. The elongate mold defines a mold cavity in which to receive the pipe such that the pipe is supported at the first end portion and the second end portion of the elongate mold. The elongate

mold comprises at least one double-walled elongate mold member extending along the length of the elongate mold and defining at least a portion of the mold cavity. The double-walled elongate mold member comprises an inner form wall and an outer jacket wall spaced apart radially outward of the inner form wall with respect to the longitudinal axis such that the inner form wall and the outer jacket wall define a fluid annulus section therebetween. The outer jacket wall is supported on the inner form wall such that the annulus section has a radial thickness with respect to the longitudinal axis of less than 1.0 inches.
(11) In another aspect, a method of making an elongate mold member of an elongate mold configured to define a mold cavity in which to receive the pipe for applying insulation material to the perimeter of the pipe comprises forming an inner form wall. An outer jacket wall member is supported on the inner form wall member such that the outer jacket wall member is radially spaced apart from the inner form wall with respect to a longitudinal axis of the elongate mold and the inner form wall and the outer jacket wall define a fluid annulus section therebetween. Each of a plurality of radial supports is placed into spaced apart openings formed in the outer jacket wall. Each of the radial supports is joined to each of the inner form wall and the outer jacket wall.
(12) Other aspects and features will be apparent hereinafter.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) FIG. **1** is a longitudinal cross section of an elongate mold for applying insulation to a pipe of the prior art, in which the pipe is simply supported at its end portions inside the elongate mold and allowed to sag at its middle;
(2) FIG. **2** is a longitudinal cross section of another elongate mold for applying insulation to a pipe of the prior art, in which the pipe is supported at its end portions inside the mold and is braced against sagging by a centralizing peg at a middle portion of the pipe;
(3) FIG. **3** is a longitudinal cross section of an elongate mold in accordance with the present disclosure, in which a pipe is simply supported at its end portions inside the elongate mold and the elongate mold is adjusted to correspond to a shape of the pipe as it sags within the mold;
(4) FIG. **4** is a perspective of a molding system that includes the elongate mold of FIG. **3** in an open position;
(5) FIG. **5** is an end elevation of the molding system;
(6) FIG. **6** is an exploded perspective of a base and a mold adjustment mechanism of the molding system;
(7) FIG. **7** is an enlarged fragmentary perspective of an end portion of a longitudinal section of the base;
(8) FIG. **8** is a perspective of the base and the mold adjustment mechanism;
(9) FIG. **9** is an enlarged view of the portion of FIG. **8** at the callout for FIG. **9**;
(10) FIG. **10** is an elevation of the base and the mold adjustment mechanism;
(11) FIG. **11** is an enlarged view of the portion of FIG. **10** at the callout for FIG. **11**;
(12) FIG. **12** is an enlarged view of the portion of FIG. **10** at the callout for FIG. **12**;
(13) FIG. **13** is a perspective of a base mold member showing how a fixture plate attaches to the elongate mold;
(14) FIG. **14** is a perspective of an elongate mold of the molding system;
(15) FIG. **15** is an exploded perspective of a double-walled base member of the elongate mold of FIG. **14**;
(16) FIG. **16** is a perspective of a radial support of the double-walled base member;
(17) FIG. **17** is a top plan view of the radial support; and
(18) FIG. **18** is a cross section of the radial support.

(19) Corresponding reference characters indicate corresponding parts throughout the drawings.

DETAILED DESCRIPTION

(20) The inventors have recognized that an advantageous way of addressing the natural tendency of a pipe to sag under its own weight is to adjust the shape of the mold to correspond to the shape of the pipe. FIG. **3** illustrates one example of an elongate mold **16** having a curved (broadly, contoured) shape that matches the curved shape of the sagging pipe P. Comparing FIGS. **1** and **3**, the illustrated pipe P sags within the molds M, **16** by the same amount. But in the prior art mold M of FIG. **1**, the middle longitudinal portion of the pipe is located much closer to the bottom of the mold than the top, causing the annular mold cavity about the middle portion of the pipe P to have different radial dimensions at different circumferential locations. By contrast, the contoured mold **16** of FIG. **3**, because its shape corresponds to the curvature of the pipe P, substantially centers the mold within the pipe along the entire length of the pipe so that the thickness of the applied insulation will be generally uniform.

(21) One conceivable approach to matching the mold shape to that of a sagging pipe would be to support an elongate mold in the same manner as the pipe—i.e., only at the longitudinal end portions of the mold—so that only the middle portion of the mold sags just as the middle portion of the pipe sags. Similarly, a mold could be rigidly constructed to have a fixed curvature that matches the known curvature of a particular type of pipe when it sags. However, the inventors have recognized that it is desirable for a molding system to accommodate many different types of pipes, and each different pipe will sag a different amount. Accordingly, the inventors have recognized a need for a molding system comprising an elongate mold having a shape that can be dynamically adjusted to correspond to the shape of a sagging pipe supported in the mold.

(22) Referring now to FIGS. **4** and **5**, an exemplary embodiment of a molding system encompassed within the scope of this disclosure is generally indicated at reference number **10**. The molding system **10** generally comprises an elongate base **12** and an elongate mold **16**, each having a first end portion and a second end portion spaced apart along a longitudinal axis LA. In general, the elongate mold has the same basic configuration has the pipe mold discussed in U.S. Patent Application Publication No. 2017/0355112, previously incorporated in this disclosure. Hence, the illustrated mold **16** comprises a longitudinal base mold member **17** and first and second longitudinal lid mold members **18** that are movably connected to the longitudinal base mold member for opening and closing the mold. As explained more fully below, the longitudinal base mold member **17** is mounted on the molding system base **12** so that a mold adjustment mechanism **20** (FIGS. **6** and **8-12**) can adjust the shape of the elongate mold **16**. A set of mold opening/closing actuators **22** (e.g., linear actuators such as hydraulic cylinders) are located along each lateral side of the base **12** and are connected between the base and a respective one of the longitudinal lid mold members **18** for moving the respective lid mold member between the opened and closed position. In the illustrated embodiment, the elongate mold **16** is formed from two elongate mold sections **16**A, **16**B that are joined together end-to-end to form the mold. In an exemplary embodiment each mold section **16**A, **16**B has a respective length that fits within a standard-sized shipping container (e.g., a length of about 22 feet), to allow for the mold to be portable or shippable. Suitably, the mold sections **16**A, **16**B come together to form an elongate mold **16** of at least about 35 feet in length (e.g., an elongate mold of 40 feet or greater in length). It is envisioned that more than two mold sections **16**A, **16**B could be assembled together end-to-end to form elongate molds of greater lengths. It is contemplated that the mold **16** will be used with a portable molding system as disclosed in U.S. patent application Ser. No. 17/505,191, filed Oct. 19, 2021, which is hereby incorporated by reference in its entirety. It is further contemplated that the mold **16** can be used to form multi-layer pipe insulations as taught by U.S. patent application Ser. No. 17/457,476, filed Dec. 3, 2021, which is hereby incorporated by reference in its entirety.

(23) In an exemplary embodiment, the elongate mold **16** is a double-walled mold which provides a fluid annulus around the exterior of the mold cavity for receiving a heat transfer fluid (e.g., water)

used, for example, to cool the contents of the mold. In a conventional double-walled mold of the three-part type disclosed in U.S. Patent Application Publication No. 2017/0355112, each of the base mold member and the lid mold members includes an inner form wall and an outer jacket wall spaced apart from the inner form wall by a radial distance of from about 1.0 inches to about 1.5 inches to define an annulus section between the inner form wall and the outer jacket wall. Flanges are disposed around the perimeter of the inner form wall and outer jacket wall to seal the perimeter of the annulus section. A plurality of bulkheads at spaced apart locations along the length of the mold member extend radially between the inner form wall and the outer jacket wall. The inventors have recognized that the conventional buildup of double-walled mold members (e.g., base and lid members) produces rigid parts that resist bending. Accordingly, the inventors have developed the double-walled elongate mold **16**, shown in greater detail in FIGS. **14-15**, to facilitate bending the mold using the mold adjustment mechanism **20** while still providing the heat transfer benefits of a double-walled mold.

(24) FIG. **14** depicts an elongate mold **16** comprising a double-walled base mold member **17** and a pair of double-walled lid mold members **18**, as explained above. FIG. **15** provides an exploded view which illustrates how the double-walled base mold member **17** is constructed. In general, the base mold member **17** comprises an inner mold form wall **101**, an outer jacket wall **103**, a perimeter seal flange **105** (broadly, a perimeter seal), and a plurality of radial supports **107**. In the elongate mold **16** depicted in FIG. **14**, each of the lid mold members is likewise constructed of an inner mold form wall, an outer jacket wall, a perimeter seal flange, and a plurality of radial supports. Comparing the illustrated base mold member **17** and each of the illustrated lid mold members **18**, the only significant difference in construction is driven by the size, shape, and arrangement of the respective mold members. Accordingly, it is to be understood that the lid mold members **18** are constructed from respective inner mold form walls **101**, outer jacket walls **103**, perimeter seal flanges **105**, and radial supports **107** in substantially the same way as described below in regard to the base mold member **17**.

(25) Referring to FIG. **15**, the inner form wall **101** is configured to define a portion of the perimeter of the mold cavity of the elongate mold **16**. The outer jacket wall **103** is spaced apart radially outward of the inner form wall **101** with respect to the longitudinal axis of the elongate mold **16** such that the inner form wall and the outer jacket wall define a fluid annulus section therebetween. (The annulus sections located between the inner form wall and outer jacket wall of the base mold member **17** and each of the lid mold members **18** collectively form the fluid annulus of the elongate mold **16**). To reduce the bending moment of the elongate mold **16**, the outer jacket wall **103** is mounted relatively close to the inner form wall **101**, which minimizes the radial thickness of the annulus section with respect to the longitudinal axis of the mold **16**. However, a sufficient radial space is still provided to allow fluid flow (e.g., predominantly laminar fluid flow) through the annulus section. In one or more embodiments, the radial thickness of the annulus section is less than about 1.0 inch, e.g., less than 0.5 inch, and the radial thickness can be about 0.375 inch. In certain embodiments, the radial thickness of the annulus section with respect to the longitudinal axis of the mold is greater than 0.25 inches.

(26) In the illustrated embodiment, each of the inner form wall **101** and the outer jacket wall **103** is formed from a single contiguous piece of sheet metal that is roll-formed to have an arcuate shape. The arcuate inner form wall **101** has a radius of curvature that is less than the radius of curvature of the arcuate jacket wall **103**. In one or more embodiments, the inner and outer surfaces of one or both of the inner form wall **103** and the outer jacket wall **103** are substantially smooth, for example, substantially free of integral protrusions or dimples.

(27) In the illustrated embodiment the outer jacket wall **103** is pre-formed to have a plurality of holes **109** at spaced apart locations along its length. The holes **109** are sized and arranged so that radial supports **107** can extend through the holes into engagement with the inner form wall **101**. In the illustrated embodiment, the outer jacket wall **103** comprises two rows of longitudinally spaced

holes **109**, and the two rows are circumferentially spaced with respect to the longitudinal axis LA of the mold **16**.

(28) Each of the inner form wall **101** and the outer jacket wall **103** comprises a respective perimeter edge margin. When the mold member **17** is assembled, the flange seal **105** extends around the perimeter edge margin of each of the inner form wall **101** and the outer jacket wall **103**. The flange seal **105** extends radially from the inner form wall **101** to the outer jacket wall **103** to enclose the perimeter of the annulus section located between the form wall and the jacket wall. In the illustrated embodiment, the flange seal **105** is seal welded (broadly, sealingly engaged with) the perimeter edge margin of the inner form wall **101** and the perimeter edge margin of the outer jacket wall **103** about the entire perimeters thereof to seal the annulus section.

(29) The radial supports **107** are connected to the double-walled mold member **117** at spaced apart locations along the length of the mold **16**. The radial supports **107** align with the holes **109** in the outer jacket **103**. Thus, In the illustrated embodiment, the mold member **17** comprises two rows of longitudinally spaced supports **107**, and the two rows are circumferentially spaced with respect to the longitudinal axis of the mold **16**. Each radial support **107** has an inner end region and an outer end region spaced apart along a respective support axis SA (FIGS. **17** and **18**). Each support axis SA extends generally radially with respect to the longitudinal axis of the elongate mold **16**. The inner end region of each radial support **107** is seal welded (broadly, joined) to the inner form wall **101**, and the outer end region of each radial support is seal welded (broadly, joined) to the outer jacket wall **103**. The radial supports **107** thereby support the inner form wall **101** and the outer jacket wall **103** in radially spaced apart relation. Unlike the internal gussets of prior art double-wall molds, which extend edge-to-edge in the annulus section and connect to the flange seal, the radial supports **107** are spaced apart from the flange seals **105** such that the fluid annulus section extends 360 degrees about each radial support with respect to the respective support axis SA. The relatively small radial supports **107** do not substantially increase the rigidity or bending moment of the mold member **17**. Further, the radial supports **107** facilitate manufacture of the mold member **17** to have an annulus section radial thickness of less than about 1.0 inch, which is not possible using known conventional manufacturing methods which place internal bulkheads inside the annulus section. Thus, in the illustrated embodiment, the relatively small radial supports **107** provide radial support to the inner form wall **101** to prevent the inner form wall from collapsing due to excess pressure in the annulus section. Moreover, the radial supports **107** prevent collapse of the inner form wall **101** without substantially increasing the rigidity or bending moment of the elongate mold member **117**.

(30) Referring to FIGS. **16-18**, in the illustrated embodiment, each radial support **107** comprises a separate annular component with an interior portion defining an inner perimeter that extends circumferentially about the support axis SA and an exterior portion defining an outer perimeter that likewise extends circumferentially about the support axis. In an exemplary embodiment, the inner perimeter of the radial support **107** is conical, for example, having an inner cross-sectional dimension that decreases along the support axis from adjacent the outer end region of the support toward the inner end region. Each radial support **107** is joined to the inner form wall **101** by a seal weld at the inner end region along the inner perimeter of the support. Further, each radial support **107** is joined to the outer jacket wall **103** by a seal weld at the outer end region along the outer perimeter.

(31) The annular radial supports **107** enable each double-walled elongate mold member **117** to be manufactured to have a relatively small radial dimension using equipment that is widely available at machine shops. In an exemplary method of manufacturing the double-walled elongate mold member **117**, the inner form wall **101** is rolled (broadly, formed) from a piece of sheet metal (e.g., sheet metal of less than 0.2 inches in thickness). Additionally, the outer jacket wall **103** is rolled (broadly, formed) from a piece of sheet metal (e.g., sheet metal of less than 0.2 inches in thickness), and the holes **109** are cut in the outer jacket wall at spaced apart locations along its length. In certain exemplary embodiments, the holes **109** have inner cross-sectional dimensions that are about

the same as the outer cross-sectional dimension of the radial supports **107**. The flange seals **105** are seal welded onto the perimeter edge margin of each of the inner form wall **101** and the outer jacket wall **103** to support the outer jacket wall on the inner form wall such that the outer jacket wall is radially spaced apart from the inner from wall with respect to the longitudinal axis of the elongate mold **16**. This positions the outer jacket wall **103** and the inner form wall **101** to define the fluid annulus section therebetween. Once the outer jacket wall **103** has been supported on the inner form wall **101**, a radial support **107** is placed into each of the openings **109**. For each radial support **107**, the manufacturer forms a seal weld between the inner end region of the radial support and the inner form wall **101**. This inner seal weld extends 360 degrees about the support axis SA along the inner perimeter of the radial support **107**. Further the manufacturer forms a seal weld between the outer end region of the radial support **107** and the outer jacket wall **103**. This outer seal weld extends 360 degrees about the support axis SA along the outer perimeter of the radial support **107**. The seal welded radial supports **107** thus seal the fluid annulus section from leaking fluid through the openings **109**. In the illustrated embodiment optional external gussets **111** are attached to the exterior of the outer jacket wall **103** at spaced apart locations along its length. The inventor believes that the external gussets **111** can be omitted to further reduce the rigidity and bending moment of the elongate mold **16**, if desired.
(32) The same basic sequence of steps can be performed to form each of the elongate lid members **18**, and then the double-walled lid members can be pivotably connected to opposite sides of the elongate base member **17** to form the mold **16**. At any point in time after the elongate base mold member **17** is formed, a plurality of mold coupling plates **52** can be attached to the base member **17** at spaced apart locations along its length. As will be explained in further detail below, mold coupling plates **52** facilitate operative connection of the mold **16** to the mold adjustment mechanism **20**.
(33) Although an exemplary embodiment of a double-walled mold **16** with relatively low resistance to bending has been described above, it will be understood that the mold adjustment mechanism **20** described in further detail below can be used with other types of elongate molds without departing from the scope of the disclosure. For instance, it is contemplated that the mold adjustment mechanism **20** can be operatively mounted on the base **12** for releasable and interchangeable attachment to various molds, including the mold **16**, via the mold coupling plates **52**. This allows for different molds to be used interchangeably with the same mold adjustment mechanism and base.
(34) Referring to FIGS. **6-12**, in an exemplary embodiment, the base **12** comprises an elongate beam that is very resistant to bending deflection (e.g., has great bending stiffness). In one or more embodiments, the base **12** can be configured for use in a partially freestanding configuration in which the base is fastened the floor only at its end portions (or not at all), with the middle portion of the base not being fastened to the floor. Hence, the base **12**, because of its inherent structural properties (e.g., beam moment of inertia, bending stiffness), is configured to deflect only minimally when the adjustment mechanism **20** imparts forces between the base and the elongate mold **16** to adjust the shape of the mold to correspond to the shape of a sagging pipe P. In one or more embodiments, the base **12** is configured to deflect less than the elongate mold **16** when the mold adjustment mechanism **20** moves a portion of the elongate mold relative to the base to adjust the shape of the mold.
(35) The illustrated base **12** has an I-beam shape including an upper flange portion **23**, a lower flange portion **24**, and a vertical web portion **26** extending between the lower flange portion to the upper flange portion. The lower flange portion **24** is wider than the upper flange portion **23** in the illustrated embodiment. The base further comprises first and second lip portions **28** extending upward from opposite lateral edge margins of the lower flange portion **24**. In the drawings, the lip portions **28** are only visible in FIGS. **4-7**; the lip portions are removed in FIGS. **8-12** for ease of visualizing other features of the molding system **10**. Each of the first and second lip portions **28** can

mount the lower end of one or more actuators for opening and closing the elongate mold **16**. However, in FIGS. **4** and **5**, another type of opening/closing actuator **22** is used which attaches to the mold **16** in a different way. Further, the lip portions **28** define cabling/hose channels on top of the lower flange portion **24** on each lateral side of the web portion **26**.

(36) To facilitate shipping the molding system **10** in standard shipping containers, the illustrated base **12** comprises first and second longitudinal base sections **12**A, **12**B (FIG. **6**) that are releasably attached end-to-end to form the full-length base. Each of the first longitudinal base section **12**A and the second longitudinal base section **12**B comprises an attachment flange **30** on a longitudinal end portion thereof. An exemplary embodiment of an attachment flange **30** is seen clearly in FIG. **7**. As shown in FIGS. **6** and **9**, the attachment flanges **30** are fastened together (e.g., via bolts or other removable fasteners) in face-to-face relationship to assemble the base. The attachment flanges **30** are designed to withstand the maximum force and moment imparted on the base **12** during operation of the adjustment mechanism **20**.

(37) In one or more embodiments, the base **12** can be equipped with several convenience features. For instance, the illustrated attachment flange **30** is shaped to permit the routing of hydraulic lines (broadly, control lines) and other wires or conduits. In addition, holes are formed in the vertical web portion **26** for lifting the base **12**, attaching various components of the adjustment mechanism **20**, routing hoses and wires, and providing maintenance access.

(38) The illustrated mold adjustment mechanism **20** generally comprises one or more linkages **40** that are connected between the base **12** and the elongate mold **16** and are movable to move a portion of the elongate mold relative to the base along an adjustment axis AA to adjust a curvature (broadly, shape) of the mold. In the illustrated embodiment, the adjustment mechanism **20** comprises a first linkage **40** on one lateral side of the base **12** and a second linkage (see FIG. **6**) that is substantially identical to the first linkage but mounts on the opposite lateral side of the base. In general, a suitable linkage **40** will comprise a coupling that is connected to a portion of the elongate mold for moving that portion of the mold along the adjustment axis LA with respect to the base.

(39) Various arrangements of linkages are contemplated to be within the scope of the present disclosure. However, the illustrated linkages **40** are generally configured to couple to the elongate mold **16** at a plurality of locations between the end portions of the elongate mold for pulling the middle portion of the mold downward with respect to the end portions of the mold and thereby adjusting the mold from a straight configuration to curved configuration in which the mold bows downward toward the middle to match the curvature of a sagging pipe P. It is also contemplated that other mechanisms or linkages could be used which primarily act to push the end portions of the mold upward with respect to the middle portion or which simultaneously push the end portions of the mold upward and pull the middle portion of the mold downward with respect to the base.

(40) Each individual linkage **40** is a multipoint linkage that couples to the elongate mold **16** at a plurality of spaced apart locations along the length of the elongate mold so that the individual linkage can adjust the shape of the mold along its length. In other words, the illustrated adjustment mechanism **20** does not use or require discrete mechanisms (e.g., individual hydraulic cylinders) for repositioning the mold at spaced apart locations along the length of the mold. Instead, the illustrated adjustment mechanism **20** is configured to use the constrained motion of individual linkages **40** to simultaneously adjust the positions of several portions of the mold **16** along the adjustment axis AA. The inventors believe that the use of a multipoint mechanical linkage **40** instead of separate actuators at spaced apart locations along the length of the mold is advantageous because it eliminates the possibility of a “zone malfunction.” Assume there were several separate hydraulic actuators acting in coordination to adjust the positions of different longitudinal zones of the mold. If one of the hydraulic actuators were to fail, it would cause the mold to deform in ways for which it was not designed, leading potentially to catastrophic failure. By contrast, the multipoint linkages **40** ensure that anytime the mold is adjusted, each attachment point between the mold **12** and the adjustment mechanism **20** is being simultaneously adjusted in way that is

consistent with the bending capabilities of the mold. If an actuator fails, the entire linkage stops moving, maintaining the mold in a non-destructive position until the actuator can be repaired. Although using multipoint linkages to adjust the shape of the mold may be preferable for the foregoing reasons, it is contemplated that an adjustable molding system could employ separate actuators at spaced apart locations along the length of the mold within the scope of this disclosure. In these embodiments, it is preferable to coordinate the control of the separate actuators so that, if one actuator were to fail, the failure is detected and the remaining actuators immediately stop moving the mold to mitigate against zone malfunctions.

(41) In an exemplary embodiment, the linkages **40** are relatively compact. Each illustrated linkage **40** is sized and arranged to fit entirely below the mold **16** along its full range of motion. Further linkages **40** are sufficiently compact (e.g., short in height) to enable safe and ergonomic preparation and filling from the top of the mold **16** during use. Each illustrated linkage **40** also fits entirely within a lateral space above the lower flange portion **24** of the base **12**, inboard of the respective lip **28**. This minimizes lateral space requirements and allows the mold opening/closing actuators **22** to mount on the base without interfering with the linkages **40**.

(42) In the illustrated embodiment, the base **12** includes a first base fixture plate **42** and a second base fixture plate **44** (each, broadly, a fixture) mounted on the first and second end portions of the base for mounting the first and second end portions of the elongate mold **16** on the base at fixed positions. The linkages **40** are both connected to a first base coupling plate **46** at a location spaced apart between the first fixture **42** and the second fixture **44**, a second base coupling plate **48** (broadly, a middle coupling plate) at a location spaced apart between the first base coupling plate and the second fixture, and a third base coupling plate **50** at a location spaced apart between the second base coupling plate and the second base fixture plate. Each base coupling plate **46**, **48**, **50** broadly comprises a coupling for attaching the linkages **40** to the mold **16** at a respective point along the length of the mold such that the linkages can drive movement of a corresponding section of the mold to adjust the mold shape.

(43) FIG. **13** shows one mold coupling plate **52** that is mounted on the base portion **17** of the mold **16** and configured to be releasably attached (e.g., via removable fasteners such as bolts) to a respective one of the base fixture plates **42**, **44** or the base coupling plates **46**, **48**, **50**. In the illustrated embodiment, it will be appreciated that the elongate mold **16** is fitted with five base fixture plates **52** at spaced apart locations along the length of the mold, one for attaching to each of the base fixture plates **42**, **44** and the base coupling plates **46**, **48**, **50**. Accordingly, the illustrated mold **16** comprises first and second mold coupling plates **52** that are configured to be fastened (e.g., bolted) to the first and second base fixture plates **42**, **44**, respectively, and three mold coupling plates **52** that are configured to be attached to each of the base coupling plates **46**, **48**, **50**. Each mold coupling plate **52** is fastened to the respective base coupling plate **46**, **48**, **50** such that the mold coupling plate moves conjointly with the base coupling plate along the adjustment axis AA with respect to the base **12**. Further, each mold coupling plate **52** is configured to cause the nearest longitudinal section or zone of the mold **16** to move substantially conjointly with the respective base coupling plate **46**, **48**, **50** along the adjustment axis AA. It can be seen that elongate molds of various configurations could be fitted with a set of mold coupling plates for selectively and operatively connecting the base **12** and the mold adjustment mechanism **20** to a mold of a desired configuration or type.

(44) Each linkage **40** comprises first, second, and, third base-mounted rockers **66**, **68**, **70** that are pivotably connected to the base **12** at spaced apart locations along the length of the base. A first coupling rocker **76** is pivotably connected to the first base-mounted rocker **66** at a first (lower) pivot point and is pivotably connected to the first base coupling plate **46** at a second (upper) pivot point. Likewise, a second coupling rocker **78** is pivotably connected to the second base-mounted rocker **68** at a first (lower) pivot point and is pivotably connected to the second base coupling plate **48** at a second (upper) pivot point. A third coupling rocker **80** is pivotably connected to the third

base-mounted rocker **70** at a first (lower) pivot point and is pivotably connected to the third base coupling plate **50** at a second (upper) pivot point. A first elongate link **82** has a first end portion pivotably connected to the first base-mounted rocker **66** and an opposite second end portion pivotably connected to the second base-mounted rocker **68**, and a second elongate link **84** has a first end portion pivotably connected to the second base-mounted rocker and an opposite second end portion pivotably connected to the third base-mounted rocker **70**. All pivot axes (not labeled) are oriented parallel to one another and orthogonal to the longitudinal axis LA and the adjustment axis AA.

(45) For each linkage **40**, a single driver **86** is configured to drive the linkage through its range of motion, thereby adjusting the location of each of the first, second, and third base mounted coupling plates **46**, **48**, **50**. In the illustrated embodiment, each driver **86** comprises a linear actuator (e.g., a hydraulic piston) having a first end portion pivotably connected to the base **12** and a second end portion pivotably connected to one of a base-mounted rockers **68** to pivot the base-mounted rocker with respect to the base **12** and thereby drive the linkage through its range of motion.

(46) Referring to FIGS. **10-12**, each driver **86** is configured to drive the linkage **40** through a range of motion that includes a first position at which the first and second base mounted fixtures **42**, **44** and each of the first, second, and third base mounted couplings **46**, **48**, **50** are located along an imaginary line IL oriented parallel to the longitudinal axis LA. Thus it can be seen that at the first position of the linkage range of motion, the linkage **40** is configured support the elongate mold **16** so that it extends in a substantially straight line along the longitudinal axis LA. As the linkages **40** move from the first position to a second (e.g., terminal) position of the linkage range of motion (shown in FIG. **10**), each of the first, second, and third base mounted couplings **46**, **48**, **50** moves downward along the adjustment axis AA below the imaginary line IL. The first and third base mounted coupling plates **46**, **50** move downward along the adjustment axis AA at about the same rate and the second base mounted coupling plate **48** moves downward at a faster rate such that the second base mounted coupling plate becomes increasingly spaced apart below the first and third base mounted coupling plates as the linkages **40** move from the first position to the second position along their range of motion. Each linkage **40** simultaneously moves each of the first, second, and third base mounted couplings **46**, **48**, **50** such that the first and second base mounted fixtures **42**, **44** and the first, second, and third base mounted couplings **46**, **48**, **50** define imaginary arcs IA of decreasing radius of curvature as the linkages moves from the first position to the second position. At the terminal second position of the range of motion, the second base mounted coupling plate **48** is offset from the first and second base mounted fixtures **42**, **44** along the adjustment axis AA by a maximum sag adjustment distance AD (FIG. **10**) in an inclusive range of from about 0.25 inches to about 12 inches (e.g., an inclusive range of from about 1 inch to about 6 inches).

(47) Referring to FIGS. **9** and **11**, the illustrated molding system **10** further comprises a base mounted transducer plate **90** for connecting a linear transducer **92** to the mold **16** at about the midpoint of the length of the mold. In the illustrated embodiment, the base mounted transducer plate **90** is located near the midpoint of the length of the base **12** and mold **16**. The base mounted transducer plate **90** is configured to releasably attach to another mold coupling plate **52** fixed on the base portion **17** of the mold **16** for conjoint movement therewith. The linear transducer **92** is connected between the base **12** and the mold transducer plate **90** to detect a position of the transducer plate along the adjustment axis AA. Thus the linear transducer **92** provides a signal that can be used for determining the location of the middle portion of the mold **16** along the adjustment axis AA, which corresponds to the position of the linkages **40** and the curvature/amount of bending (broadly, shape) of the mold. The molding system **10** can further comprise a measurement device (not shown) on (e.g., inside of) the elongate mold **16** that is configured to measure a radial distance between the elongate mold and the pipe with respect to the longitudinal axis A. This measurement device and the linear transducer **92** can be used to provide feedback for controlling the mold adjustment mechanism **20** for adjusting the shape (e.g., curvature) of the mold to correspond to the

shape (e.g., curvature) of the sagging pipe inside the mold.

(48) An exemplary method of using the molding system **10** will now be briefly described. Initially, the elongate mold **16** is opened and the pipe P is placed into the mold so that the pipe is supported at its opposite end portions and allowed to sag within the mold cavity. In an exemplary embodiment, the mold **16** is closed before the adjustment mechanism **20** is actuated to adjust the shape of the mold. After closing the mold **16**, the adjustment mechanism **20** is actuated to move within its range of motion from the first position at which the first and second base mounted fixtures **42**, **44** and each of the first, second, and third base mounted couplings **46**, **48**, **50** are located along the imaginary line IL toward the second position so that the first and second base mounted fixtures **42**, **44** and the first, second, and third base mounted couplings **46**, **48**, **50** define an imaginary arc IA. Thus, the adjustment mechanism **20** pulls the middle portion of the elongate mold **16** downward to cause the mold to curve in way that corresponds to the curvature of the sagging pipe. By monitoring the signals from the linear transducer **92** and the pipe position measurement device (not shown) on the mold **16**, a user or a controller can determine when the shape of the mold **16** has been adjusted so that the pipe P is substantially centered within the mold. The linkages **40** are maintained at this position as moldable material is imparted into the mold **16** and cured. In preferred embodiments, the moldable material is, when cured, a thermally insulating material. However, other types of moldable material may be applied.

(49) When introducing elements of the present disclosure or the preferred embodiment(s) thereof, the articles “a”, “an”, “the” and “said” are intended to mean that there are one or more of the elements. The terms “comprising”, “including” and “having” are intended to be inclusive and mean that there may be additional elements other than the listed elements.

(50) In view of the above, it will be seen that the several objects of the disclosure are achieved and other advantageous results attained.

(51) As various changes could be made in the above products and methods without departing from the scope of the disclosure, it is intended that all matter contained in the above description shall be interpreted as illustrative and not in a limiting sense.

Claims

1. A molding system for applying insulation to a pipe, the molding system comprising: an elongate mold having a length along a longitudinal axis extending from a first end portion to a second end portion, the elongate mold including a mold member having a base mold member and at least one lid mold member mounted on the base mold member for opening and closing the elongate mold, and an inner form wall defining a mold cavity in which to receive the pipe such that the pipe is supported at the first end portion and the second end portion of the elongate mold and is allowed to sag in the mold cavity between the first end portion and the second end portion of the elongate mold; and a mold adjustment mechanism connected to the mold member to adjust the base mold member from a straight configuration to a curved configuration in which the base mold member bows downward to match a curvature of the pipe as the pipe sags and for moving the mold member to adjust a shape of the inner form wall of the mold member to correspond to a shape of the pipe as the pipe sags in the mold cavity.

2. The molding system as set forth in claim 1, further comprising a base, the mold adjustment mechanism being configured to move the base mold member relative to the base along an adjustment axis oriented transverse to the longitudinal axis to adjust the shape of the mold.

3. The molding system as set forth in claim 2, wherein the mold adjustment mechanism comprises a linkage connected between the base and the elongate mold.

4. The molding system as set forth in claim 3, wherein the linkage comprises a coupling connected to the base mold member and wherein the mold adjustment mechanism is configured to move said coupling relative to the base to move the base mold member relative to the base.

5. The molding system as set forth in claim 4, wherein said coupling comprises a plurality of couplings at spaced apart locations along the length of the elongate mold.
6. The molding system as set forth in claim 5, wherein the linkage is configured to simultaneously move the plurality of couplings along the adjustment axis.
7. The molding system as set forth in claim 6, further comprising a single driver configured to drive movement of the linkage.
8. The molding system as set forth in claim 7, wherein the base has a length along the longitudinal axis and the linkage comprises: first, second, and, third base-mounted rockers pivotably connected to the base at spaced apart locations along the length of the base; a first coupling rocker pivotably connected to the first base-mounted rocker, the plurality of couplings comprising a first coupling pivotably connected to the first coupling rocker; a second coupling rocker pivotably connected to the second base-mounted rocker, the plurality of couplings comprising a second coupling pivotably connected to the second coupling rocker; a third coupling rocker pivotably connected to the third base-mounted rocker, the plurality of couplings comprising a third coupling pivotably connected to the third coupling rocker; a first elongate link having a first end portion pivotably connected to the first base-mounted rocker and an opposite second end portion pivotably connected to the second base-mounted rocker; and a second elongate link having a first end portion pivotably connected to the second base-mounted rocker and an opposite second end portion pivotably connected to the third base-mounted rocker.
9. The molding system as set forth in claim 8, wherein the single driver comprises a linear actuator having a first end portion pivotably connected to the base and a second end portion pivotably connected to one of the first, second, and third base-mounted rockers.
10. The molding system as set forth in claim 9, wherein the linkage and the single driver is located on a first lateral side of the base, the adjustment mechanism further comprising another linkage and another driver located on an opposite second lateral side of the base.
11. The molding system as set forth in claim 8, further comprising a first fixture connecting the first end portion of the elongate mold to the base at a fixed position and a second fixture connecting the second end portion of the elongate mold to the base at a fixed position, the first coupling, the second coupling, and the third coupling being spaced apart along the length of the mold between the first fixture and the second fixture.
12. The molding system as set forth in claim 11, wherein the driver is configured to drive the linkage through a range of motion that includes a first position at which the first fixture, the second fixture, the first coupling, the second coupling, and the third coupling are located along an imaginary line oriented parallel to the longitudinal axis and a second position at which each of the first coupling, the second coupling, and the third coupling are spaced apart along the adjustment axis below the imaginary line.
13. The molding system as set forth in claim 12, wherein when the linkage is at the second position of the range of motion, the second coupling is spaced apart along the adjustment axis below the first coupling and the third coupling.
14. The molding system as set forth in claim 13, wherein when the linkage is at the second position of the range of motion, the first fixture, the second fixture, the first coupling, the second coupling, and the third coupling are located along an imaginary arc having a finite radius of curvature.
15. The molding system as set forth in claim 12, wherein at the second position of the range of motion the second coupling is offset from the first and second fixtures along the adjustment axis by a sag adjustment distance in an inclusive range of from about 0.25 inches to about 12 inches.
16. The molding system as set forth in claim 7, wherein the single driver is configured to drive the linkage through a range of motion that includes a first position at which the plurality of couplings are located along an imaginary line oriented parallel to the longitudinal axis and a second position at which the plurality of couplings are located along an imaginary arc having a finite radius of curvature.

17. The molding system as set forth in claim 5, wherein each of the plurality of couplings comprises a base coupling plate, the elongate mold comprising a corresponding mold coupling plate for each base coupling plate, each mold coupling plate being fastened to the base coupling plate such that the mold coupling plate moves conjointly with the base coupling plate with respect to the base.
18. The molding system as set forth in claim 17, wherein each mold coupling plate is mounted on the elongate mold at a respective location along the length of the mold such that the mold coupling plate is configured to cause the base mold member to move substantially conjointly with the mold coupling plate with respect to the base at the respective location along the length of the mold.
19. The molding system as set forth in claim 2, further comprising a linear transducer connected between the base and the base mold member to detect movement of the base mold member along the adjustment axis.
20. The molding system as set forth in claim 2, wherein the base is configured to deflect less than the elongate mold when the mold adjustment mechanism moves the base mold member relative to the base along an adjustment axis.
21. The molding system as set forth in claim 2, wherein the base has an I-beam shape including an upper flange portion, a lower flange portion, and a vertical web portion extending from the lower flange portion to the upper flange portion.
22. The molding system as set forth in claim 21, wherein the lower flange portion is wider than the upper flange portion.
23. The molding system as set forth in claim 21, wherein the base further comprises first and second lip portions extending upward from opposite first and second lateral edge margins of the lower flange portion.
24. The molding system as set forth in claim 23, wherein each of the first and second lip portions is configured to attach to one or more actuators for opening and closing the elongate mold.
25. The molding system as set forth in claim 2, wherein the base comprises a first longitudinal base section and a second longitudinal base section releasably attached to the first longitudinal base section in end-to-end relationship therewith.
26. The molding system as set forth in claim 25, wherein each of the first longitudinal base section and the second longitudinal base section comprises an attachment flange on a longitudinal end portion thereof, the attachment flanges being fastened together in face-to-face relationship.
27. The molding system as set forth in claim 1, further comprising a measurement device on the elongate mold configured to measure a radial distance between the elongate mold and the pipe.
28. The molding system as set forth in claim 1, wherein the length of the elongate mold is greater than 35 feet.
29. A molding system for applying insulation to a pipe, the molding system comprising: an elongate mold having a length along a longitudinal axis extending from a first end portion to a second end portion, the elongate mold including a mold member having a base mold member and at least one lid mold member mounted on the base mold member for opening and closing the elongate mold, and an inner form wall defining a mold cavity in which to receive the pipe such that the pipe is supported at the first end portion and the second end portion of the elongate mold and is allowed to sag in the mold cavity between the first end portion and the second end portion of the elongate mold; and a mold adjustment mechanism connected to the mold member to move the base mold member from a straight configuration to a curved configuration.