

PATENT SPECIFICATION

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(54) SACRIFICIAL ANODE FOR CATHODIC PROTECTION OF PIPELINES

(71) We, FEDERATED METALS CORPORATION, a Corporation organized and existing under the laws of the State of New Jersey, United States of America, of
5 120 Broadway, New York, New York 10005, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to
10 be particularly described in and by the following statement:—

This invention relates to cathodic protection of pipelines and more particularly to improvements in a sacrificial
15 anode of the bracelet type for embracing a pipeline for cathodic protection of the pipeline, which improvements minimize or substantially minimize distortion of the anode segments during cooling after casting
20 and also minimize or substantially minimize fracturing of the anode segments during installation about the pipeline.

Semi-cylindrical galvanic anode segments for embracing a pipeline for
25 cathodic protection of the pipeline are known in the prior art and are disclosed in United States Patent 3,616,422, reissued as Reissue Patent 27,529. Although such anode segments give entirely satisfactory
30 results in certain respects, one drawback of such semi-cylindrical segments is their tendency to become distorted during cooling of the metal after casting of the segments and also to fracture during
35 installation about the pipeline, and this was particularly the case with the longer semicylindrical segments which are utilized with the larger diameter pipelines. The desideratum is to provide the curved anode
40 segments with a curvature which closely approximates the curvature of the coated pipeline about which the anode segment is to be installed so that the curved segments will fit closely about the pipeline and it was,
45 generally speaking, virtually impossible to cast a curved anode segment every time having a curvature closely approximating

the curvature of the pipeline. And this was especially the situation when casting the longer anode segments for use about the large diameter pipelines. When the anode segment does not have sufficient curvature to correspond to that of the pipeline, it is necessary to bend end portions and/or
55 other portions of the segment inwardly by application of pressure to obtain the necessary curvature to conform to and closely fit about the pipeline, and the pressure application required for the bending may result in cracking of the anode
60 segment. Sometimes it is necessary to bend the curved anode segments outward by application of pressure to obtain the necessary curvature to closely fit about the pipeline and this pressure application may
65 also result in cracking of the segment. Cracking of the sacrificial anode metal of the segment is undesirable for the reason a crack or cracks in the sacrificial anode metal may expose the cathodic core metal
70 of the anode, which is embedded within the sacrificial anode metal. Consequently, after installation and exposure of the cathodic core metal to the electrolyte due to the crack or cracks in the anode metal, the
75 anode expends itself of sacrificial anode metal to protect the core metal with the resultant inefficiency and wasting of sacrificial anode metal. Notches have been provided in the aforementioned prior art
80 semi-cylindrical anode segments for promoting cracking at the center of the segment.

The publication "Cathodic Protection of Submarine Pipeline", reprinted from the
85 Federated Metals Digest of the American Smelting and Refining Company, Federated Metals Division, published 1958, discloses a sacrificial anode assembly wherein the anode segments are indirectly
90 connected together by the steel cores of the anodes being welded to steel bands. The major axis of the cores of the anodes are parallel to the major axis of the pipe, and the cores extend from that portion of the
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anode which are the side edges of the anode.

Heretofore non-arcuate shaped anode segments have been heated and then bent in the heated condition to fit the segment about the shaft housing of a marine propeller. The anode segments were welded to non-anodic housing structural members and were not connected to one another about the housing. The problem is that when the anode segments are of zinc or zinc base alloy the segments tend to crack during the bending at ambient temperature due to the brittle nature of the zinc. Arcuate-shaped anode segments have also been cast heretofore and bolted about the shaft housing of a marine propeller. Again the segments were not connected to one another about the housing.

The terms "fracturing" and "fracture" are used herein in a broad sense to mean cracking of the anode segment with or without exposure of the cathodic core metal of the anode segment, and/or breaking of the anode segment into pieces or fragments. The terms "pipe diameter" and "diameter of the pipe" are used herein to mean the diameter of the pipeline pipe having the anti-corrosive coating thereover, as contrasted with the diameter of the negative buoyancy-providing concrete layer over the pipe, or with the diameter terminating at each end at the external surface of the anticorrosive coating. The term "arc length" or "arc lengths" used herein with respect to the arcuate anode segment or segments means the length or lengths of the arcuate anode segment or segments measured on the inner periphery of the segment. The term "arc length" used

herein with reference to the length of the mold cavity means the length of that arc of the mold cavity which forms a portion of an imaginary circle with is the closest to the center of such circle.

In accordance with the invention there is provided a sacrificial anode for cathodic protection of a pipeline comprising an even-numbered plurality in the range of 4 to 8 arcuate-shaped anode segments of sacrificial anode metal adapted to be connected about a corrosible metallic pipeline having a diameter in the range of 20 inches to 72 inches in pipe-embracing relationship thereto, said plurality of anode segments being 4 anode segments for a pipeline of pipe diameter in the range of 20 inches to 36 inches, 6 anode segments for a pipeline of pipe diameter in the range of 30 inches to 54 inches, 8 anode segments for a pipeline of pipe diameter in the range of 40 inches to 72 inches, 4 or 6 anode segments for a pipeline of pipe diameter in the range of 30 inches to 36 inches, and 6 or 8 anode segments for a pipeline of pipe diameter in the range of 40 inches to 54 inches, each anode segment comprising at least one metal core cathodic to the anode metal concentrically embedded entirely within the anode metal except for portions of the core extending from opposite end edges of the anode segment, the anode segments being adapted to be directly connected together in pipe-embracing relationship by at least one joint formed at or adjacent the ends of the core and each anode segment having a maximum arc length in the range of 14 inches to 27 inches and the maximum arc length of each anode segment being determined by the formula:

$$\text{Maximum arc length of anode segment} = \frac{\pi D}{n} - 2"$$

wherein D is the diameter of the pipeline in inches and n is the total number of anode segments in the assembly.

The invention also relates to a sacrificial anode and pipeline assembly comprising a corrodible metallic pipeline having a diameter in the range of 20 to 72 inches disposed in an electrolyte, said pipeline having secured thereabout in pipe-embracing relationship thereto a sacrificial anode according to the invention, the plurality of anode segments in said sacrificial anode being 4 anode segments for a pipeline of pipe diameter in the range of 20 inches to 36 inches, 6 anode segments for a pipeline of pipe diameter in the range of 30 inches to 54 inches, 8 anode segments for a pipeline of pipe diameter in the range of 40 inches to 72 inches, 4 or 6 anode segments for a pipeline of pipe diameter in

the range of 30 inches to 36 inches and 6 or 8 anode segments for a pipeline of pipe diameter in the range of 40 inches to 54 inches.

The minimum arc length of the arcuate-shaped anode segments of this invention is not critical and the anode segments herein can be any of desired arc length so long as the arc length does not exceed the predetermined maximum arc length as is hereinbefore disclosed.

In an embodiment of this invention, one or more metal cores are embedded within the anode metal of a plurality of arcuate shaped segments of sacrificial anode metal of an anode section, the metal core or cores being common to all of the segments of each anode or anode section. The common core or cores which are of metal cathodic to the anode metal, have end portions

(12)

extending from end edges of the segments disposed on opposite end portions of such core or cores, for forming joint elements for connecting this anode together with adjacent anodes or anode segments about a pipeline in pipe-embracing relationship. Means are also provided for minimizing fracturing of the anode segments during installation of the anode. This embodiment having the core or cores common to and embedded within a plurality of the anode segments facilitates installation of the anode about the pipeline for the reason joints do not have to be welded between all adjacent anode segments, and the number of joints that have to be formed is materially reduced.

In the last-mentioned embodiment, the length of the common core or cores of the anode section is preferably not in excess of one-half the outer circumference of the pipe or pipeline. The reason for this is to facilitate assembly of the anode about the pipe or pipeline. When the length of the arcuate common core or cores is materially greater than one-half the outer circumference of the pipeline it may be difficult to position the anode about the pipeline for installation, or it may be necessary to bend the opposite end portions of the common core or cores outwardly to give clearance for positioning the anode about the pipeline or inwardly to give a close fit about the pipeline. And the bending of the common core or cores may be difficult due to being formed of usually a ferrous metal such as steel. If desired, however, the length of the common core or cores can be materially greater than one-half the outer circumference of the pipeline. Indeed the length of the common core or cores can range up to the outer circumference or thereabout of the pipe or pipeline or the like. If one does not object to having to bend the cores. With the last-mentioned length of the common core or cores, only a single joint would have to be formed.

In the anode section of the last-mentioned embodiment, to minimize or substantially minimize fracturing of the anode segments during their installation about the pipeline and distortion of the segments during cooling of the metal after casting, the arc length of each of the anode segments should not exceed the predetermined critical maximum arc length as is previously disclosed herein.

The arcuate-shaped anode segments may be prepared by melting the sacrificial anode metal, e.g., zinc, magnesium, aluminum, or conventional sacrificial alloys based on one of these metals such as magnesium based alloy containing aluminum and zinc or a zinc base alloy containing aluminum and

cadmium, and feeding or supplying the molten anode metal into the cavity of a suitable mold, for instance of ferrous metal, which is ordinarily preheated and wherein the cavity is of the shape and configuration corresponding to that of the arcuate-shaped anode segment desired, and of a predetermined maximum arc length in accordance with the invention. One or metal cores which are of metal cathodic to the anode metal, e.g., steel, and which ordinarily have been preheated are previously positioned and secured in the mold cavity with the opposite end portions of the cores protruding from the opposite ends of the mold cavity. The metal core or cores are secured in the proper position in the mold cavity by their end portions extending through tight fitting openings in the opposite end of the mold and formed by the mold halves. The metal in the mold cavity is cooled, ordinarily by being allowed to cool to below its melting point, which is for example 419.4°C. in the case of zinc, or to below its solidus to solidify the molten metal. The solidified anode metal casting having the metal core or cores embedded therewithin and extending from opposite ends thereof is separated from the mold cavity.

In the preparation of the anode section comprising a plurality of spaced-apart arcuate-shaped anode segments, and the core or cores concentrically embedded within the segment anode metal and common to all of the anode segments of the section, the method is as heretofore described except that the metal core or cores are positioned in the mold cavity with a relatively short end portion of the core or cores protruding from one end of the mold cavity, and a relatively long portion of the core or cores protruding from the opposite end of the mold cavity. After cooling the solid anode segment having the metal core or cores embedded therewithin is separated from the mold cavity, after which the protruding relatively long remaining portion of the core or cores is moved or shifted over the desired extent and again properly positioned in the mold cavity prior to feeding the molten anode metal into such cavity, with the cast, solidified anode segment and its core or cores extending from one end of the mold cavity, and a relatively short end portion of the core or cores protruding from the opposite end of the mold cavity. The molten anode metal is then fed into the mold cavity after which the melt in the mold cavity is cooled to below its melting point, ordinarily by being permitted to cool to below its melting point, to solidify the molten anode metal. If only two anode segments are desired in the anode section, the anode segment with the

common core or cores is then removed from the mold cavity and no more casting is required. However, if more than two anode segments are required in the anode section, the shifting and casting procedure disclosed immediately above is repeated one or more times to provide the number of anode segments desired in the anode section. Of course the core or cores utilized has to be of sufficient length to accommodate the number of anode segments to be cast thereon.

Alternatively, the anode section can be prepared by employing a plurality of molds with the number thereof corresponding to the number of anode segments desired in the anode section. The common core or cores are then properly positioned in the mold cavities of the properly spaced molds, after which the molten anode metal is fed into all the mold cavities. The molten metal is then cooled to below its melting point, ordinarily by being allowed to cool to below its melting point. The cast solidified anode section is then removed with its common core or cores from the mold cavities. In this alternative embodiment for preparing the anode sections, the metal core or cores extend from opposite end portions of the spaced apart molds through tightly fitting openings formed in the molds.

In all embodiments of the preparation method for producing the anode sections, the mold cavity or cavities are of a configuration and shape which correspond to that of the anode segment desired and of the predetermined maximum arc length previously disclosed herein.

The invention will be described with reference to the accompanying drawings, in which:

Fig. 1 is a transverse section through the anode of the present invention taken along line 1—1 of Fig. 4 with one anode segment shown in section;

Fig. 2 is a transverse section through the anode in accordance with another embodiment of the invention with one anode segment shown in section;

Fig. 3 is a view taken on line 3—3 of Fig. 1;

Fig. 4 is a perspective view, partially broken away, showing the anode of the present invention installed on a pipeline, the pipeline also having a negative buoyancy providing coating of concrete;

Fig. 5 is a view taken on line 5—5 of Fig. 2;

Fig. 6 is a longitudinal section taken on line 6—6 of Fig. 9;

Fig. 7 is a top plan view partially broken away through an anode segment and its core in accordance with another embodiment of the invention;

Fig. 8 is a longitudinal section through the anode segment and its core of Fig. 1;

Fig. 9 is a top plan view partially broken away showing the anode segment and its core of Fig. 6;

Fig. 10 is a transverse section through the anode in accordance with another embodiment of the invention;

Fig. 11 is a transverse section through the anode in accordance with still another embodiment of the invention with one anode segment shown in section;

Fig. 12 is a transverse section through an anode assembly in accordance with another embodiment of the invention with one anode segment shown in section;

Fig. 13 is a transverse section through another modification of the anode of the embodiment of Fig. 11 with one anode segment shown in section;

Fig. 14 is a transverse section through an anode assembly in accordance with a further embodiment of the invention with one anode segment shown in section;

Fig. 15 is a longitudinal section taken on line 15—15 of Fig. 16;

Fig. 16 is a top plan view showing the anode and its common core of Fig. 15;

Fig. 17 is a longitudinal section taken on line 17—17 of Fig. 18;

Fig. 18 is a top plan view showing the anode and its common core of Fig. 17; and

Fig. 19 is a transverse section through the anode in accordance with an additional embodiment of the invention with two anode segments shown partially in section.

With reference to Figs. 1 and 4, anode 15, secured about ferrous metal pipe 16 of a pipeline having a continuous anti-corrosive coating 17, for example of coal tar enamel, thereover includes arcuate-shaped or substantially arcuate-shaped segments 18 of sacrificial anode metal. As shown in Fig. 1, there are 4 of the anode segments 18 in the embodiment of the invention, the segments are substantially identical in size, shape and structure and each are of shorter length than semi-cylindrical length. Each anode segment 18 comprises a solid, one piece body 19 of any suitable sacrificial anode metal, e.g., zinc, magnesium, aluminum, or alloys thereof as previously described. Each anode segment 18 also includes core bar 20 of a metal cathodic to the anode metal, e.g., steel. The major axes of the cores or core bars herein are in a plane which is normal to the major axis of the pipe. The intermediate portion 41 of core bar 20 and the major portion of this core bar is concentrically or substantially concentrically embedded entirely within anode segment 18, and the end portions 42 and 43 of the core bar project from the opposite ends of segment 18 for forming joints with the core bar end portions 42 and 43 projecting from the

5 opposite ends of immediately adjacent
 anode segments 18. The end portion 43 of
 the core bar 20 of each anode segment 18 is
 offset laterally for receiving in overlapping
 5 relationship the non-offset end portion 42
 of each core bar 20 of the immediately
 adjacent anode segment. The overlapping
 core bar end portions 42 and 43 are welded
 10 together to form joint elements 44 which
 connect and secure the anode segments 18
 together closely about the pipe in pipe-
 embracing relationship thereto. As shown
 in Fig. 4, pipe 16 is encased in layer 57 of
 15 concrete over anti-corrosive coating 17 on
 each lateral side of anode 15. The concrete
 layers 57 can be applied to the pipe after
 the anodes have been installed about the
 pipe and the cores electrically grounded to
 20 the pipe, by cables 58 and 59 secured to the
 end portion of the core bar or bars and the
 metal of pipe 16 by Thermit (Registered
 Trade Mark) welding or brazing. Alternately,
 the concrete layers can be
 25 applied to the pipe before installation of the
 anodes by leaving a gap of suitable width
 between the spaced apart concrete layers,
 then installing the anodes about the pipe
 and electrically grounding the cores to the
 30 pipe as disclosed immediately above,
 followed by filling in with concrete any
 space between the original concrete layers
 and the anodes. The gap between the
 opposing ends of the anode segments may
 35 also be filled with concrete. The concrete
 provides desired negative buoyancy besides
 additional protection for the pipe when the
 pipe is to be submerged in a body of water,
 e.g., a body of sea water, lake or river.
 40 Concrete layers 57 may be omitted when
 the pipe is to be installed in the ground and
 not in a body of water or if the negative
 buoyancy and additional protection is not
 45 desired. Core 20, shown also in Figs. 3 and
 8, has spaced-apart apertures 21 extending
 through the bar and communicating one
 side of the bar with the opposite side
 thereof. Anode metal is solidified
 50 continuously through apertures 21 which
 aids in anchoring bar 20 within the anode
 segment. Instead of two apertures 21, core
 bar 20 can, if desired, have more than two
 apertures, e.g., three spaced-apart
 55 apertures, extending through the core bar
 for aiding in anchoring the bar 20 within the
 anode. Also core bar 20 can have but one
 aperture, if desired, extending through the
 bar for the purpose disclosed immediately
 60 above. Core bar 23, shown in Fig. 7, has an
 intermediate section 24 of expanded steel
 and end sections welded to opposite ends of
 intermediate section 24. A multiplicity of
 65 orifices or apertures 26 provided by the
 expanded metal communicate one side of
 intermediate section 24 with the opposite
 side thereof, and the solidified anode metal

extends continuously through orifices 26 to
 aid in anchoring core bar 23 in the anode.
 Intermediate section 24 of the core bar 23 is
 embedded within the anode metal, and end
 sections 25, which are free of apertures,
 70 protrude from opposite ends of the anode.
 Another modification of the core bar is
 shown in Figs. 6 and 9 wherein the
 intermediate section 27 of the core bar of
 anode 18 is thinner than the opposite end
 75 sections 29 of such core bar which are
 thicker. Intermediate section 27 is
 embedded within the anode and end
 sections 29 protrude from opposite ends of
 the anode. Intermediate section 27 is also
 80 narrower than the wider end sections 29.
 The wider as well as thicker end sections 29
 serve to facilitate joining by welding to
 protruding end portions of core bars of the
 immediately adjacent anode segments. 85

Referring to Fig. 2, in another
 embodiment of the invention, the anode 30,
 secured about the larger diameter ferrous
 metal pipe 31 of a pipeline having a
 continuous anti-corrosive coating 32
 90 thereover, includes 6 arcuate-shaped or
 substantially arcuate-shaped segments 33 of
 sacrificial anode metal. Each anode
 segment 33 has a solid, one piece body of
 sacrificial anode metal, and a core 34
 95 comprising two spaced apart, parallel or
 substantially parallel core bars 35 of steel,
 shown in Fig. 5. The intermediate and
 major portion 36 of core bars 35 are
 concentrically embedded entirely within
 100 each anode segment 33 adjacent the inner
 periphery 40 thereof, with the end portions
 37 projecting from opposite ends of
 segments 33 for forming joints with
 immediately adjacent anode segments. The
 105 end portion 38 of each core bar 35 is offset
 laterally for receiving in overlapping
 relationship the non-off-set end portion 37
 of each core bar 35 of the immediately
 adjacent anode segment. The overlapping
 110 core bar end portions 37 and 38 are welded
 together to form joint elements 39 which
 connect and secure the anode segments 33
 together closely about the pipeline in pipe-
 embracing relationship thereto. 115

With reference to Fig. 10, in still another
 embodiment of the invention, the anode 46
 secured about ferrous metal pipe 47 of a
 pipeline of still larger diameter than the
 pipe of Figs. 1 and 2 and having continuous
 120 anti-corrosive coating 48 thereover,
 comprises 8 arcuate-shaped or substantially
 arcuate-shaped segments 49 of sacrificial
 anode metal. Anode segments 49 each have
 a solid, one-piece body of sacrificial anode
 125 metal, and a core bar 50 of steel. The
 intermediate and major portion 51 of core
 50 is concentrically or substantially
 concentrically embedded entirely within
 anode segment 49, and the end portions 52 130

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and 53 of core bar 50 project from opposite ends of segment 49 for forming joints with the core bar end portions 52 and 53 projecting from the opposite ends of immediately adjacent anode segments 49. End portion 53 of each core bar 50 is offset laterally and end portion 52 of each core 50 not offset whereby the offset end portions 53 can be overlapped with the non-offset end portions 52 of the core bar 50, and then welded together to form joint elements 54. The anode segments are thereby connected together and embrace the pipeline. Segments 49 have spaced apart apertures 55 extending through the core bars 50 for facilitating anchoring of bars 50 within the anode segment, the anode metal extending continuously through apertures 55.

Each of the anode segments 18 shown in Fig. 1, each of the anode segments 33 shown in the Fig. 2 embodiment, and each of the anode segments 49 shown in the Fig. 10 embodiment has an arc length which is less than the predetermined critical maximum arc length, thereby to minimize distortion of the segment during cooling of the metal after casting the segment and to minimize fracturing of the segment during installation of the anode segment about the pipeline.

Referring to Figs. 11, 15 and 16, in still other embodiments of the invention anode 57, secured about ferrous metal pipe 58 of a pipeline having continuous anti-corrosive coating 59, for example, of coal tar enamel, thereover includes anode or anode section 60 comprising arcuate-shaped or substantially arcuate-shaped segments 61 of sacrificial anode metal, and continuous metal core or core bar 62 common to and embedded within the anode metal of segments 61. Each anode segment 61 of anode section 60 comprises a solid one piece body 63 of any suitable sacrificial anode metal, e.g., zinc, magnesium, aluminum, or alloys thereof as previously described. The core 62 of each anode segment 61 is of a metal cathodic to the anode metal, e.g., steel. Intermediate portions 64 and 65 of the core 62, which together constitute a major portion of the core, are concentrically or substantially concentrically embedded entirely within the anode segments 61. An exposed portion 66 of the core is located between segments 61, and exposed core portion 66 can be of greater or lesser arcuate length than as shown. The end portions 67 and 68 of the core 62 project from opposite ends of the segments 61 of the anode section 60 for forming joints with the core bar end portions 69 and 70 projecting from the adjacent segments. End portion 67 of the core bar of the anode section 60 is offset laterally for receiving in overlapping

relationship the non-offset end portion 69 of the core bar of anode segment 72, and non-offset end portion 68 overlaps the offset end portion 70 of the core bar of anode segment 72. The overlapping core bar end portions 67 and 69, 68 and 70 as well as 73 and 74 between arcuate-shaped anode segments 72 are welded together to form joint elements 79, which connect and secure the anode section 60 and the individual anode segments 72 not having the common core together closely about the pipe in pipe-embracing relationship thereto. The two individual arcuate-shaped or substantially arcuate-shaped anode segments 72 shown in Fig. 11 each comprise a solid one piece body 77 of sacrificial anode metal, e.g., zinc, magnesium, aluminum, or alloys thereof as previously described, with a separate core or core bar 78 concentrically or substantially concentrically embedded entirely within anode segment 72 and with the end portions of the core bars projecting from the opposite ends of the segment for forming the joint elements as is hereinbefore disclosed. Spaced apart apertures 80 extend through the core bar 62 of anode section 60 for facilitating anchoring of bar 62 within the anode segments 61, the solidified anode metal extending continuously through apertures 80. Spaced apart apertures 81 also extend through each core bar 78 of the individual anode segments 72 also for facilitating anchoring of the core bars within segments 72.

The anode installation of Fig. 12 differs from that shown in Fig. 11 in that in the installation shown in Fig. 12, two substantially identical anode sections 60 each having a common core or core bar 62 are joined together at joint elements 83 by welding together overlapping end portions of the common core bars 62.

The anode installation shown in Fig. 13 is substantially the same as that shown in Fig. 11 except that in the embodiment of Fig. 13, the anode section 85, which is shown also in Figs. 17 and 18, includes three anode segments 86 having the continuous core bar 87 common to all the segments 86. Also, in the Fig. 13 embodiment, three of the individual arcuate-shaped anode segments 88 are joined together with each other and with anode section 85 about the pipe by welding of their overlapping core bar end portions to form joint elements 89 and 90 respectively. Pipe 91 of the Fig. 13 embodiment, as shown, is also of larger diameter than the pipe of Fig. 11. Continuous anti-corrosive coating, for example, of coal tar pitch, is designated at 92.

The anode installation shown in Fig. 14 is substantially the same as that shown in Fig. 130

12 except that in the Fig. 14 embodiment, the two anode sections 85 each include the three anode segments 86 having continuous core bar 87 common to all the segments 86.

5 Anode sections 85 are joined together with one another about the pipe by welding of their overlapping core bar end portions to form joint elements 94 and 95.

10 The anode installation shown in Fig. 19 differs from that shown in Figs. 11, 12, 13 and 14 in that in the Fig. 19 installation, a single anode section 96 has four arcuate-shaped or substantially arcuate-shaped anode segments 97 of sacrificial anode metal and a continuous core bar 98 common to all the segments 97. A major portion of common core bar 98 is concentrically or substantially concentrically embedded entirely within the anode segments, with a minor portion of the core bar 98 not being embedded in segments 97 but being exposed between the spaced apart end portions of segments 97. Each anode segment 97 comprises a solid, one piece body 99 of any suitable sacrificial anode metal, e.g., zinc, magnesium, aluminum or alloys thereof as previously described. Common core 98 is of a metal cathodic to the anode metal, e.g., steel. Anode section 96 is secured about pipe 93 by welding of its overlapping core bar end portions to form joint element 100. Continuous anticorrosive coating, e.g., of coal-tar pitch, is designated at 101.

35 It is preferred to employ the following ratios and relationships:

(a) a ratio of the thickness of each anode segment to the pipe diameter in the range of 1:5 to 1:15, respectively, for pipelines of pipe diameter in the range of 20 inches to 26 inches, and such ratio of segment thickness to pipe diameter in the range of 1:10 to 1:20, respectively, for pipelines of pipe diameter in the range of 37 inches to 45 72 inches; and/or

(b) a ratio of the width of the anode segment to the width of the anode core or total width of the anode cores when more than one core per anode segment is utilized in the range of 2:1 to 5:1, respectively, when at least 50% of the length of that portion of the core or cores embedded in the anode metal has a width of 1 inch or greater and a thickness of 3/16 th inch or greater; and/or

55 (c) a thickness of the core of the anode segment, or of each core of the anode segment when more than one core per segment is employed, in the range of 3/16 th inch to 7/16 th inch when at least 50% of the length of that portion of the core or cores which is embedded in the anode metal has a width of 1 inch or greater. More preferably we prefer to employ at least two of ratios or relationships (a), (b) and (c) set forth

65 immediately above, and still more preferably all three of such ratios and relationships (a), (b) and (c).

The present invention is especially well suited for use when the sacrificial anode metal of the anode segments is zinc or a zinc base alloy, inasmuch as the fracturing and cracking problem, which is overcome by this invention, is an especially serious problem when the anode metal is zinc or a zinc base alloy, e.g., a zinc base alloy containing aluminum and cadmium, with or without silicon, and a zinc base alloy containing aluminum, with or without silicon, or unalloyed high purity zinc.

80 The following examples further illustrate the invention but are not intended to be restrictive thereof.

EXAMPLE I

A bracelet-type anode including four so-called quarter circle arcuate anode segments of a zinc alloy is installed about a pipeline coated with coal tar enamel and wherein the pipeline has a pipe diameter of 20.25 inches. Overlapping end portions of steel core bars which protrude from the ends of immediately adjacent segments are welded together in installing the anode about the pipeline. Each anode segment has an arc length of 14 inches and a thickness of 2.25 inches which is a ratio of thickness of the anode segment to the pipe diameter of 1 to 9, respectively. Each anode segment has one core bar. The arcuate, non-distorted anode segments fit closely about the coated surface of the pipeline and no significant pressure application for bending is required at the end portions of the anode segments during the installation on the pipeline. Consequently, no fracturing of the anode segment occurs during the installation on the pipeline. Further, no distortion of the anode segment occurs during cooling of the anode segment after casting.

EXAMPLE II

A bracelet-type anode including six arcuate segments of a zinc alloy is installed about a pipeline coated with coal tar enamel and wherein the pipe is of diameter of 49 inches. Overlapping end portions of steel core bars which protrude from each end of immediately adjacent anode segments are welded together in installing the anode about the pipeline. Each segment had two spaced-apart core bars with spaced apart holes in each core bar through which the anode metal had solidified. Each anode segment has an arc length of 23.75 inches, and a thickness of 3.5 inches which corresponds to a ratio of thickness of the anode segment to pipe diameter of 1 to 14. The arcuate, non-distorted anode segments fit closely about

the coated surface of the pipeline and no significant pressure application for bending is required at the end portions of the anode segments during the installation on the pipeline. Consequently, no fracturing of the anode segment occurs during the installation on the pipeline. Further, no distortion of the anode segment occurs during cooling of the anode segment after casting.

EXAMPLE III

A bracelet-type anode including two arcuate anodes or anode sections is installed about a pipeline coated with coal tar enamel, and wherein the pipeline has a diameter of 20.25 inches. Each arcuate anode section consists of two arcuate anode segments of a zinc alloy cast on a steel core bar, which core bar is common to both anode segments, with the adjacent ends of the anode segments being spaced apart from each other about 1 1/2 inches on the core bar. The arc length of the core bar of each anode section is about one-half the outer circumference of the enamel-coated pipe. Overlapping end portions of the steel core bars which protrude from the opposite ends of immediately adjacent anode segments of each anode section are welded together in installing the anode about the pipeline. Each anode segment of each anode section has an arc length of 14 inches and a thickness of 2.25 inches, which is a ratio of the thickness of the anode segment to the pipe diameter of 1 to 9. The arcuate, non-distorted anode segments of each anode section fit closely about the coated surface of the pipeline, and no pressure application for bending is required at the end portions of the anode segments during the installation of each anode section on the pipeline. Consequently, no fracturing of the anode segments occurs during the installation of each anode section on the pipeline. The core bar, where exposed between the anode segments, can be bent, if required, to provide a better fit of the anode section to the pipeline. Further, no significant distortion of the anode segments occurs during cooling of the segments of each anode section after casting.

EXAMPLE IV

A bracelet-type anode including two arcuate anodes or anode sections is installed about a pipeline coated with coal tar enamel, and wherein the pipeline has a diameter of 49 inches. Each arcuate anode section consists of three arcuate anode segments of a zinc alloy cast on two steel core bars, which core bars are common to all three anode segments, with the adjacent

ends of the anode segments being spaced apart from each other about 2 inches on the core bars. The two core bars of each anode section are arcuate in shape and substantially parallel to each other. The arc length of each core bar of each anode section is about 79 inches. Overlapping end portions of the steel core bars which protrude from the ends of immediately adjacent anode segments of each anode section are welded together in installing the anode about the pipeline. Each anode segment of each anode section has an arc length of about 23.7 inches and a thickness of 3.5 inches, which is a ratio of the thickness of each anode segment to the pipe diameter of 1 to 14. The arcuate, nondistorted anode segments of each anode section fit closely about the coated surface of the pipeline, and non significant pressure application for bending is required at the end portions of the anode segments during the installation of each anode section on the pipeline. Consequently, no fracturing of the anode segments occurs during the installation of the anode segments on the pipeline. Further, no distortion of the anode segments occurs during cooling of the segments of each anode section after casting.

WHAT WE CLAIM IS:—

1. A sacrificial anode for cathodic protection of a pipeline comprising an even numbered plurality in the range of 4 to 8 arcuate shaped anode segments of sacrificial anode metal adapted to be connected about a corrosible metallic pipeline having a diameter in the range of 20 inches to 72 inches in pipe embracing relationship thereto, said plurality of anode segments being 4 anode segments for a pipeline of pipe diameter in the range of 20 inches to 36 inches, 6 anode segments for a pipeline of pipe diameter in the range of 30 inches to 54 inches, 8 anode segments for a pipeline of pipe diameter in the range of 40 inches to 72 inches, 4 or 6 anode segments for a pipeline of pipe diameter in the range of 30 inches to 36 inches, and 6 or 8 anode segments for a pipeline of pipe diameter in the range of 40 inches to 54 inches, each anode segment comprising at least one metal core cathodic to the anode metal concentrically embedded entirely within the anode metal except for portions of the core extending from opposite end edges of the anode segment, the anode segments being adapted to be directly connected together in pipe embracing relationship by at least one joint formed at or adjacent the ends of the core and each anode segment having a maximum arc length in the range



the coated surface of the pipeline and no significant pressure application for bending is required at the end portions of the anode segments during the installation on the pipeline. Consequently, no fracturing of the anode segment occurs during the installation on the pipeline. Further, no distortion of the anode segment occurs during cooling of the anode segment after casting.

EXAMPLE III

A bracelet-type anode including two arcuate anodes or anode sections is installed about a pipeline coated with coal tar enamel, and wherein the pipeline has a diameter of 20.25 inches. Each arcuate anode section consists of two arcuate anode segments of a zinc alloy cast on a steel core bar, which core bar is common to both anode segments, with the adjacent ends of the anode segments being spaced apart from each other about 1 1/2 inches on the core bar. The arc length of the core bar of each anode section is about one-half the outer circumference of the enamel-coated pipe. Overlapping end portions of the steel core bars which protrude from the opposite ends of immediately adjacent anode segments of each anode section are welded together in installing the anode about the pipeline. Each anode segment of each anode section has an arc length of 14 inches and a thickness of 2.25 inches, which is a ratio of the thickness of the anode segment to the pipe diameter of 1 to 9. The arcuate, non-distorted anode segments of each anode section fit closely about the coated surface of the pipeline, and no pressure application for bending is required at the end portions of the anode segments during the installation of each anode section on the pipeline. Consequently, no fracturing of the anode segments occurs during the installation of each anode section on the pipeline. The core bar, where exposed between the anode segments, can be bent, if required, to provide a better fit of the anode section to the pipeline. Further, no significant distortion of the anode segments occurs during cooling of the segments of each anode section after casting.

EXAMPLE IV

A bracelet-type anode including two arcuate anodes or anode sections is installed about a pipeline coated with coal tar enamel, and wherein the pipeline has a diameter of 49 inches. Each arcuate anode section consists of three arcuate anode segments of a zinc alloy cast on two steel core bars, which core bars are common to all three anode segments, with the adjacent

ends of the anode segments being spaced apart from each other about 2 inches on the core bars. The two core bars of each anode section are arcuate in shape and substantially parallel to each other. The arc length of each core bar of each anode section is about 79 inches. Overlapping end portions of the steel core bars which protrude from the ends of immediately adjacent anode segments of each anode section are welded together in installing the anode about the pipeline. Each anode segment of each anode section has an arc length of about 23.7 inches and a thickness of 3.5 inches, which is a ratio of the thickness of each anode segment to the pipe diameter of 1 to 14. The arcuate, nondistorted anode segments of each anode section fit closely about the coated surface of the pipeline, and non significant pressure application for bending is required at the end portions of the anode segments during the installation of each anode section on the pipeline. Consequently, no fracturing of the anode segments occurs during the installation of the anode segments on the pipeline. Further, no distortion of the anode segments occurs during cooling of the segments of each anode section after casting.

WHAT WE CLAIM IS:—

1. A sacrificial anode for cathodic protection of a pipeline comprising an even numbered plurality in the range of 4 to 8 arcuate shaped anode segments of sacrificial anode metal adapted to be connected about a corrosible metallic pipeline having a diameter in the range of 20 inches to 72 inches in pipe embracing relationship thereto, said plurality of anode segments being 4 anode segments for a pipeline of pipe diameter in the range of 20 inches to 36 inches, 6 anode segments for a pipeline of pipe diameter in the range of 30 inches to 54 inches, 8 anode segments for a pipeline of pipe diameter in the range of 40 inches to 72 inches. 4 or 6 anode segments for a pipeline of pipe diameter in the range of 30 inches to 36 inches, and 6 or 8 anode segments for a pipeline of pipe diameter in the range of 40 inches to 54 inches, each anode segment comprising at least one metal core cathodic to the anode metal concentrically embedded entirely within the anode metal except for portions of the core extending from opposite end edges of the anode segment, the anode segments being adapted to be directly connected together in pipe embracing relationship by at least one joint formed at or adjacent the ends of the core and each anode segment having a maximum arc length in the range

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of 14 inches to 27 inches and the maximum arc length of each anode segment being determined by the formula:

$$\text{Maximum arc length of anode segment} = \frac{\pi D}{n} - 2''$$

5 wherein D is the diameter of the pipeline in inches and n is the total number of anode segments in the assembly.

2. An anode according to claim 1, in which the ratio of the width of the anode segment to the width of the anode core or total width of the anode cores when more than one core per anode segment is utilized is in the range of 2:1 to 5:1 when at least 50% of the length of that portion of the core or cores embedded in the anode metal has a width of 1 inch or greater and a thickness of 3/16 th inch or greater.

3. A sacrificial anode according to claim 1 or 2, in which each anode segment has a separate metal core embedded therein, said anode segments being adapted to be directly connected one to another at joints formed at or adjacent the ends of the cores.

4. A sacrificial anode according to claim 1 or 2, in which a plurality of the anode segments have a continuous common metal core.

5. An anode according to any one of the preceding claims, wherein the anode segments are in an as-cast, non-rolled condition.

6. An anode according to any one of the preceding claims, wherein the sacrificial anode metal is metallic zinc.

7. An anode according to any one of the preceding claims, wherein the thickness of the core of the anode segment or of each

core of the anode segment when more than one core per segment is employed is in the range of 3/16 th inch to 7/16 th inch when at least 50% of the length of that portion of the core or cores which is embedded in the anode metal has a width of 1 inch or greater.

8. A sacrificial anode comprising a number of anode segments substantially as hereinbefore described and as illustrated in the accompanying drawings.

9. A sacrificial anode and pipeline assembly comprising a corrodible metallic pipeline having a diameter in the range of 20 to 72 inches disposed in an electrolyte, said pipeline having secured thereabout in pipe embracing relationship thereto a sacrificial anode according to any one of the preceding claims, the plurality of anode segments in said sacrificial anode being 4 anode segments for a pipeline of pipe diameter in the range of 20 inches to 36 inches, 6 anode segments for a pipeline of pipe diameter in the range of 30 inches to 54 inches, 8 anode segments for a pipeline of pipe diameter in the range of 40 inches to 72 inches, 4 or 6 anode segments for a pipeline of pipe diameter in the range or 30 inches to 36 inches and 6 or 8 anode segments for a pipeline of pipe diameter in the range of 40 inches to 54 inches and the maximum arc length of each anode segment being determined by the formula:

$$\text{Maximum arc length of anode segment} = \frac{\pi D}{n} - 2''$$

wherein D is the diameter of the pipeline in inches and n is the total of anode segments in the assembly.

10. An assembly according to claim 9, wherein the ratio of the thickness of each anode segment to the pipe diameter is in the range of 1:5 to 1:15 respectively for a pipe diameter in the range of 20 inches to 36 inches and said ratio of segment thickness to pipe diameter is in the range of 1:10 to 1:20 for a pipe diameter in the range of 37 inches to 72 inches.

11. An assembly according to claims 9 or 10, wherein the thickness of the core of the anode segment or of each core of the anode segment when more than one core per

segment is employed is in the range of 3/16 th inch to 7/16 th inch when at least 50% of the length of that portion of the core or cores which is embedded in the anode metal has a width of one inch or greater.

12. A sacrificial anode and pipeline assembly substantially as hereinbefore described and as illustrated in the accompanying drawings.

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