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CTC GLOBAL CORPORATION

UNITED STATES DISTRICT COURT

CENTRAL DISTRICT OF CALIFORNIA

SOUTHERN DIVISION

CTC GLOBAL CORPORATION, a Delaware corporation

Plaintiff,

v.

MERCURY CABLE & ENERGY, INC. d/b/a Mercury Cable & Energy, LLC, a Nevada corporation; ENERGY TECHNOLOGIES INTERNATIONAL COMPANY, a Cook Islands company; ADVANCED TECHNOLOGIES HOLDINGS, LTD., a Belize international business company; RONALD MORRIS, an individual; TODD HARRIS, an individual; and DOES 1-10.

Defendants.

Case No. SACV13 - 00753 JVS (ANx)

COMPLAINT FOR PATENT INFRINGEMENT AND UNFAIR COMPETITION BASED ON VIOLATION OF LANHAM ACT

DEMAND FOR JURY TRIAL

Plaintiff CTC Global Corporation files this Complaint against defendants Mercury Cable & Energy, Inc. d/b/a Mercury Cable & Energy, LLC ("Mercury"), Advanced Technology Holdings, Ltd., Energy Technologies International Company, Ronald Morris, Todd Harris, and Does 1-10, and demanding a trial by jury, alleges as follows:

JURISDICTION AND VENUE

1. This is an action for patent infringement arising under the patent laws of the United States, Title 35 of the United States Code. This Court has original jurisdiction over the subject matter of this action pursuant to 28 U.S.C. §§ 1331 and 1338(a).

2. This is also an action for unfair competition based on violations of Section 43(a) of the Lanham Act as set forth in 15 U.S.C. § 1051 et seq. which prohibits any person from utilizing in commerce any word, term, name, symbol, or device, or any combination thereof, or any false designation of origin, false or misleading description of fact, or false or misleading representation of fact, that among other things, misrepresents the nature, characteristics, qualities or geographic origin of his or another person's goods, services, or commercial activities.

3. Venue is proper in this Court under 28 U.S.C. §§ 1391(b) and (c), and 1400(a) and (b).

THE PARTIES

4. Plaintiff CTC Global Corporation ("CTC Global") is a corporation organized and existing under the laws of the State of Delaware with its principal place of business at 2026 McGaw Avenue, Irvine, California 92614, within this judicial district.

5. CTC Global acquired the patents at issue in this action, U.S. Patent Nos. 7,368,162 ("'162 patent") and 7,211,319 ("'319 patent"), from the bankruptcy estate of Composite Technology Corporation.

6. More specifically, Composite Technology Corporation filed for bankruptcy in April, 2011 before the United States Bankruptcy Court for the Central District of California ("Bankruptcy Court"),

7. In August of 2011, CTC Global was formed. CTC Global is a separate company with different ownership and different management than CTC.

8. On August 4, 2011, Composite Technology Corporation and CTC Global entered into an agreement for the sale of assets including the '162 and '319 patents.

9. The Bankruptcy Court approved this sale in an order dated August 11, 2011 (the "Sale Order"), which provided that CTC Global acquired all right, title and interest to the '162 and '319 patents, as well as all rights to bring any claims for infringement of those patents. The August 11, 2011 Sale Order also stated that CTC Global's acquisition of the '162 and '319 patents was to be free and clear of any liens, encumbrances, claims or restrictions of any nature whatsoever.

10. CTC Global and its claims for patent infringement set forth herein are not related to any ongoing proceedings in the bankruptcy estate of Composite Technology Corporation. Even with respect to the previously-existing patent litigation between Composite Technology Corporation and Defendant Mercury that is currently stayed in light of the bankruptcy proceedings, the Bankruptcy Court recently stated as follows in an Order dated April 1, 2013:

> "Now that the sale of assets has been completed, the bankruptcy estate [of Composite Technology Corporation] and this Court no longer possess any significant concerns regarding the future prosecution of the Patent Litigation. The prosecution of the Patent Litigation by CTC Global has no meaningful effect, one way or another, on the bankruptcy estate. Based on the Debtors' and the Official Committee of Unsecured

> Creditors' silence regarding the recent activities to lift the stay in the District Court, it is our belief that the Debtors intended to transfer the future prosecution of the Patent Litigation to CTC Global.... [T]he courtesies extended by the District Court's extension of the stay throughout the pendency of these bankruptcy cases have now ceased to be required, with our gratitude. If the District Court so desires, lifting of the litigation stay will cause no issue with, or have any further effect on, the proceedings before this Court." [Case 8:11-bk-15058-SC, April 1, 2013 Order, Dkt. No. 656.]

11. CTC Global paid valuable consideration for all right, title and interest in the '162 and '319 patents, as well as all rights to bring any claims for infringement of those patents, free and clear of any encumbrances whatsoever. In view of foregoing, CTC Global has standing to bring the patent claims asserted herein. CTC Global also has standing to bring the unfair competition claim asserted herein. As such, CTC Global now brings this action against the following defendants.

12. Defendant Mercury is, upon information and belief, a corporation organized under the laws of the State of Nevada, and doing business as Mercury Cable & Energy, and having a place of business at 30448 Rancho Viejo Road, San Juan Capistrano, California 92675, and doing business in this judicial district, including business related to the claims asserted in this Complaint.

13. Defendant Energy Technologies International Company ("ETIC") is, upon information and belief, a corporation organized under the laws of the Cook Islands by Defendant Mercury, is merely an alter ego of Defendant Mercury, and is doing business in this judicial district, including business related to the claims asserted in this Complaint. On information and belief, Defendant ETIC was formed

at the direction of Mercury officers including Defendant Morris. On information and belief, Defendant ETIC is a part owner of a Chinese based company known as Mercury Composites Co., Ltd. ("Mercury Composites") which operates a facility in Hai'an, China producing carbon and glass reinforced composite core conductors for electric power companies. Defendant ETIC operates out of the same offices as Defendant Mercury and utilizes Defendant Mercury's email address.

14. Defendant Advanced Technologies Holdings, Ltd. ("ATH") is, upon information and belief, an international business company, organized under the laws of the country of Belize by the Individual Mercury Defendants. On information and belief, Defendant ATH is merely an alter ego of the Individual Mercury Defendants and is doing business in this judicial district, including business related to the claims asserted in this Complaint.

15. CTC Global alleges on information and belief that Defendant Ronald Morris is the Chief Executive Officer, a director, and a principal shareholder of Defendants Mercury, ATH and ETIC, and that Defendant Morris directs, conducts, controls and/or ratifies the actions of Defendants Mercury, ATH, and ETIC, including directing, conducting, controlling or ratifying (i) the unauthorized infringement of the '162 and '319 patents, as well as (ii) the conduct that forms the basis for CTC Global's unfair competition claim. Defendant Morris is a resident of this judicial district and is also doing business in this judicial district, including business related to the claims asserted in this Complaint.

16. CTC Global alleges on information and belief that Defendant Todd Harris is the president, director, and a principal shareholder of Defendants Mercury, ATH and ETIC, and that Defendant Harris directs, conducts, controls and/or ratifies the actions of Defendants Mercury ATH, and ETIC, including directing, conducting, controlling, or ratifying (i) the unauthorized infringement of the '162 patent and the '319 patent, as well as (ii) the conduct that forms the basis for CTC Global's unfair competition claim. Defendant Harris is a resident of this judicial

district and is also doing business in this judicial district, including business related to the claims asserted in this Complaint.

17. Defendant Mercury, Defendant ETIC, Defendant ATH, Defendant Morris, and Defendant Harris are collectively referred to as "the Mercury Defendants."

18. Defendant Morris and Defendant Harris are collectively referred to as "the Individual Mercury Defendants."

19. CTC Global alleges on information and belief that the Individual Mercury Defendants have repeatedly abused the corporate structure in an effort to hide evidence concerning their business dealings, including conduct related to the claims asserted in this Complaint. Specifically, the Individual Mercury Defendants have formed multiple "shell" corporate entities solely to escape liability for their wrongful conduct. These shell corporations, which include both Belizean and Cook Islands corporations, include at least the following entities:

a. Mercury Cable & Energy, Inc.,

b. Mercury Cable & Energy, LLC,

c. Mercury Composite Company Ltd.,

d. Energy Technologies International Company,

e. Energy Technologies International, LLC ,

f. Mercury (Huizhou) Composites Co. Ltd,

g. Global Energy Technologies Ltd., and

h. Advanced Technology Holdings Ltd.

20. On information and belief, these corporate entities are "shells" that are mere alter egos of the Individual Mercury Defendants. In particular, CTC Global alleges on information and belief that the Individual Mercury Defendants have given little respect to the separate identity of the above corporations, including, for example, a disregard of corporate formalities. In addition, recognition of the corporate form here would either sanction a fraudulent intent to evade liability, or

promote injustice to CTC Global. Because of the Individual Mercury Defendants' abuse of the corporate structure, it is appropriate to pierce the corporate veil and hold the Individual Mercury Defendants liable for any and all wrongful conduct of the shell corporations Defendants Mercury, ATH, and ETIC behind which they have sought to hide, including liability for the claims for patent infringement and unfair competition set forth in this Complaint.

21. CTC Global is ignorant of the true names and capacities of the defendants sued herein under the fictitious names Does One through Ten, inclusive (the "Doe Defendants"). Upon information and belief, the Doe Defendants are involved with Defendants and/or the activities alleged herein, but CTC Global has been unable to identify the names of the Doe Defendants from public records or other information available to CTC Global. Accordingly, CTC Global has sued the Doe Defendants by their fictitious names. CTC Global will seek leave to amend this Complaint to allege the true names and capacities of the Doe Defendants when ascertained.

22. CTC Global is informed and believes and, on that basis, alleges that the Doe Defendants, and each of them, are responsible in some manner, by their acts and omissions, for the matters alleged herein. CTC Global is further informed and believes and, on that basis, alleges that the Doe Defendants, and each of them, at all material times herein alleged, were the agents, servants or employees of the other Defendants.

23. Upon information and belief, at all times relevant herein, Defendants were the agents of each other, and in the course of the conduct alleged herein, each Defendant was acting within the course and scope of its, his or her agency and was subject to and under the supervision of the other Defendants.

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THE '162 AND '319 PATENTS AND THEIR REVOLUTIONARY TECHNOLOGY

24. The '162 and '319 patents at issue in this action cover technology in the field of electricity transmission relating to electrical conductors or power lines that are hung between towers in a power grid. This patented technology represents a revolutionary advance in electricity transmission.

25. For over 100 years, bare overhead electrical transmission cables around the world have used the same technology: strands of steel wire comprising a central "core" that provides the strength necessary to hang the cables between towers, with aluminum wire stranded around this core to conduct electricity. This type of cable is referred to as Aluminum Conductor Steel Reinforced ("ACSR"). This dated design has serious limitations. For example, the steel core used in this design is heavy and expands from the heat caused by electrical resistance when electricity flows through the aluminum conductor.

26. Once heated, the steel core expands and causes the ACSR cable to sag significantly. When ACSR cables sag, they may hit trees or other objects causing power outages and other problems, including devastating fires. The heat caused by electrical resistance (and subsequent conductor sag) also limits how much electricity may be transmitted through ACSR cables.

27. The technology of the '162 and '319 patents overcame the significant drawbacks of the traditional ACSR conductor by replacing the steel core with a high strength, lightweight, and sag-resistant composite "core." Trapezoidal shaped conductive aluminum wire is then typically stranded around this innovative composite core. A commercial embodiment of the '162 and '319 patents sold by CTC Global is the ACCC® conductor.

28. The composite core in the ACCC® conductor utilizes lightweight fibers, *e.g.*, carbon and glass, that are stronger and lighter than steel. This allows the composite core to comprise less volume of the overall conductor than does the

steel core in a similarly sized ACSR conductor. This in turn allows more conductive aluminum to be stranded around the composite core without any increased overall weight or diameter when compared to the conventional ACSR conductor. These attributes provide increased electrical capacity, and substantially reduced line losses, decreased thermal sag and improved reliability.

29. The revolutionary technology of the '162 and '319 patents provides increased efficiency in electricity transmission that benefits the population of the United States and the world. The revolutionary technology of the '162 and '319 patents also helps avoid the dangers of sagging power lines that can cause catastrophic power outages, fires and other problems.

30. The revolutionary technology of the '162 and '319 patents also represents the culmination of years and years of development efforts and costs. At the end of the day, Defendants are engaging in blatant and willful patent infringement and unfair competition, and are unfairly riding the coattails of this development.

THE VALIDITY OF THE '162 AND '319 PATENTS IS CONFIRMED TWICE BY TWO ROUNDS OF REEXAMINATION PROCEEDINGS

31. The '319 and '162 patents originally issued in 2007 and 2008, respectively. Like any patent issued by the Patent Office, the '162 and '319 patents enjoyed a presumption of validity.

32. In 2009, several years prior to its bankruptcy, Composite Technology Corporation brought an action against Mercury for infringement of the '162 and '319 patents. Later in 2009, Mercury initiated reexaminations of both patents based on several prior art references and obtained a stay of the litigation. In reality, Mercury's initiation of these reexaminations was nothing more than an attempt to escape liability for patent infringement. However, both patents emerged from reexamination in 2010 with only minor changes to their existing claims. A number of new claims were also added to each patent. Accordingly, the validity of the '162

and '319 patents was upheld. Furthermore, Mercury's HVCRC products infringed the claims of the reexamined '162 and '319 patents.

33. In 2011, Mercury initiated a second round of reexaminations of the '162 and '319 patents based on different prior art. As with the first round of reexaminations in 2009, Mercury initiated the second round of reexaminations in a further attempt to escape liability for patent infringement. But once again, both patents emerged from reexamination with only minor changes to their claims. In fact, an author of Mercury's cornerstone item of prior art in these second reexaminations actually confirmed that the claims of the '162 and '319 patents were valid over this prior art. Accordingly, the validity of the '162 and '319 patents was upheld a second time. Furthermore, Mercury's HVCRC products infringed the claims of the twice-reexamined '162 and '319 patents.

34. After twice failing to invalidate the '162 and '319 patents and escape liability for patent infringement through reexamination proceedings, Mercury continues to infringe. Accordingly, CTC Global brings this action against the Defendants for their willful infringement of patents that have been examined by the Patent Office three times.

DEFENDANTS' INFRINGEMENT AND UNFAIR COMPETITION

35. Defendant Mercury was formed by several individuals, including Defendant Morris, who had consulted for Composite Technology Corporation several years before its bankruptcy. In their consulting roles, Defendant Morris and the other consultants gained intimate knowledge of the technology related to the '162 and '319 patents and the ACCC® conductor.

36. Defendant Mercury distributes products that it refers to as the High Voltage Composite Reinforced Conductor ("HVCRC"). Mercury's HVCRC products include a composite core as well as the overall conductor wherein the composite core is stranded with trapezoidal shaped aluminum conductor.

Mercury's composite core, and its HVCRC conductors both infringe the '162 and '319 patents.

37. CTC Global recently learned from Mercury's own court-filed documents in Mercury's lawsuit against one of its former officers, that Mercury exports the carbon and glass fibers used in its HVCRC core outside of the United States where these fibers are used to produce composite core. This exportation also constitutes infringement because the production of composite core based on these exported components would constitute infringement if this production occurred within the United States.

38. Mercury's infringement is willful when considering, for example, that Mercury searched high and low for all prior art it could find in attempts to invalidate the '162 and '319 patents through two rounds of reexamination proceedings. However, the prior art that Mercury uncovered did not serve to invalidate the '162 and '319 patents, and Mercury failed twice in its attempts to avoid liability through reexaminations. Despite the validity of these patents, as evidenced by the fact that they have been examined by the Patent Office a total of three times, Mercury still sees fit to distribute infringing HVCRC products.

39. Besides its willful patent infringement, the Mercury Defendants have also unfairly competed with CTC Global since CTC Global was formed in August 2011. As set forth in more detail below in CTC Global's fifth cause of action, the Mercury Defendants' strategy is premised on a platform of false and misleading statements, or statements for which they have no good faith belief are true, regarding their business, that they disseminate and promote to the marketplace through their web site, publications and other promotions.

40. Since August 2011 when CTC Global was formed, the Mercury Defendants' statements include: Mercury states that it is a leading developer of conductor products, when in fact it has not devoted anywhere near the time and money necessary to develop a product of the type at issue; Mercury states that it has

developed the next generation conductor, when in fact Mercury has no proven track record of its products being installed and operating successfully in a real life power grid for a sufficient length of time; Mercury falsely represents the extent of its manufacturing capabilities with a focus in China, when in fact its China facility was recently seized by the Chinese government; Mercury states to the marketplace that it has a number of partnerships with companies that provide Mercury with significant capabilities, when in fact many of these relationships do not exist; Mercury states that it has an extensive patent portfolio, when in reality at least several of its patents were fraudulently obtained; Mercury misrepresents the capabilities and credentials of its technical staff; Mercury has made unfounded statements that its HVCRC products are superior to CTC Global's ACCC® conductor, when in fact CTC Global's ACCC® conductors have a proven track record while Mercury's HVCRC do not.

41. Defendants' pattern of false and misleading statements has deceived, or at least has the tendency to deceive the marketplace. For example, Defendants' false statements have conditioned the market to incorrectly believe that Mercury's HVCRC product is a viable alternative to CTC Global's ACCC® conductor. CTC Global has been harmed and/or is likely to be harmed by Defendants' false and misleading statements. For example, CTC Global has suffered price erosion, and has had to engage in business on less favorable terms in connection with the distribution of its ACCC® conductor than it would have otherwise in the absence of Defendants' unfair competition.

42. In reality, Mercury's HVCRC products are based on technology that infringes on CTC Global's '162 and '319 patents. Indeed, during the development of Defendant Mercury's HVCRC product, several representatives for Defendant Mercury have referred to Defendant Mercury's HVCRC conductor as a "clone" of the patented ACCC® product. If anything, Mercury has ridden the developmental coattails of CTC with its infringing core and has thus been unjustly enriched.

FIRST CAUSE OF ACTION

(As to all Defendants: Infringement of U.S. Patent No. 7,368,162
Based on 35 U.S.C. § 271(a)-(c))

43. CTC Global repeats, realleges and incorporates by reference, as though fully set forth herein, the allegations contained in all preceding and subsequent paragraphs.

44. CTC Global is the owner of the '162 patent. The '162 patent was duly and legally issued by the United States Patent Office on May 6, 2008, and is valid and subsisting and in full force and effect. A copy of the '162 patent is attached to the Complaint as **Exhibit A**. A copy of Reexamination Certificate No. 7,368,162 C1 that issued on June 8, 2010 and that sets forth the claims that were allowed by the U.S. Patent Office following the first reexamination of the '162 patent is attached to the Complaint as **Exhibit B**. A copy of Reexamination Certificate No. 7,368,162 C2 ("Second '162 Reexamination Certificate") that issued on May 8, 2012 and that sets forth the claims that were allowed by the U.S. Patent Office following the second reexamination of the '162 patent is attached as **Exhibit C**. References to the '162 patent below generally relate to the Second '162 Reexamination Certificate unless otherwise stated.

45. The '162 patent contains claims that cover both a composite core for an overhead electrical cable as well as an overhead electrical cable including a composite core. Defendants have infringed the '162 patent under 35 U.S.C. § 271(a) by, themselves and/or through their agents, unlawfully and wrongfully making, using, offering to sell, selling and/or importing into the United States, products, including its HVCRC products, embodying one or more of the inventions claimed therein, within the United States without permission or license from CTC Global. Defendants will continue to do so unless enjoined by this Court. Defendants' infringement has involved both the composite core and conductor or cable used in its HVCRC products.

46. Defendants have also infringed the '162 patent under 35 U.S.C. § 271(b) or (c) by supplying infringing HVCRC products to others to use, thereby inducing and/or contributing to the infringement of the '162 patent. On information and belief, this infringement has included Defendants' distribution of infringing HVCRC products to customers and other third parties with the intention that such customers and third parties use Defendants' HVCRC products to infringe the '162 patent. On information and belief, this infringement has also occurred by Defendants' distribution of components, such as composite core, that Defendants know are especially made for use with Defendants' HVCRC products and that are not staple articles or commodities of commerce suitable for substantial noninfringing use. Defendants will continue to do so unless enjoined by this Court.

47. Defendants' continuing infringement has inflicted and, unless restrained by this Court, will continue to inflict great and irreparable harm upon CTC Global. CTC Global has no adequate remedy at law. CTC Global is entitled to preliminary and permanent injunctions enjoining Defendants from engaging in further acts of infringement.

48. As a direct and proximate result of the foregoing acts of Defendants, CTC Global has suffered, and is entitled to, monetary damages in an amount not yet determined. CTC Global is also entitled to its costs of suit and interest.

49. Defendants have notice and knowledge of the '162 patent, and of CTC Global's rights therein.

50. Upon information and belief, Defendants' acts were in conscious and willful disregard for CTC Global's rights, and the resulting damage to CTC Global is such as to warrant the trebling of damages to provide just compensation.

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SECOND CAUSE OF ACTION

(As to all Defendants: Infringement of U.S. Patent No. 7,368,162
Based on 35 U.S.C. § 271(f) re Exportation of Components)

51. CTC Global repeats, realleges and incorporates by reference, as though fully set forth herein, the allegations contained in all preceding and subsequent paragraphs.

52. On information and belief, the Defendants also supply or cause to be supplied in or from the United States, components of one or more of the inventions claimed by the '162 patent to locations outside of the United States in an effort to evade United States patent laws. For example, the Mercury Defendants sell and export component materials, including glass fibers and military grade carbon, to their affiliates outside of the United States including Mercury Composites in China. In turn, the Mercury Defendants and the Individual Mercury Defendants actively induce and direct Mercury Composites to combine these components outside the United States to form HVCRC products.

53. The combination of these components outside of the United States would infringe the '162 patent if such combination occurred within the United States. On information and belief, the Mercury Defendants also perform similar export, integration and combination activities in India and/or South Korea. The Mercury Defendants then market for sale their infringing HVCRC products in both the United States and internationally.

54. On information and belief, Defendants have infringed and are currently infringing the '162 patent in violation of 35 U.S.C. § 271(f)(1) by, among other things, supplying or causing to be supplied in or from the United States, all or a substantial portion of the components of one or more of the inventions claimed by the '162 patent, where such components are uncombined in whole or in part, in such a manner as to actively induce the combination of such components outside

the United States in a manner that would infringe the '162 patent, if such combination occurred within the United States.

55. On information and belief, Defendants have infringed and are currently infringing the '162 patent in violation of 35 U.S.C. § 271(f)(2) by supplying or causing to be supplied in or from the United States components of one or more inventions claimed by the '162 patent, including composite core, that are especially made or especially adapted for use in the invention and not a staple article or commodity of commerce suitable for substantial noninfringing use, where such component is uncombined in whole or in part, knowing that such component is so made or adapted and intending that such component will be combined outside of the United States in a manner that would infringe the '162 patent if such combination occurred within the United States.

56. Defendants' continuing infringement has inflicted and, unless restrained by this Court, will continue to inflict great and irreparable harm upon CTC Global. CTC Global has no adequate remedy at law. CTC Global is entitled to preliminary and permanent injunctions enjoining Defendants from engaging in further acts of infringement.

57. As a direct and proximate result of the foregoing acts of Defendants, CTC Global has suffered, and is entitled to, monetary damages in an amount not yet determined. CTC Global is also entitled to its costs of suit and interest.

58. Defendants have notice and knowledge of the '162 patent and of CTC Global's rights therein.

59. Upon information and belief, Defendants' acts were in conscious and willful disregard for CTC Global's rights, and the resulting damage to CTC Global is such as to warrant the trebling of damages to provide just compensation.

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THIRD CAUSE OF ACTION

(As to all Defendants: Infringement of U.S. Patent No. 7,211,319
Based on 35 U.S.C. § 271(a)-(c))

60. CTC Global repeats, realleges and incorporates by reference, as though fully set forth herein, the allegations contained in all preceding and subsequent paragraphs.

61. CTC Global is the owner of United States Patent No. 7,211,319 (the "'319 patent"). The '319 patent was duly and legally issued by the United Sates Patent Office on May 1, 2007, and is valid and subsisting and in full force and effect. A copy of the '319 Patent is attached to the Complaint as **Exhibit D**. A copy of Reexamination Certificate No. 7,211,319 C1 that issued on June 1, 2010 and that sets forth the claims that were allowed by the U.S. Patent Office following the first reexamination of the '319 Patent is attached to the Complaint as **Exhibit E**. A copy of Reexamination Certificate No. 7,211,319 C2 ("Second '319 Reexamination Certificate") that issued on June 5, 2012 and that sets forth the claims that were allowed by the U.S. Patent Office following the second reexamination of the '319 Patent is attached as **Exhibit F**. References to the '319 patent below generally relate to the Second '319 Reexamination Certificate unless otherwise stated.

62. The '319 patent contains claims that cover both a composite core for an overhead electricity transmission cable, as well as an overhead electrical cable including a composite core. Defendants have infringed the '319 patent under 35 U.S.C. § 271(a) by, themselves and/or through their agents, unlawfully and wrongfully making, using, offering to sell, selling and/or importing into the United States, products, including its HVCRC products, embodying one or more of the inventions claimed therein, within the United States without permission or license from CTC Global. Defendants will continue to do so unless enjoined by this Court.

Defendants' infringement has involved both the composite core and the overhead electrical cable used in its HVCRC products.

63. Defendants have also infringed the '319 patent under 35 U.S.C. § 271(b) or (c) by supplying infringing HVCRC products to others to use, thereby inducing and/or contributing to the infringement of the '319 patent. On information and belief, this infringement has included Defendants' distribution of infringing HVCRC products to customers and other third parties with the intention that such customers and third parties use Defendants' HVCRC products to infringe the '319 patent. On information and belief, this infringement has also occurred by Defendants' distribution of components, such as composite core, that Defendants know are especially made for use with Defendants' HVCRC products and that are not staple articles or commodities of commerce suitable for substantial noninfringing use. Defendants will continue to do so unless enjoined by this Court.

64. Defendants' continuing infringement has inflicted and, unless restrained by this Court, will continue to inflict great and irreparable harm upon CTC Global. CTC Global has no adequate remedy at law. CTC Global is entitled to preliminary and permanent injunctions enjoining Defendants from engaging in further acts of infringement.

65. As a direct and proximate result of the foregoing acts of Defendants Mercury, CTC Global has suffered, and is entitled to, monetary damages in an amount not yet determined. CTC Global is also entitled to its costs of suit and interest.

66. Defendants have notice and knowledge of the '319 patent and of CTC Global's rights therein.

67. Upon information and belief, Defendants' acts were in conscious and willful disregard for CTC Global's rights, and the resulting damage to CTC Global is such as to warrant the trebling of damages to provide just compensation.

FOURTH CAUSE OF ACTION

(As to all Defendants: Infringement of U.S. Patent No. 7,211,319 Based on 35 U.S.C. § 271(f) re Exportation of Components)

68. CTC Global repeats, realleges and incorporates by reference, as though fully set forth herein, the allegations contained in all preceding and subsequent paragraphs.

69. On information and belief, the Defendants also supply or cause to be supplied in or from the United States, components of one or more of the inventions claimed by the '319 patent, to locations outside of the United States in an effort to evade United States patent laws. For example, the Mercury Defendants sell and export component materials, including glass fibers and military grade carbon, to their affiliates outside of the United States including Mercury Composites in China. In turn, the Mercury Defendants and the Individual Mercury Defendants actively induce and direct Mercury Composites to combine these components outside the United States to form HVCRC products.

70. The combination of these components outside of the United States would infringe the '319 patent if such combination occurred within the United States. On information and belief, the Mercury Defendants also perform similar export, integration and combination activities in India and/or South Korea. The Mercury Defendants then market for sale their infringing HVCRC products in both the United States and internationally.

71. On information and belief, Defendants have infringed and are currently infringing the '319 patent, in violation of 35 U.S.C. § 271(f)(1), by, among other things, supplying or causing to be supplied in or from the United States, all or a substantial portion of the components of one or more of the inventions claimed by the '319 patent, where such components are uncombined in whole or in part, in such a manner as to actively induce the combination of such

components outside the United States in a manner that would infringe the '319 patent if such combination occurred within the United States.

72. On information and belief, Defendants have infringed and are currently infringing the '319 Patent in violation of 35 U.S.C. § 271(f)(2) by, supplying or causing to be supplied in or from the United States, components of one or more inventions claimed by the '319 Patent, including composite core, that are especially made or especially adapted for use in the invention and not a staple article or commodity of commerce suitable for substantial noninfringing use, where such component is uncombined in whole or in part, knowing that such component is so made or adapted and intending that such component will be combined outside of the United States in a manner that would infringe the '319 Patent if such combination occurred within the United States.

73. Defendants' continuing infringement has inflicted and, unless restrained by this Court, will continue to inflict great and irreparable harm upon CTC Global. CTC Global has no adequate remedy at law. CTC Global is entitled to preliminary and permanent injunctions enjoining Defendants from engaging in further acts of infringement.

74. As a direct and proximate result of the foregoing acts of Defendants Mercury, CTC Global has suffered, and is entitled to, monetary damages in an amount not yet determined. CTC Global is also entitled to its costs of suit and interest.

75. Defendants have notice and knowledge of the '319 Patent, and of CTC Global's rights therein.

76. Upon information and belief, Defendants' acts were in conscious and willful disregard for CTC Global's rights, and the resulting damage to CTC Global is such as to warrant the trebling of damages to provide just compensation.

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FIFTH CAUSE OF ACTION

(Unfair Competition Based on Violation of Lanham Act, 15 U.S.C. §§ 1051 et seq.)

77. CTC Global repeats, realleges and incorporates by reference, as though fully set forth herein, the allegations contained in all preceding and subsequent paragraphs.

78. Since CTC Global was formed in August 2011, Defendants have violated the Lanham Act by making false and misleading statements, or statements for which they have no good faith belief are true, in its commercial advertising and promotion regarding their business and their HVCRC products. These statements have been disseminated to the marketplace through Defendants' web site, articles in trade publications and through other promotions and materials. These statements have deceived and continue to have the capacity to deceive a substantial segment of potential customers in the market for composite reinforced electrical conductors. These deceptions are material in that they are likely to influence potential customers' purchasing decisions. For example, these statements misrepresent the quality and characteristics of Defendants' HVCRC products and also falsely portray the HVCRC products as having a proven track record. CTC Global has been and will continue to be harmed, and/or is likely to be harmed, as a result of these statements. Since August 2011, these statements have included and continue to include the following.

79. The Mercury Defendants state that they are a leading developer of conductor products based on "10 years of research and development" and that they have spent "in excess of $4.5 million dollars" developing its "revolutionary" product based on Mercury's "innovative design." However, these statements are false for several reasons. First, Mercury did not develop its HVCRC conductor, but instead based its development on its efforts to "clone" CTC Global's ACCC® conductor. Second, Mercury cannot be a leading developer of this technology given the fact that it has no proven track record of its HVCRC products being

installed and operating successfully in a real life power grid for a sufficient length of time. Third, a former officer of Defendant Mercury, Wang Chen, has stated in a sworn affidavit that he was fired as a result of his refusal to comply with Defendant Morris' request to falsify Mercury's financial reports to its investors regarding the manner in which the investors' money had been actually spent. Mr. Chen further stated that Defendants Harris and Morris were infuriated at his efforts to communicate his concerns to other Mercury shareholders because they might request an accounting from them as to how their investment funds were spent. Fourth, the supposed level of monetary investment that Mercury states it expended in developing the HVCRC products would not rise to anywhere near the level of investment required to produce a product of the type at issue. If anything, the level of investment stated by Mercury confirms that Defendants are unjustly riding the coattails of the development that resulted in CTC Global's ACCC® conductor and that Defendants' HVCRC products have no proven track record indicative of a viable product.

80. The Mercury Defendants have also falsely stated that Mercury has developed the next generation conductor and that its own "scientists and engineering team developed the HVCRC technology." The Mercury Defendants have repeatedly held themselves out as an industry leader and as having provided solutions to the problems encountered by transmission grid operations in the United States, China, India and other industrialized and developing nations throughout the world. These statements are false because the Mercury Defendants have no proven track record of Mercury's HVCRC products being installed and operating successfully in a real-life power grid for a sufficient length of time. These statements are also false because the technology used in the HVCRC products are based on infringement of CTC Global's patents.

81. The Mercury Defendants falsely represent the extent of their manufacturing capabilities with a focus in China. For example, the Mercury

Defendants represent that they have a manufacturing facility in China capable of producing commercial quantities of their HVCRC conductor. However, in 2012, the Chinese government seized Mercury Cable's manufacturing facility and it is not operating to produce products for Mercury.

82. The Mercury Defendants also falsely state to the marketplace that Mercury has a number of partnerships with companies that provide it with significant capabilities, when in fact many of these relationships do not exist. To this end, Mercury has stated to the marketplace that "Global Energy Partners Choose Mercury Cable" and that Defendant Mercury has existing partnerships with a number of entities experienced in the manufacture, sale and installation of electrical transmission lines. However, these statements are false.

83. For example, the Mercury Defendants represent on their website that they have an existing partnership with General Cable, an established strander for electrical conductors in the United States. However, no such partnership exists. In actuality, CTC Global has an existing contractual relationship with General Cable, the terms of which provide that General Cable will not strand for any other entity selling composite core reinforced electrical conductors. Moreover, representatives of General Cable have directly refuted Mercury Cable's claim of a partnership.

84. Similarly, the Mercury Defendants have claimed that Mercury has an existing partnership with Wuxi Cable in China. However, no such relationship exists as confirmed by representatives from Wuxi. In actuality, it is CTC Global that currently has a stranding/manufacturing agreement with Wuxi.

85. The Mercury Defendants also state that they have an existing partnership with the University of Southern California. These statements are an attempt to support an illusion that Mercury has a viable conductor product that may be hung between towers at significant distances. However, this representation is also false in that the University of Southern California has merely tested short lengths of Mercury Cable's infringing HVCRC conductor from time to time.

86. These false "partnership" representations have been and continue to be made by the Mercury Defendants in order to falsely portray Mercury as having experience in the industry and an ability to successfully produce, market and install their HVCRC conductor. More specifically, Mercury's misrepresentations create the illusion that it is positioned with other entities in the utility industry to actually deploy product in a real-life power grid for a sufficient length of time. Mercury has no such capability.

87. The Mercury Defendants also falsely state that they have an extensive patent portfolio covering its HVCRC products, when in reality at least several of its patents were fraudulently obtained in China. To this end, in or about 2006, a company named International Energy Technologies, Inc. applied for and obtained a utility model patent in China on a compound reinforced electric transmission conductor. On information and belief, International Energy Technologies, Inc. is the same company as Defendant Energy Technology International Company identified above. The individual identified as the "inventor" of this application in China was Defendant Morris.

88. In reality, the contents of this Chinese utility model patent were copied almost verbatim from U.S. Patent No. 7,015,395 ("the '395 patent"). The '395 patent issued from U.S. Patent Application Serial No. 10/037,814 which was filed in the United States in 2001 naming William Brandt Goldsworthy and George Korzeniowski as inventors. In fact, George Korzeniowski is a named inventor of CTC Global's '162 and '319 patents. Accordingly, several of the Defendants identified above obtained Chinese patent protection on an invention that in reality others had invented and had also patented in the United States, by copying the contents of that United States patent.

89. Beyond the Mercury Defendants' conduct in connection with the '395 patent, they perpetrated the same scheme with regard to a Chinese invention application that matured into a Chinese patent, but was in reality was a copy of U.S.

Patent No. 6,805,596 ("the '596 patent") that covered technology invented by others. In this case, the applicant in China was indicated to be International Energy Technology Co., Ltd. On information and belief, this is the same entity as Defendant ETIC. The "inventors" on this Chinese invention application were identified as Ed Siconiezini [sic – Ed Skonezny] and Wang Chen. Mr. Skonezny is an individual who has participated in the business of Defendant Mercury, and Mr. Chen is the same individual discussed above who stated in a sworn affidavit that Defendant Morris had asked him to falsify Mercury Cable's financial reports to its investors. In this instance, the contents of the '596 patent were copied verbatim by these Defendants in their Chinese invention application and they obtained a Chinese patent.

90. The Mercury Defendants also falsely state, in an attempt to create the illusion of technical expertise sufficient to actually deploy product in real-life situations, the capabilities and credentials of its technical staff. For example, the Mercury Defendants advertise on their website that their Chief Operating Officer, Terry S. McQuarrie, has a Ph.D. However, Mr. McQuarrie has testified under oath that his Ph.D. is actually an honorary degree awarded by an entity called Hamilton University. Hamilton University was unaccredited and closed pursuant to Court order. It had operated out of a former Motel 6 building and issued its "degrees" based on the "life experiences" of its applicants. Hamilton University's founder was recently sentenced to 24 months in prison for tax fraud and Hamilton University has since relocated to the Bahamas under the name of Richardson University.

91. The Mercury Defendants have also made false statements that its HVCRC products are superior to CTC Global's ACCC® conductor, and that the HVCRC conductor is the strongest, lightest, and "most efficient conductor in the world." The Mercury Defendants have further stated that Mercury Cable's "world class production team has consistently produced results that dwarf our competitors

and set new standards for quality." These statements are false because while CTC Global has thousands of miles of ACCC® product installed around the world, the Mercury Defendants have no proven track record of its HVCRC products being installed and operating successfully in a real life power grid for a sufficient length of time. These statements are also false because they are either supported by unreliable tests or studies, and/or not supported by reliable tests or studies.

92. The Defendants have also taken many steps in the United States to coordinate efforts around the world to unfairly compete with CTC Global. For example, the Mercury Defendants and Individual Mercury Defendants have directed the conduct of its affiliates in China and other foreign countries to unfairly compete with CTC Global, wherein much of this conduct is based on the false and misleading statements and conduct referenced above.

93. The false and misleading statements by the Defendants referenced above constitute violations of Section 43(a) of the Lanham Act as set forth in 15 U.S.C. § 1051 et seq. which prohibits, among other things, any person from making false designation of origin, false or misleading description of fact, or false or misleading representation of fact, which is likely to cause confusion, or to cause mistake within the commercial marketplace, or which misrepresent the nature, characteristics, qualities, or geographic origin of his or another's goods, services or commercial activities.

94. Mercury's pattern of false and misleading statements have harmed and/or are likely to harm CTC Global. For example, CTC Global has suffered price erosion and has had to engage in business on less favorable terms in connection with the distribution of its ACCC® conductor. This is at least because Mercury's false statements have conditioned the market to incorrectly believe that its HVCRC is a viable alternative to the ACCC® conductor.

95. The improper acts of Defendants as alleged herein have caused, and unless restrained by this Court will continue to cause, CTC Global great and

irreparable harm for which CTC Global has no adequate remedy at law. CTC Global is entitled to preliminary and permanent injunctive relief enjoining Defendants from engaging in such conduct.

96. As a direct and proximate result of the foregoing acts by these Defendants, CTC Global has suffered and is entitled to monetary damages in an amount to be determined at trial. CTC Global is also entitled to its attorneys' fees and the costs of suit it has incurred and will incur with respect to this litigation.

97. Defendants' acts were in conscious and willful disregard for CTC Global's rights and with intent to deceive the marketplace and the resulting damage to CTC Global is such as to warrant the trebling of damages in order to provide just compensation.

PRAYER FOR RELIEF

WHEREFORE, CTC Global respectfully demands that this Court:

A. Enter judgment that the Defendants have violated the Lanham Act;

B. Enter an order preliminarily and permanently enjoining the Defendants, their members, managers, officers, agents, affiliates, employees, and any others acting in concert with any of them, from unfairly competing with CTC Global;

C. Award CTC Global damages resulting from the Defendant's violation of the Lanham Act, which award is trebled due to the willful nature of Defendant's unfair competition;

D. Enter judgment that the Defendants have directly and indirectly infringed the '162 patent and the '319 patent;

E. Enter an order preliminarily and permanently enjoining the Defendants, their members, managers, officers, agents, affiliates, employees, and any others acting in concert with any of them, from directly or indirectly infringing the '162 patent and the '319 patent;

F. Enter an order precluding the Defendants from servicing, repairing, or providing parts or components for any products that infringe any claim of the '162 patent or the '319 patent;

G. Enter an order preventing the Defendants' exportation of components in violation of 35 U.S.C. § 271(f)(1) or (2);

H. Award CTC damages resulting from the Defendants' patent infringement pursuant to 35 U.S.C. § 284;

I. Find that the Defendants' patent infringement has been willful and increase the damages awarded to CTC Global to three times the amount assessed pursuant to 35 U.S.C. § 284;

J. Find this to be an exceptional case and award CTC Global's attorneys' fees, pursuant to 35 U.S.C. § 285;

K. Award CTC Global its costs and attorneys' fees in connection with this action;

L. Enter an order requiring Defendants to identify, locate, recall and destroy all materials which infringe the '162 patent' or the '319 patent';

M. Enter an order requiring each Defendant to file with the Court and serve upon CTC Global's counsel within thirty (30) days after entry of the order of injunction, a report setting forth the manner and form in which each Defendant has complied with the injunction;

N. Award CTC Global damages for corrective advertising in an amount to be determined at trial;

O. Award CTC Global prejudgment interest and post judgment interest on the damages and award CTC Global's costs;

P. Award CTC Global punitive and exemplary damages in an amount to be determined at trial; and

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DEMAND FOR JURY TRIAL

Pursuant to Federal Rule of Civil Procedure 38(b) and Local Rule 38-1, CTC Global Corporation hereby demands trial by jury on all issues triable in this action.

Dated: May 10, 2013

FAIRFIELD AND WOODS, PC

By: ______________________
Matthew S. Rork

MACEIKO IP

By: ______________________
Theodore S. Maceiko

Attorneys for Plaintiff
CTC GLOBAL CORPORATION

EXHIBIT A

US007368162B2

(12) **United States Patent**
Hiel et al.

(10) **Patent No.: US 7,368,162 B2**
(45) **Date of Patent: *May 6, 2008**

(54) **ALUMINUM CONDUCTOR COMPOSITE CORE REINFORCED CABLE AND METHOD OF MANUFACTURE**

(75) Inventors: **Clem Hiel**, Rancho Palos Verdes, CA (US); **George Korzienowski**, Woodland Hills, CA (US)

(73) Assignee: **CTC Cable Corporation**, Irvine, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 205 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **10/511,881**

(22) PCT Filed: **Apr. 23, 2003**

(86) PCT No.: **PCT/US03/12520**

§ 371 (c)(1),
(2), (4) Date: **Oct. 19, 2004**

(87) PCT Pub. No.: **WO03/091008**

PCT Pub. Date: **Nov. 6, 2003**

(65) **Prior Publication Data**

US 2005/0227067 A1 Oct. 13, 2005

Related U.S. Application Data

(60) Provisional application No. 60/374,879, filed on Apr. 23, 2002.

(51) **Int. Cl.**
B32B 27/04 (2006.01)
H02G 3/00 (2006.01)

(52) **U.S. Cl.** .... **428/300.7**; 428/297.4; 428/299.4; 428/299.1; 428/298.1; 428/300.4; 174/70 R; 174/102 R; 174/106 R; 174/113 C

(58) **Field of Classification Search** .... 428/291.4, 428/298.1, 299.4, 299.1, 300.4, 300.7, 301.4; 174/70 R, 102 R, 106 R, 113 C; 427/384, 427/372.2, 430.1, 434.2, 434.6
See application file for complete search history.

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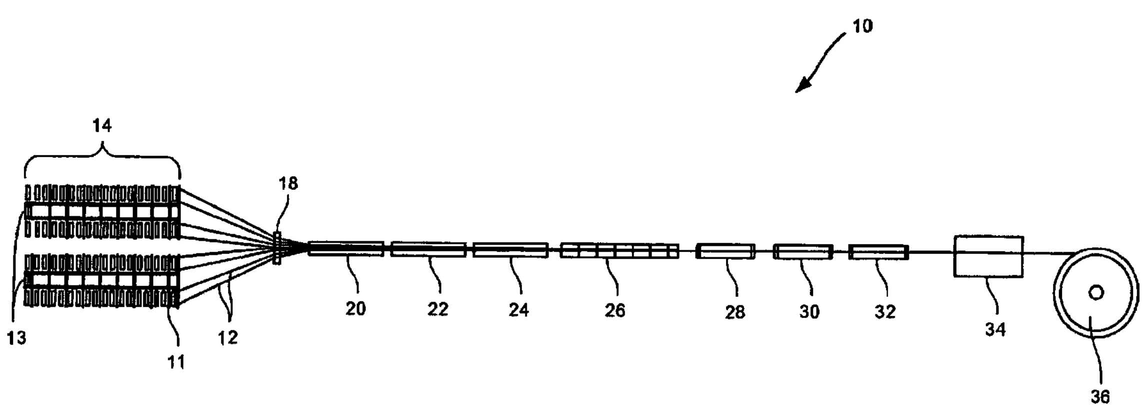
Primary Examiner—Jill Gray
(74) *Attorney, Agent, or Firm*—Brownstein Hyatt Farber Schreck, LLP

(57) **ABSTRACT**

This invention relates to an aluminum conductor composite core reinforced cable (ACCC) and method of manufacture. An ACCC cable having a composite core surrounded by at least one layer of aluminum conductor. The composite core comprises at least one longitudinally oriented substantially continuous reinforced fiber type in a thermosetting resin matrix having an operating temperature capability within the range of about 90 to about 230° C., at least 50% fiber volume fraction, a tensile strength in the range of about 160 to about 240 Ksi, a modulus of elasticity in the range of about 7 to about 30 Msi and a thermal expansion coefficient in the range of about 0 to about 6×10^{-6} m/m/C. According to the invention, a B-stage forming process may be used to form the composite core at improved speeds over pultrusion processes wherein the speeds ranges from about 9 ft/min to about 50 ft/min.

36 Claims, 11 Drawing Sheets



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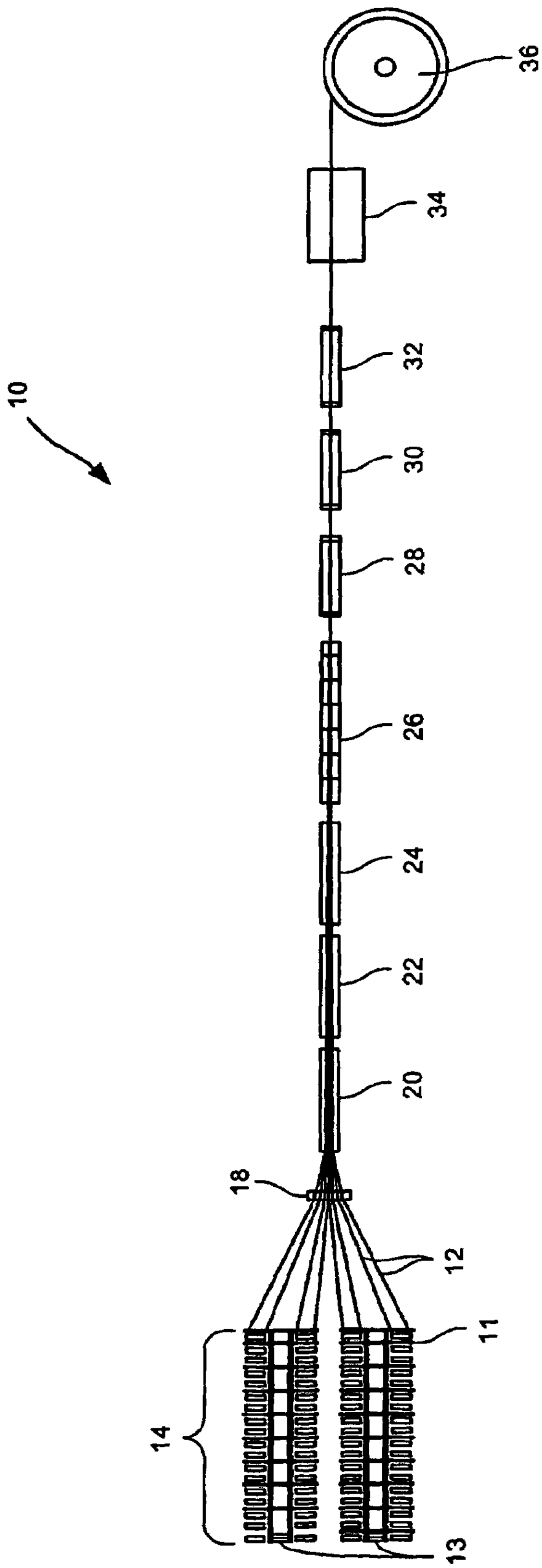

FIG. 1

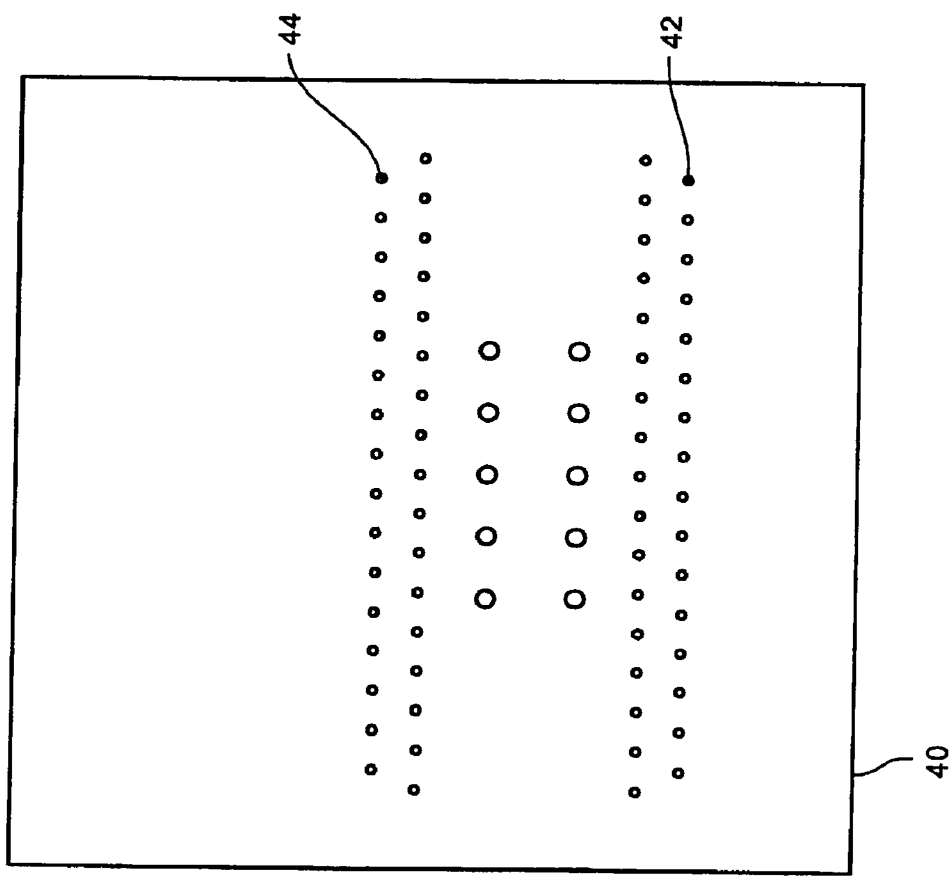

FIG. 2

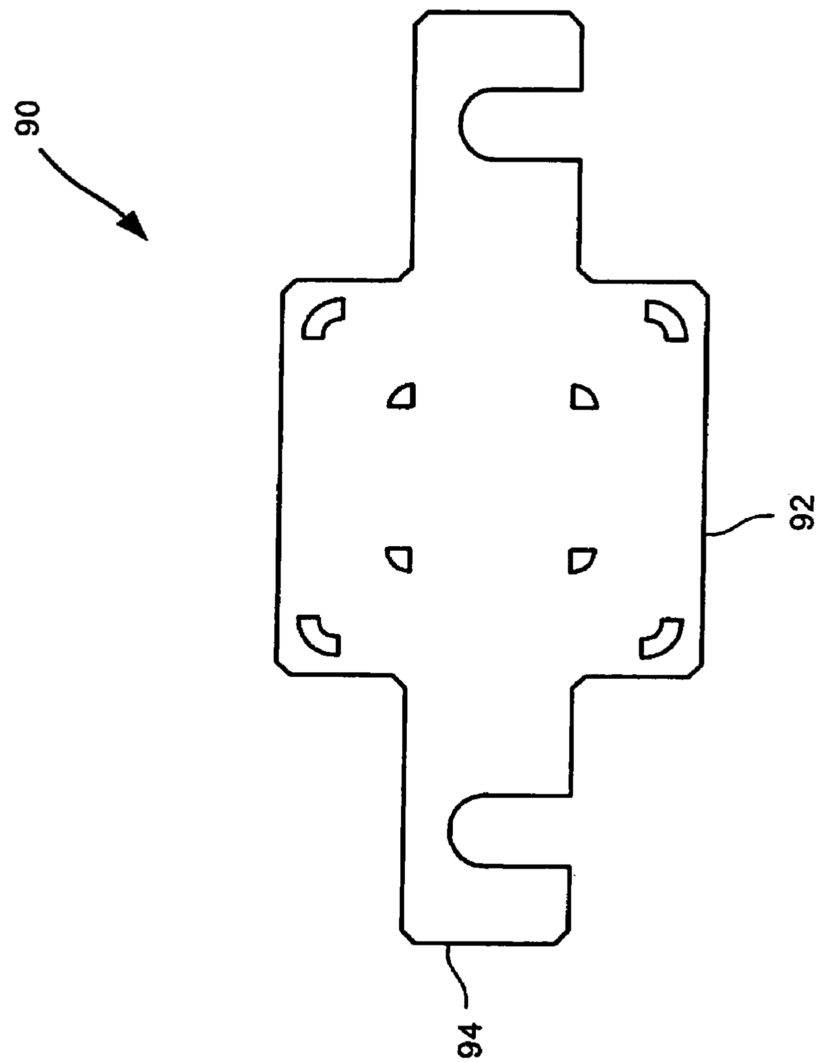

FIG. 3

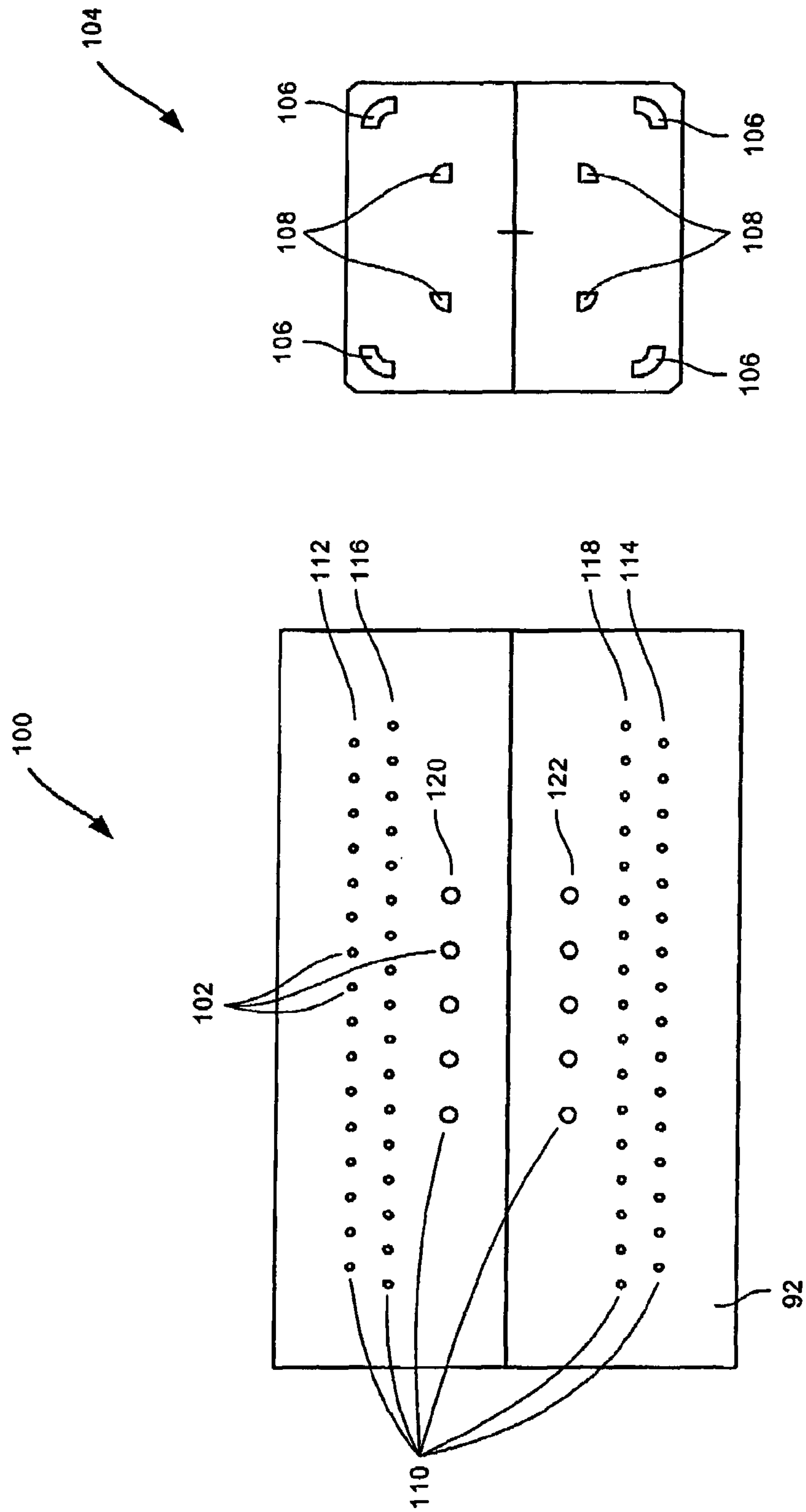
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FIG. 4

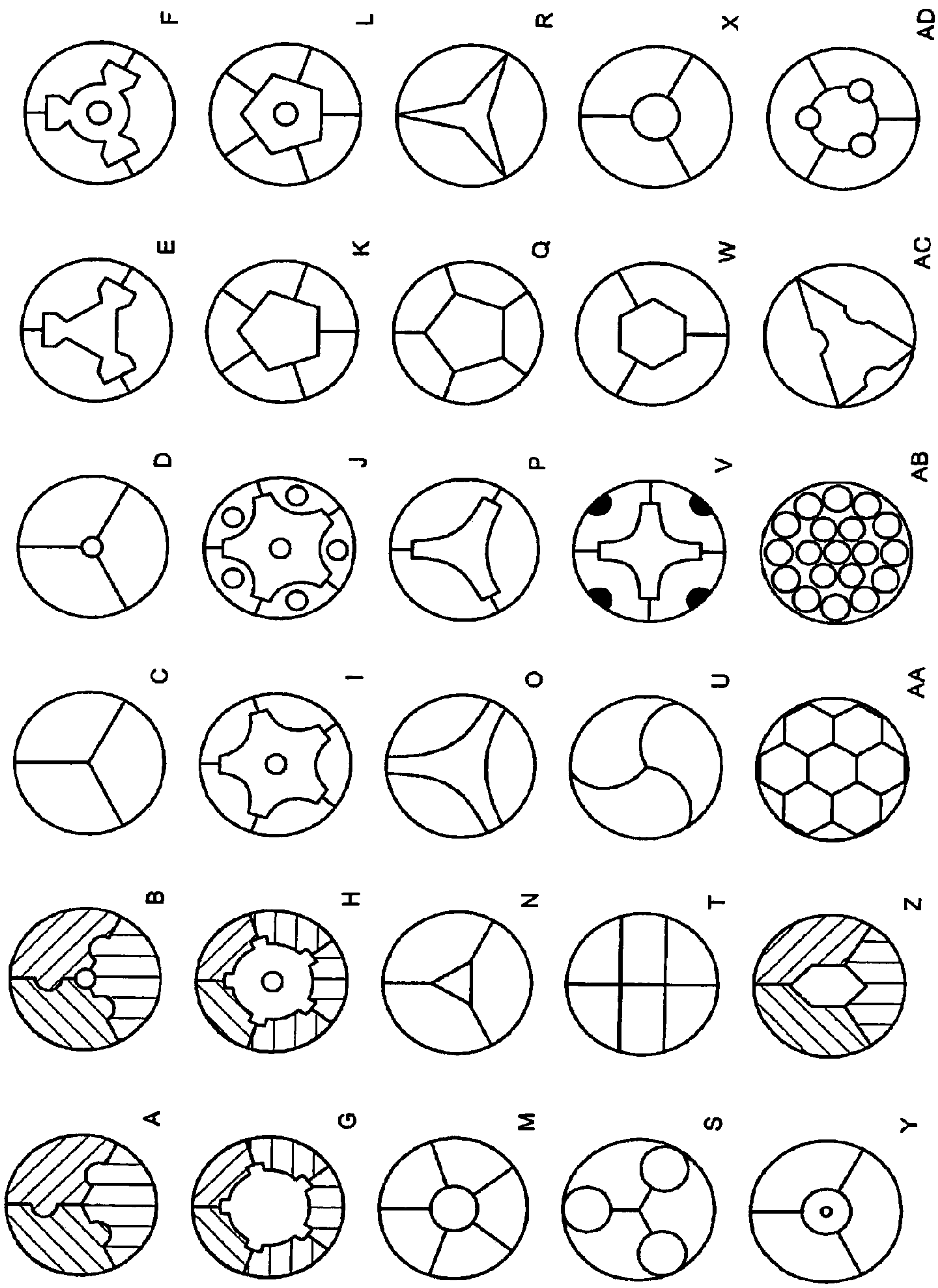

FIG. 5

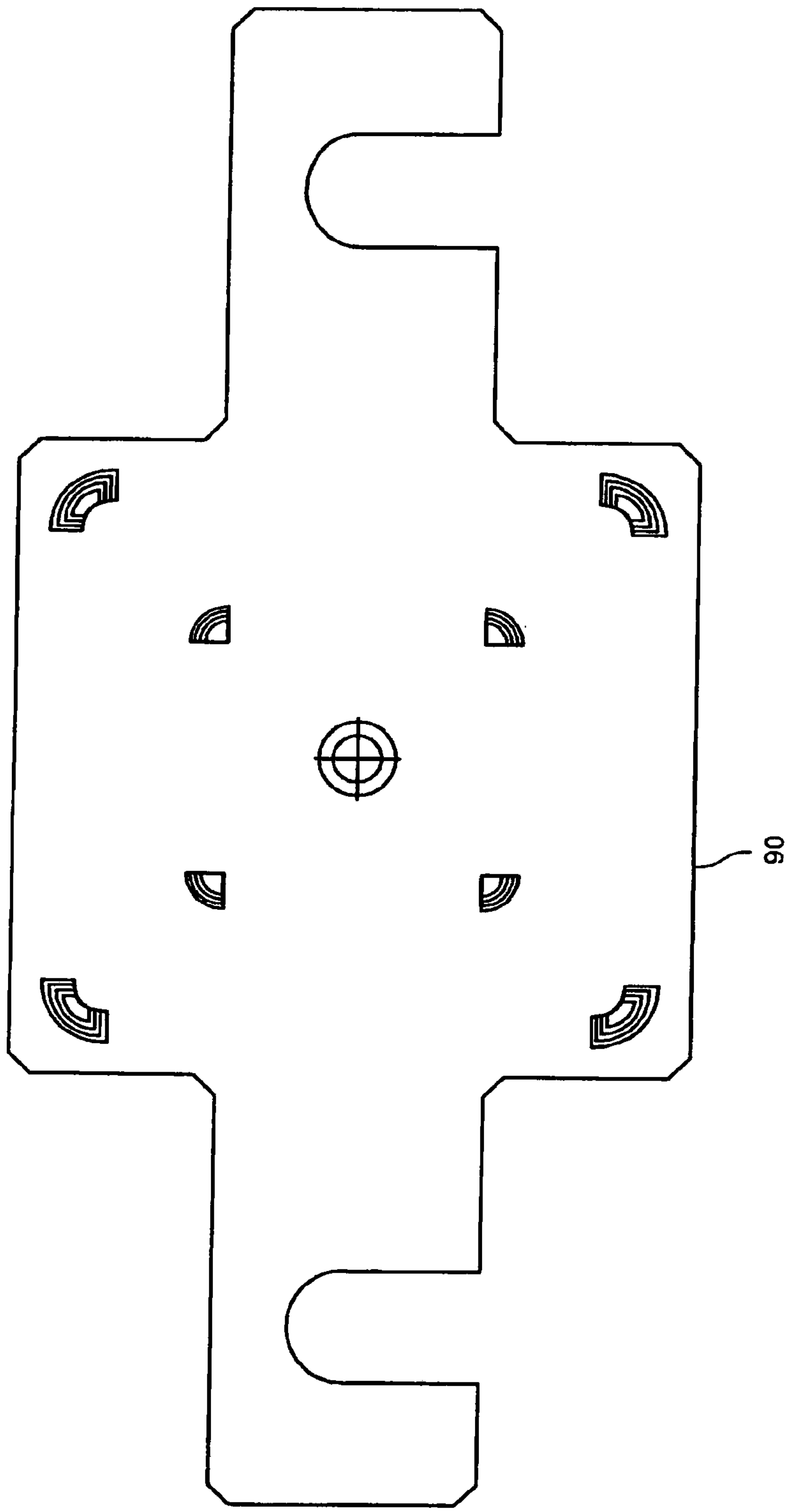

FIG. 6

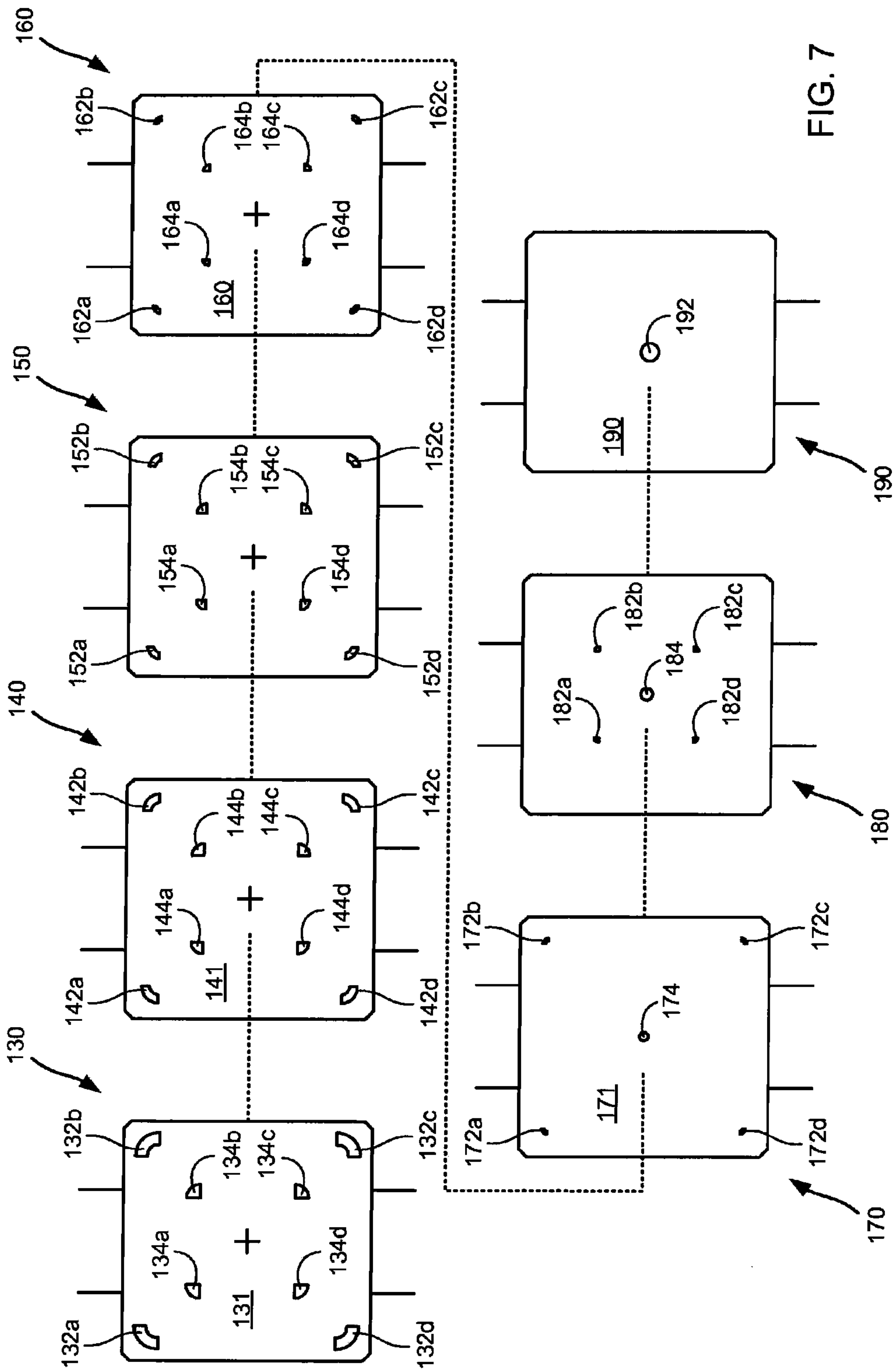
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FIG. 7

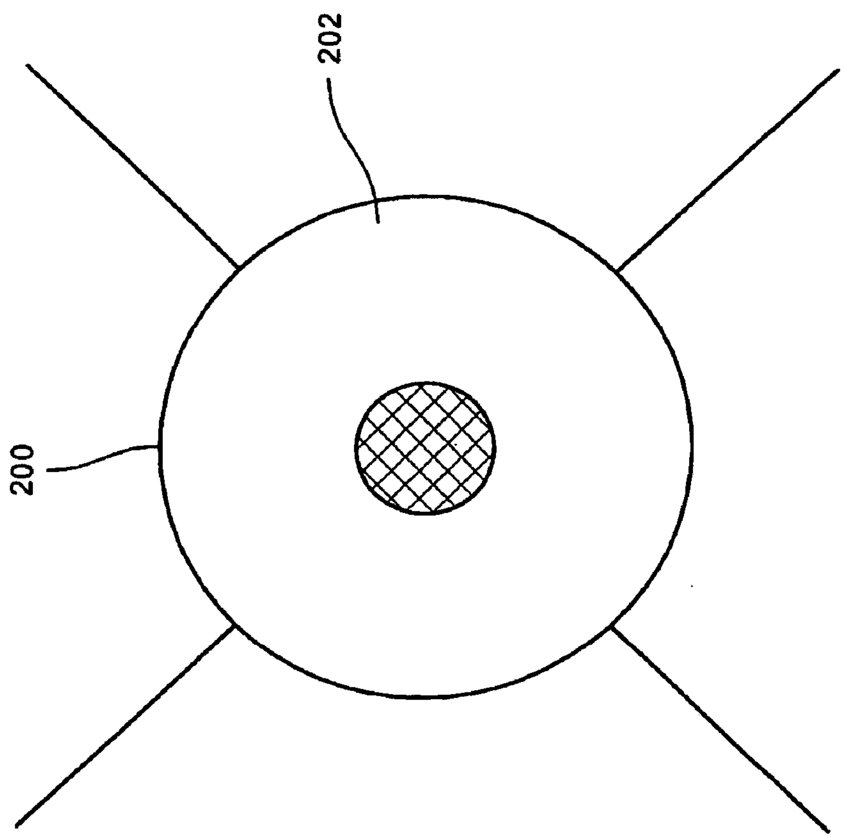


FIG. 8

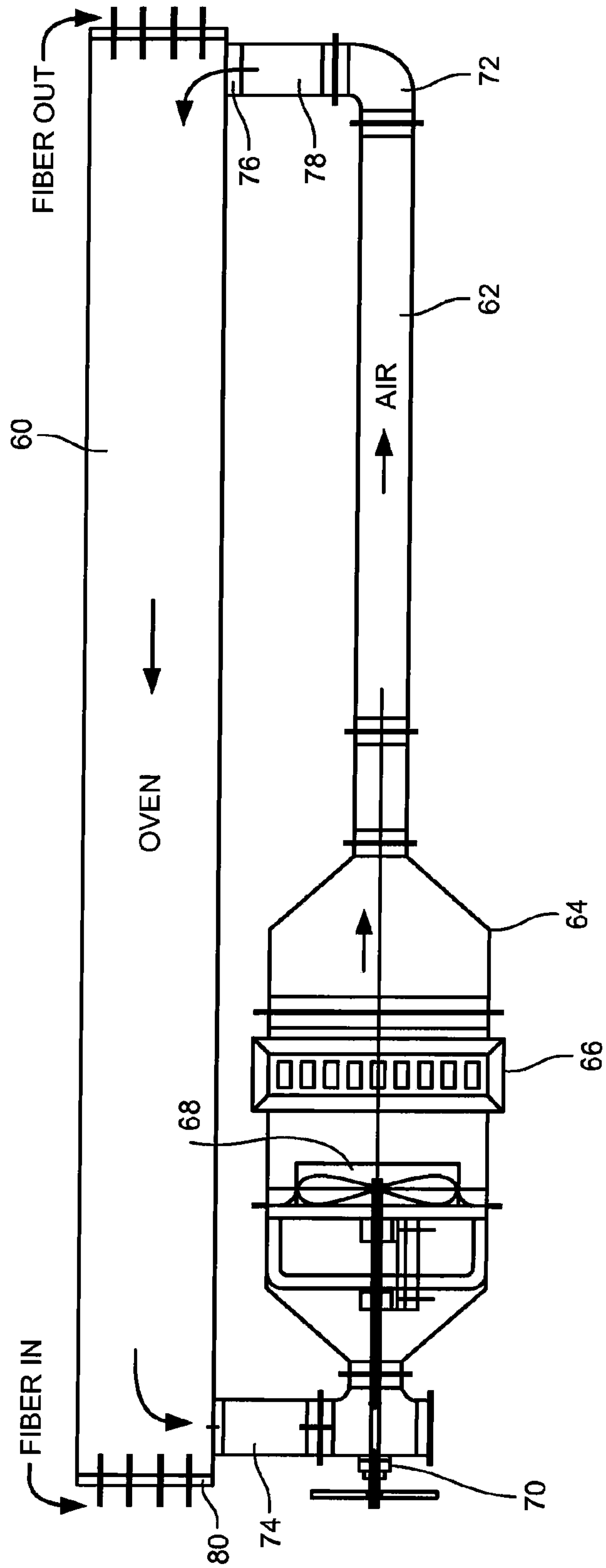


FIG. 9

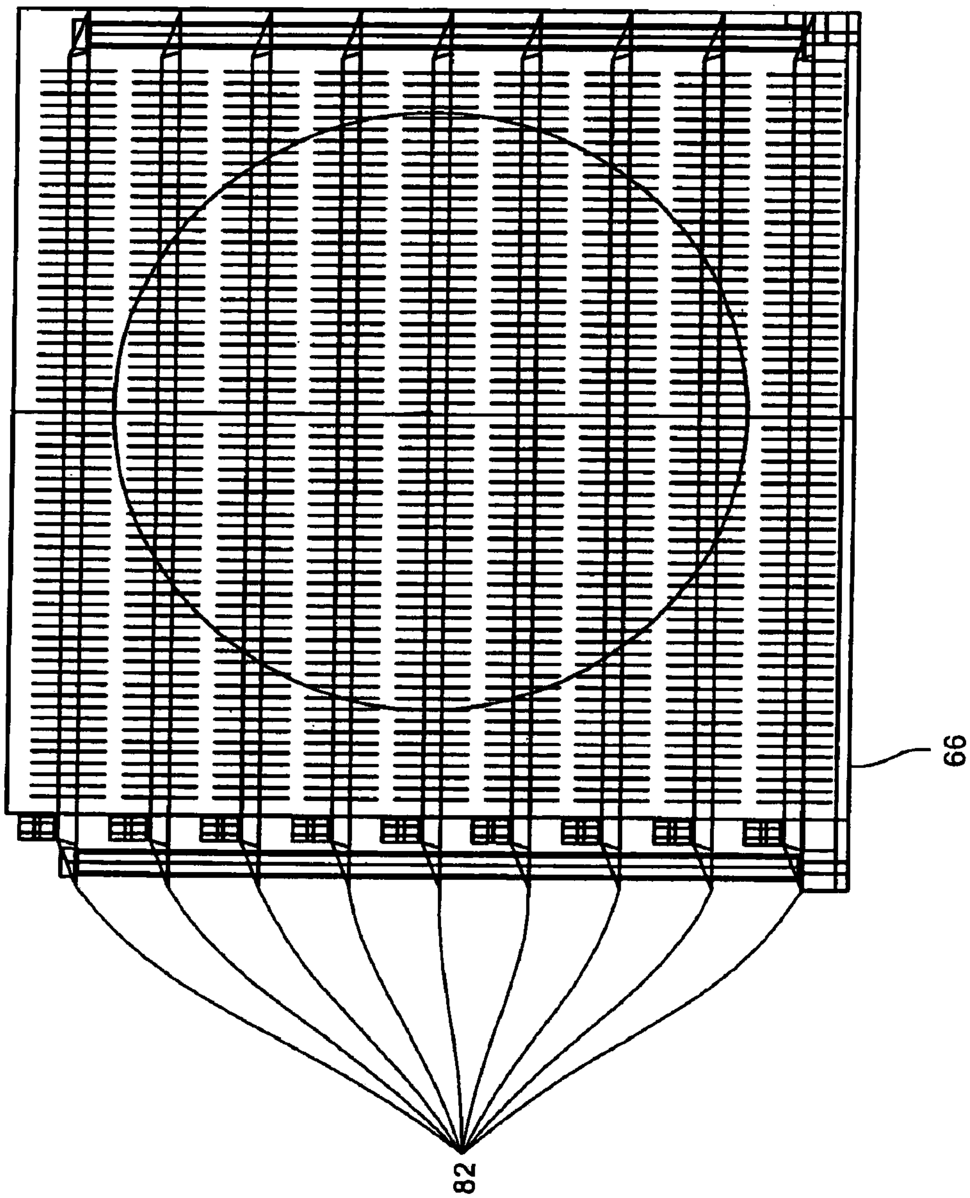


FIG. 10

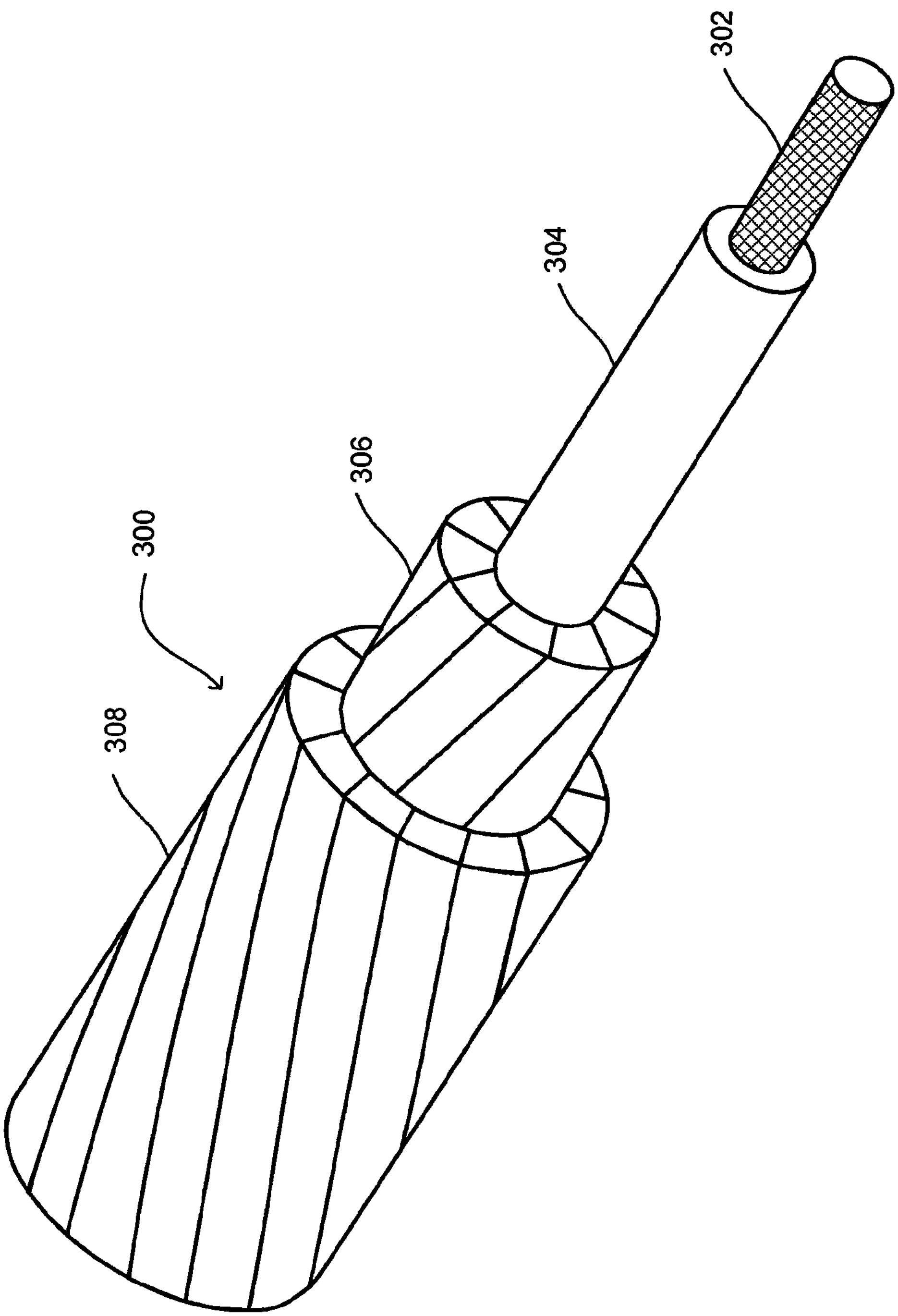


FIG. 11

ALUMINUM CONDUCTOR COMPOSITE CORE REINFORCED CABLE AND METHOD OF MANUFACTURE

CLAIM FOR PRIORITY

In relation to this International Application, applicants claim priority of earlier U.S. provisional application Ser. No. 60/374,879 filed in the United States Patent and Trademark Office on 23 Apr. 2002, the entire disclosure of which is incorporated by reference herein.

TECHNICAL FIELD

The present invention relates to an aluminum conductor composite core (ACCC) reinforced cable and method of manufacture. More particularly, to a cable for providing electrical power having a reinforced fiber thermosetting resin composite core surrounded by aluminum conductor capable of carrying increased ampacity at elevated temperatures.

BACKGROUND OF INVENTION

This invention relates to composite core members and aluminum conductor composite core (ACCC) reinforced cable products made therefrom. This invention further relates to a forming process for an aluminum conductor composite core reinforced cable (ACCC). In the traditional aluminum conductor steel reinforced cable (ACSR) the aluminum conductor transmits the power and the steel core is designed to carry the transfer load.

In an ACCC cable, the steel core of the ACSR cable is replaced by a composite core comprising at least one reinforced fiber type in a thermosetting resin matrix. Replacing the steel core has many advantages. An ACCC cable can maintain operating temperatures in the range of about 90 to about 230° C. without corresponding sag induced in traditional ACSR cables. Moreover, to increase ampacity, an ACCC cable couples a higher modulus of elasticity with a lower coefficient of thermal expansion.

This invention relates to an aluminum conductor composite core reinforced cable suitable for operation at high operating temperatures without being limited by current operating limitations inherent in other cables for providing electrical power wherein provision of electrical power includes both distribution and transmission cables. Typical ACSR cables can be operated at temperatures up to 100° C. on a continuous basis without any significant change in the conductor's physical properties related to a reduction in tensile strength. These temperature limits constrain the thermal rating of a typical 230-kV line, strung with 795 kcmil ACSR "Drake" conductor, to about 400 MVA, corresponding to a current of 1000 A.

Conductor cables are constrained by the inherent physical characteristics of the components that limit ampacity. More specifically, the ampacity is a measure of the ability to send power through the cable wherein increased power causes an increase in the conductor's operating temperature. Excessive heat causes the cable to sag below permissible levels. Therefore, to increase the load carrying capacity of transmission cables, the cable itself must be designed using components having inherent properties that withstand increased ampacity without inducing excessive sag.

Although ampacity gains can be obtained by increasing the conductor area that wraps the core of the transmission cable, increasing conductor weight increases the weight of the cable and contributes to sag. Moreover, the increased weight requires the cable to use increased tension in the cable support infrastructure. Such large load increases typically would require structure reinforcement or replacement, wherein such infrastructure modifications are typically not financially feasible. Thus, there is financial motivation to increase the load capacity on electrical transmission cables while using the existing transmission liens.

European Patent Application No. EP1168374A3 discloses a composite core comprised of a single type of reinforced glass fiber and thermoplastic resin. The object is to provide an electrical transmission cable which utilizes a reinforced plastic composite core as a load bearing element in the cable and to provide a method of carrying electrical current through an electrical transmission cable which utilizes an inner reinforced plastic core. The composite core fails in these objectives. A one fiber system comprising glass fiber does have the required stiffness to attract transfer load and keep the cable from sagging. Secondly, a composite core comprising glass fiber and thermoplastic resin does not meet the operating temperatures required for increased ampacity, namely, between 90 and 230° C.

Composite cores designed using a carbon epoxy composite core also have inherent difficulties. The carbon epoxy core has very limited flexibility and is cost prohibitive. The cable product having a carbon epoxy core does not have sufficient flexibility to permit winding and transport. Moreover, the cost for carbon fibers are expensive compared to other available fibers. The cost for carbon fibers is in the range of $5 to $37 per pound compared to glass fibers in the range of $0.36 to $1.20 per pound. Accordingly, a composite core constructed of only carbon fibers is not financially feasible.

Physical properties of composite cores are further limited by processing methods. Previous processing methods cannot achieve a high fiber/resin ratio by volume or weight. These processes do not allow for creation of a fiber rich core that will achieve the strength to compete with a steel core. Moreover, the processing speed of previous processing methods are limited by inherent characteristics of the process itself. For example, traditional pultrusion dies are approximately 36 inches, having a constant cross section. The result is increased friction between the composite and the die slowing processing time. The processing times in such systems for epoxy resins range within about 6 inches/minute to about 12 inches/minute, which is not economically feasible. Moreover, these processes do not allow for composite configuration and tuning during the process, wherein tuning comprises changing the fiber/resin ratio.

It is therefore desirable to design economically feasible ACCC cables having at least one reinforced fiber type in a thermosetting resin matrix comprising inherent physical characteristics that facilitate increased ampacity without corresponding cable sag. It is further desirable to process composite cores using a process that allows configuration and tuning of the composite cores during processing and allows for processing at speeds in the range of about 9 ft/min to 50 ft/min.

SUMMARY OF THE INVENTION

Increased ampacity can be achieved by using an aluminum conductor composite core (ACCC) reinforced cable. An ACCC reinforced cable is a high-temperature, low-sag conductor, which can be operated at temperatures above 100° C. while exhibiting stable tensile strength and creep elongation properties. It is further desirable to achieve practical temperature limits of up to 230° C. Using an ACCC reinforced cable, which has the same diameter as the original, at 180° C. also increases the line rating by 50% without any significant change in structure loads. If the replacement conductor has a lower thermal elongation rate than the original, then the support structures will not have to be raised or reinforced.

In particular, replacing the core of distribution and transmission conductor cables with a composite strength member comprising fiber and resin with a relatively high modulus of elasticity and a relatively low coefficient of thermal expansion facilitates an increased conductor cable ampacity. It is further desirable to design composite cores having long term durability allowing the composite strength member to operate at least sixty years, and more preferably seventy years at the temperatures associated with the increased ampacity, about 90 to 230° C., without having to increase either the diameter of the composite core, or the outside diameter of the conductor. This in turn allows for more physical space to put more aluminum and for the mechanical and physical performance to be able to meet the sag limits without increased conductor weight.

Further, the invention allows for formation of a composite core having a smaller core size. A smaller core size allows the conductor cable to accommodate an increased volume of aluminum wherein an ACCC cable has the same strength and weight characteristics as a conductor cable without a composite core.

To achieve the desired ampacity gains, a composite core according to the invention may also combine fibers having a low modulus of elasticity with fibers having a high modulus of elasticity for increased stiffness of the core and a lower elongation percent. By combining fibers, a new property set including different modulus of elasticity, thermal expansion, density and cost is obtained. Sag versus temperature calculations show achievable ampacity gains when an advanced composite is combined with low modulus reinforced fibers having inherent physical properties within the same range as glassfiber.

Composite cores according to the invention meet certain physical characteristics dependent upon the selection of reinforced fiber types and thermosetting resins with desired inherent physical properties. Composite cores according to the invention have substantially low thermal expansion coefficients, substantially high tensile strength, ability to withstand a substantially high range of operating temperatures, ability to withstand a low range of ambient temperatures, substantially high dielectric properties and sufficient flexibility to permit winding. In particular, composite cores according to the present invention have a tensile strength within the range of about 160 to about 240 Ksi, a modulus of elasticity within the range of about 7 to about 30 Msi, an operating temperature within the range of about 90 to about 230° C. and a thermal expansion coefficient within the range of about 0 to about 6×10^{-6} m/m/C. These ranges can be achieved by a single reinforced fiber type or a combination of reinforced fiber types. Theoretically, although the characteristics could be achieved by a single fiber type alone, from a practical point of view, most cores within the scope of this invention comprise two or more distinct reinforced fiber types. In addition, depending on the physical characteristics desired in the final composite core, the composite core accommodates variations in the relative amounts of fibers.

Composite cores of the present invention can be formed by a B-stage forming process wherein fibers are wetted with resin and continuously pulled through a plurality of zones within the process. The B-stage forming process relates generally to the manufacture of composite core members and relates specifically to an improved apparatus and process for making resin impregnated fiber composite core members. More specifically, according to a preferred embodiment, a multi-phase B-stage process forms a composite core member from fiber and resin with superior strength, higher ampacity, lower electrical resistance and lighter weight than previous core members. The process enables formation of composite core members having a fiber to resin ratio that maximizes the strength of the composite, specifically flexural, compressive and tensile strength. In a further embodiment, the composite core member is wrapped with high conductivity aluminum resulting in an ACCC cable having high strength and high stiffness characteristics.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other features of the invention are best understood by referring to the detailed description of the invention, read in light of the accompanying drawings, in which:

FIG. **1** is a schematic diagram of a B-stage forming process used for forming reinforced fiber composite core members in accordance with the present invention.

FIG. **2** is a schematic diagram of a bushing showing sufficiently spaced passageways for insertion of the fibers in a predetermined pattern to guide the fibers through the B-stage forming process in accordance with the present invention.

FIG. **3** is a schematic view of the structure of a bushing, said view showing the passageways used to shape and compress the bundles of reinforced fibers in accordance with the present invention.

FIG. **4** is schematic comparison of two different bushings showing a reduction in the passageways from one bushing to the next to shape and compact the fibers into bundles in forming the composite core in accordance with the present invention.

FIG. **5** shows a cross-sectional view of thirty possible composite core cross-section geometries according to the invention.

FIG. **6** is a multi-dimensional cross-sectional view of a plurality of bushings overlaid on top of one another showing the decreasing passageway size with respective bushings.

FIG. **7** is a multi-phase schematic view of a plurality of bushings showing migration of the passageways and diminishing size of the passageways with each successive bushing in accordance with the invention.

FIG. **8** is a cross sectional view of one embodiment of a composite core according to the invention.

FIG. **9** is a schematic view of an oven process having cross circular air flow to keep the air temperature constant in accordance with the invention.

FIG. **10** is a cross-sectional view of the heating element in the oven represented in FIG. **9** showing each heater in the heating element in accordance with the invention.

FIG. **11** is a schematic view of one embodiment of an aluminum conductor composite core (ACCC) reinforced cable showing an inner advanced composite core and an outer low modulus core surrounded by two layers of aluminum conductor according to the invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that the disclosure will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like elements throughout. The drawings are not necessarily drawn to scale but are configured to clearly illustrate the invention.

The present invention relates to a reinforced composite core member made from reinforced fibers embedded in a high temperature resin for use in aluminum conductor composite core reinforced (ACCC) cables to provide for electrical power distribution wherein electrical power distribution includes distribution and transmission cables. FIG. **11** illustrates a typical embodiment of an ACCC reinforced cable **300**. FIG. **11** illustrates an ACCC reinforced cable having a reinforced carbon fiber/epoxy resin composite inner core **302** and a reinforced glass fiber/epoxy resin composite outer core **304**, surrounded by a first layer of aluminum conductor **306** wherein a plurality of trapezoidal shaped aluminum strands wrap around the composite core and having a second layer of aluminum conductor **308** wherein a plurality of trapezoidal shaped aluminum strands wrap around the first aluminum layer **306**.

Composite cores of the present invention comprise the following characteristics: at least one type of reinforced fiber, variable relative amounts of each reinforced fiber type, reinforced fiber types of substantially small diameter, reinforced fiber types of a substantially continuous length, composite cores having a high packing density, reinforced fiber tows having relative spacing within the packing density, a volume fraction at least 50%, a fiber weight fraction between about 60 and about 75%, adjustable volume fraction, substantially low thermal expansion coefficient, a substantially high tensile strength, ability to withstand a substantially high range of operating temperatures, ability to withstand substantially low ambient temperature, having the potential to customize composite core resin properties, substantially high dielectric properties, having the potential of a plurality of geometric cross section configurations, and sufficient flexibility to permit winding of continuous lengths of composite core.

A composite core of the following invention has a tensile strength in the range of about 160 to about 240 Ksi, a modulus of elasticity in the range of about 7 to about 30 Msi, an operating temperature in the range of about 90 to about 230° C. and a thermal expansion coefficient in the range of about 0 to about 6×10^{-6} m/m/C. To achieve these physical characteristics, composite cores of the present invention can comprise one type of reinforced fiber having inherent physical properties to enable the composite core to meet the required physical specifications. From a practical point of view, most cables within the scope of this invention comprise at least two distinct reinforced fiber types.

Combining two or more reinforced fibers into the composite core member offers substantial improvements in strength to weight ratio over materials commonly used for cable in an electrical power transmission system. Fibers may be selected from the group comprising, for example: carbon fibers—both HM and HS (pitch based), Kevlar fibers, basalt fibers, glass fibers, Aramid fibers, boron fibers, liquid crystal fibers, high performance polyethylene fibers and carbon nanofibers. Several types of carbon, boron, Kevlar and glass fibers are commercially available. Each fiber type has subtypes of varying characteristics that may be combined in various combinations in order to achieve a particular composite. It is noted that these are only examples of fibers that meet the specified characteristics of the invention, such that the invention is not limited to these fibers only. Other fibers meeting the required physical characteristics of the invention may be used.

Composite cores of the present invention preferably comprise fiber tows having relatively small yield or K numbers. A fiber tow is an untwisted bundle of continuous microfibers wherein the composition of the tow is indicated by its yield or K number. For example, 12K tow has 12,000 individual microfibers. Ideally, microfibers wet out with resin such that the resin coats the circumference of each microfiber within the bundle or tow. Wetting may be affected by tow size, that is, the number of microfibers in the bundle, and individual microfiber size. Larger tows create more difficulty wetting around individual fibers in the bundle due to the number of fibers contained within the bundle whereas smaller fiber diameter increases the distribution of resin around each fiber within each fiber tow. Wetting and infiltration of the fiber tows in composite materials is of critical importance to performance of the resulting composite. Incomplete wetting results in flaws or dry spots within the fiber composite reducing strength and durability of the composite product. Fiber tows may also be selected in accordance with the size of fiber tow that the process can handle in order to enable forming a composite having optimal desired physical characteristics. One process for forming composite cores in accordance with the present invention is called B-stage forming process. Fiber tows of the present invention for carbon are selected preferably in the range of about 4K to about 50K and glass fiber tows are preferably selected in the range of about 800 to about 1200 yield.

Individual reinforced fiber sizes in accordance with the present invention preferably are within the range of about 8 to about 15 μm for glass fibers and most preferably about 10 μm in diameter whereas carbon fibers are preferably in the range of about 5 to about 10 μm and most preferably about 7 μm in diameter. For other types of fibers a suitable size range is determined in accordance with the desired physical properties. The ranges are selected based on optimal wet-out characteristics and feasibility. For example, fibers less than about 5 μm are so small in diameter that they pose certain health risks to those that handle the fibers. On the other end, fibers approaching 25 μm in diameter are difficult to work with because they are stiffer and more brittle.

Composite cores of the present invention comprise fiber tows that are substantially continuous in length. In practice, carbon fiber tows comprising the present invention are preferably between about 1000 and 3000 meters in length, depending on the size of the spool. However, glass fiber lengths can range up to 36 km depending on the size of the spool. Most preferably, fibers are selected in the range of 1000 to 33,000 meters. It is most preferable to select the longest fibers that the processing equipment will accommodate due to less splicing of fibers to form a continuous composite core in excess of 6000 feet. Fiber ends may be glued end-to-end forming a substantially continuous fiber tow length. Continuous towing orients the fibers longitudinally along the cable.

Composite cores of the present invention comprise fibers having a high packing efficiency relative to other conductor cable cores. In particular, traditional steel conductor cables generally comprise several round steel wires. Due to the round shape of the wires, the wires cannot pack tightly together and can only achieve a packing efficiency of about 74%. The only way that a steel core could have 100% packing efficiency would be to have a solid steel rod as opposed to several round steel wires. This is not possible because the final cable would be to stiff and would not bend. In the present invention, individual fibers are oriented longitudinally, wherein each fiber is coated with resin. and cured forming a hybridized composite core member having 100% packing efficiency. Higher packing efficiency yields a composite strength that is greater for a given volume relative to other cables. In addition, higher packing efficiency allows for formation of a composite core of smaller diameter thereby increasing the amount of aluminum conductor material capable of wrapping around the composite conductor core.

Composite cores of the present invention comprise reinforced fibers that are substantially heat resistant. Heat resistance enables an ACCC cable to transmit increased power due to the ability of the composite core to withstand higher operating temperatures. The fibers used in the present invention have the ability to withstand operating temperatures between the range of about 90 and about 230° C. Most preferably, the fibers in the present invention have the ability to withstand operating temperatures between the range of about 170 to 200° C. Moreover, fibers used in the present invention can preferably withstand an ambient temperature range between about −40 to about 90° C. That is, under ambient conditions with no current flowing in an ACCC cable, the composite core is able to withstand temperatures as low as about −40° C. without suffering impairment of physical characteristics.

Relative amounts of each type of reinforced fiber varies depending on the desired physical characteristics of the composite cable. For example, fibers having a lower modulus of elasticity enable formation of a high strength, stiff composite core. Carbon fibers have a modulus of elasticity preferably in the range of about 22 to about 37 Msi whereas glassfibers are considered low modulus reinforced fibers The two types of fibers may be combined to take advantage of the inherent physical properties of each fiber to create a high strength, high stiffness composite core with added flexibility. In one embodiment, for example, the composite core comprises an inner carbon/resin core having an area of 0.037 sq. in. and a fiber resin ratio of about 70/30 by weight and an outer glass/epoxy layer having an area of 0.074 sq. in. and a fiber/resin ratio of about 75/25 by weight.

In accordance with the present invention, the physical characteristics of the composite core may be adjusted by adjusting the fiber/resin ratio of each component. Alternatively, the physical characteristics of the composite core may be adjusted by adjusting the area percentage of each component within the composite core member. For example, by reducing the total area of carbon from 0.037 sq. in. and increasing the area of glass from 0.074 sq. in., the composite core member product has reduced stiffness in the carbon core coupled with increased flexibility. In addition, due to the smaller tow diameter of glass compared to carbon, the resulting composite core is smaller in diameter enabling increased conductor for the same resulting cable size. Alternatively, a third fiber, for example basalt, may be introduced into the composite core. The additional fiber changes the physical characteristics of the end product. For example, by substituting basalt for some carbon fibers, the core has increased dielectric properties and a relative decrease in core stiffness.

Composite cores of the present invention comprise reinforced fibers having relatively high tensile strength. The degree of sag in an overhead voltage power transmission cable varies as the square of the span length and inversely with the tensile strength of the cable such that an increase in

the tensile strength effectively reduces sag in an ACCC cable. Carbon fibers are selected having a tensile strength preferably in the range of about 350 to about 750 Ksi. More preferably in the range between 710 Ksi to 750 Ksi. Glassfibers are selected having a tensile strength preferably in the range of about 180 to about 220 Ksi. The tensile strength of the composite is enhanced by combining glassfibers having a lower tensile strength with carbon fibers having a higher tensile strength. The properties of both types of fibers are combined to form a new cable having a more desirable set of physical characteristics.

Composite cores of the present invention comprise longitudinal fibers embedded within a resin matrix having a fiber/resin volume fraction in a ratio of at least 50:50%. The volume fraction is the area of fiber divided by the total area of the cross section wherein the weight of the fiber will determine the final percentage ratio by weight. In accordance with the invention, preferably the volume fraction of fiber in the fiber/resin composite is within the range of about 50 to about 57% by value. Most preferably, the volume fraction is calculated to yield a fiber/resin ratio of 72% by weight depending on the weight of the fiber.

In accordance with the present invention, the composite core is designed based on the desired physical characteristics of an ACCC reinforced cable. More preferably, the composite core is designed having an inner strengthening core member comprising an advanced composite surrounded by an outer more flexible layer. An advanced composite is a composite having continuous fibers having a greater than 50% volume fraction and mechanical properties exceeding the mechanical properties of glassfibers. Further, it is preferable to have an outer layer low modulus composite having mechanical properties in the range of glass fiber. A low modulus fiber has mechanical characteristics in the range of glass fiber. The mechanical properties of glass fibers accommodate splicing whereas the advanced composite is more brittle and does not undertake splicing well.

Fibers forming an advanced composite are selected preferably having a tensile strength in the range of about 350 to about 750 Ksi; a modulus of elasticity preferably in the range of about 22 to about 37 Msi; a coefficient of thermal expansion in the range of about −0.7 to about 0 m/m/C; yield elongation percent in the range of about 1.5 to 3%; dielectric properties in the range of about 0.31 W/m·K to about 0.04 W/m·K and density in the range of about 0.065 lb/in^3 to about 0.13 lb/in^3.

Fibers forming the outer low modulus layer surrounding the advanced composite preferably have a tensile strength in the range within about 180 to 220 Ksi; a coefficient of thermal expansion in the range of about 5×10^{-6} to about 10×10^{-6} m/m/C; yield elongation percent in the range of about 3 to about 6%; and dielectric properties in the range of about 0.034 to about 0.04 W/m·K and density in the range of about 0.065 to about 0.13 lbs/in^3.

A composite core member having an inner core comprising an advanced composite in accordance with the preferred ranges of values set forth above surrounded by an outer low modulus layer in accordance with the preferred ranges of values set forth above, has increased ampacity over other conductor cables by about 0 to about 200%. In particular, the final composite core has the following preferable physical characteristics. Tensile strength in the range within about 160 to about 240 Ksi. More preferably, having tensile strength of about 185 Ksi. Modulus of elasticity preferably in the range of within about 7 to about 30 Msi. More preferably, having a modulus of elasticity of about 14 Msi.

Operating temperature in the range within about 90 to about 230° C. More preferably, the composite core is able to withstand operating temperatures at least about 190° C. Thermal expansion coefficient within the range of about 0 to about 6×10^{-6} m/m/C. More preferably, the core thermal expansion coefficient is about 2.5×10^{-6} m/m/C.

Preferably, particular combinations of reinforced fibers are selected based on the reinforced fiber's inherent physical properties in order to produce a composite core product having particular physical properties. In particular, to design an ACCC cable able to withstand ampacity gains, the composite core comprises both a higher modulus of elasticity and a lower coefficient of thermal expansion. The fibers preferably are not conductive but have high dielectric properties. An ACCC cable operates at higher operating temperatures without a corresponding increase in sag. Sag versus temperature calculations require input of modulus of elasticity, thermal expansion coefficient, weight of the composite strength member and conductor weight. Accordingly, these physical characteristics are taken into account in designing the composite core.

While it is preferable to form a composite core having an inner advanced composite surrounded by a low modulus composite, it is feasible to make a composite core comprising interspersed high modulus of elasticity fibers and low modulus of elasticity fibers. Depending on the strain:failure ratio, this type of core may have to be segmented in order to achieve an appropriate degree of winding. Moreover, the composite core is designed having the fiber of increased modulus of elasticity in the inner core surrounded by a fiber having a lower modulusof elasticity due to the decreased degree of strain on the inner core.

For example, carbon is selected for high modulus of elasticity in the range of about 22 to about 37 Msi, low thermal expansion coefficient in the range of about −0.7 to about 0 m/m/C, and elongation percent in the range of about 1.5 to about 3%. Glassfibers are selected for low modulus of elasticity, low thermal expansion coefficient in the range of about 5×10^{-6} to about 10×10^{-6} m/m/C and elongation percent in the range of about 3 to about 6%. The strain capability of the composite is tied in with the inherent physical properties of the components and the volume fraction of components. After the fiber/resin composite is selected, the-strain to failure ratio of each fiber/resin composite is determined. In accordance with the present invention, the resins can be customized to achieve certain properties for processing and to achieve desired physical properties in the end product. As such, the fiber/customized resin strain to failure ratio is determined. For example, carbon/epoxy has a strain to failure ratio of 2.1% whereas glassfiber/epoxy has a strain to failure ratio of 1.7%. Accordingly, the composite core is designed having the stiffness of the carbon/epoxy in the inner core and the more flexible glassfiber/epoxy in the outer core to create a composite core with the requisite flexibility and low thermal expansion coefficient.

Alternatively, another advanced composite having mechanical properties in excess of glassfiber could be substituted for at least a portion of the carbon fibers and another fiber having the mechanical property range of glassfiber could be substituted for glassfiber. For example, basalt has the following properties: high tensile strength in the range of about 701.98 Ksi (compared to the range of about 180 to about 500 Ksi for glassfibers), high modulus of elasticity in the range of about 12.95 Msi, low thermal expansion coefficient in the range of about 8.0 ppm/C (compared to about 5.4 ppm/C for glassfibers), and elongation percent in the range of about 3.15% (compared the range of about 3 to about 6% for glassfibers). The basalt fibers provide increased tensile strength, a modulus of elasticity between carbon and glassfiber and an elongation % close to that of carbon fibers. A further advantage is that basalt has superior dielectric properties to carbon. Preferably, the composite core comprises an inner strength member that is non-conductive. By designing an advanced composite core having fibers of inherent physical characteristics surrounded by low modulus fiber outer core, a new property set for the composite core is obtained.

Sag versus temperature is determined by considering the modulus of elasticity, the thermal expansion coefficient, the weight of the composite strength member, and the conductor weight. The higher modulus of elasticity and lower coefficient of thermal expansion in the resulting composite core enables an ACCC cable to withstand ampacity gains and operating temperatures between about 90 to about 230° C.

The composite core of the present invention comprises thermosetting resins having physical properties that are adjustable to achieve the objects of the present invention. Depending on the intended cable application, suitable thermosetting resins are selected as a function of the desired cable properties to enable the composite core to have long term durability at high temperature operation. Suitable thermosetting resins may also be selected according to the process for formation of the composite core in order to minimize friction during processing, increase process speed and preferable viscosity to achieve the appropriate fiber/resin ratio in the final composite core.

The composite core of the present invention comprises resins having good mechanical properties and chemical resistance at prolonged exposure for at least about 60 years of usage. More preferably, the composite core of the present invention comprises resins having good mechanical properties and chemical resistance at prolonged exposure for at least about 70 years of usage. Further, the composite core of the present invention comprises resins that operate preferably within the range of about 90 to about 230° C. More preferably, the resin operates within the range of about 170 to about 200° C.

The composite core of the present invention comprises a resin that is tough enough to withstand splicing operations without allowing the composite body to crack. An essential element of the present invention is the ability to splice the composite core member in the final cable product. The composite core of the present invention comprises resin having a neat resin fracture toughness preferably within the range of about 0.87 INS-lb/in to about 1.24 INS-lb/in.

The composite core of the present invention comprises a resin having a low coefficient of thermal expansion. A low coefficient of thermal expansion reduces the amount of sag in the resulting cable. A resin of the present invention preferably operates in the range of about 15×10^{-6} C and about 42×10^{-6} C. The composite core of the present invention comprises a resin having an elongation greater than about 4.5%.

A composite core of the present invention comprises fibers embedded in a high temperature resin having at least a 50% volume fraction. The fiber to resin ratio affects the physical properties of the composite core member. In particular, the strength, electrical conductivity, and coefficient of thermal expansion are functions of the fiber volume of the composite core. Generally, the higher the volume fractions of fibers in the composite, the higher the tensile strength for the resulting composite. A fiber to resin volume fraction of the present invention preferably is within the range of about

50 to 57% corresponding to preferably within about 62 to about 75% by weight. More preferably, the fiber/resin ratio in the present invention is about 65 to about 72% by weight. Most preferably, the fiber volume fraction in the present invention meets or exceeds about 72% by weight.

Each fiber type of the composite core may have a different fiber/resin ratio by weight relative to the other fibers. This is accomplished by selecting the appropriate number of each fiber type and the appropriate resin type to achieve the desired ratio. For example, a composite core member having a carbon/epoxy inner core surrounded by an outer glass/epoxy layer may comprise 126 spools of glass fiber and epoxy resin having a viscosity of about 2000 to about 6000 cPs at 50° C. which yields a pre-determined fiber/resin ratio of about 75/25 by weight. Preferably, the resin may be tuned to achieve the desired viscosity for the process. The composite may also have 16 spools of carbon fiber and epoxy resin having a viscosity of about 2000 to about 6000 cPs at 50° C. which yields a predetermined fiber/resin ratio of about 70/30 by weight. Changing the number of spools of fiber changes the fiber/resin by weight ratio thereby changing the physical characteristics of the composite core product. Alternatively, the resin may be adjusted thereby increasing or decreasing the resin viscosity to change the fiber/resin ratio.

The composite cables made in accordance with the present invention exhibit physical properties wherein these certain physical properties may be controlled by changing parameters during the composite core forming process. More specifically, the composite core forming process is adjustable to achieve desired physical characteristics in a final ACCC cable.

In accordance with the invention, a multi-phase B-stage forming process produces a composite core member from substantially continuous lengths of suitable fiber tows and heat processable resins. In a further step, the composite core member is wrapped with high conductivity aluminum.

A process for making composite cores for ACCC cables according to the invention is described as follows. Referring to FIG. **1**, the conductor core B-stage forming process of the present invention is shown and designated generally by reference number **10**. The B-stage forming process **10** is employed to make continuous lengths of composite core members from suitable fiber tows or rovings and heat processable resins. The resulting composite core member comprises a hybridized concentric core having an inner and outer layer of uniformly distributed substantially parallel fibers.

In starting the operation, the pulling and winding spool mechanism is activated to commence pulling. The unimpregnated initial fiber tows extending from the exit end of the cooling portion in zone **9** serve as leaders at the beginning of the operation to pull fiber tows **12** from spools **11** through fiber tow guide **18** and the composite core processing system.

In FIG. **1**, multiple spools of fiber tows **12** are contained within a rack system **14** and are provided with the ends of the individual fiber tows **12**, leading from spools **11**, being threaded through a fiber tow guide **18**. The fibers undergo tangential pulling to prevent twisted fibers. Preferably, a pulling device **34** at the end of the apparatus pulls the fibers through the apparatus. Each dispensing rack **14** comprises a device allowing for the adjustment of tension for each spool **11**. For example, each rack **14** may have a small brake at the dispensing rack to individually adjust the tension for each spool. Tension adjustment minimizes catemary and cross-over of the fiber when it travels and aids in the wetting process. The tows **12** are pulled through the guidelS and into a preheating oven **20** that evacuates moisture. The preheating oven **20** uses continuous circular air flow and a heating element to keep the temperature constant.

The tows **12** are pulled into a wet out tank **22**. Wet out tank **22** is filled with resin to impregnate the fiber tows **12**. Excess resin is removed from the fiber tows **12** during wet out tank **22** exit. The fiber tows **12** are pulled from the wet out tank **22** to a secondary system, B-stage oven **24**. The B-stage oven heats the resin to a temperature changing the liquid stage of resin to a semi-cure stage. B-stage cure resin is in a tacky stage which permits the fiber tows **12** to be bent, changed, compressed and configured. The tackiness is controlled by manipulation of the type of resin, the fiber type, thread count and size of the fibers and temperature of the oven. Fiber tows **12** maintained separated by the guide **18**, are pulled into a second B-stage oven **26** comprising a plurality of consecutive bushings to compress and configure the tows **12**. In the second B-stage oven **26**, the fiber tows **12** are directed through a plurality of passageways provided by the bushings. The consecutive passageways continually compress and configure the fiber tows **12** into the final uniform composite core member.

Preferably, the composite core member is pulled from the second B-stage oven **26** to a next oven processing system **28** wherein the composite core member is cured and pulled to a next cooling system **30** for cooling. After cooling, the composite core is pulled to a next oven processing system **32** for post curing at elevated temperature. The post-curing process promotes increased cross-linking within the resin matrix resulting in improved physical characteristics of the composite member. The process generally allows an interval between the heating and cooling process and the pulling apparatus **36** to cool the product naturally or by convection such that the pulling device **34** used to grip and pull the product will not damage the product. The pulling mechanism pulls the product through the process with precision controlled speed.

Referring now more particularly to FIG. **1**, in a preferred embodiment, the process continuously pulls fiber from left to right of the system through a series of phases referred to herein as zones. Each zone performs a different processing function. In this particular embodiment, the process comprises 9 zones. The process originates from a series of fiber dispensing racks **14** whereby a caterpuller **34** continuously pulls the fibers **12** through each zone. One advantage to the caterpullar system is that it functions as a continuous pulling system driven by an electrical motor as opposed to the traditional reciprocation system. The caterpullar system uses a system of two belts traveling on the upper and lower portions of the product squeezing the product there between. Accordingly, the caterpuller system embodies a simplified uniform pulling system functioning at precision controlled speed using only one device instead of a multiplicity of interacting parts functioning to propel the product through the process. Alternatively, a reciprocation system may be used to pull the fibers through the process.

The process starts with zone **1**. Zone **1** comprises a type of fiber dispensing system. Fibers that can be used for example are: glass fibers, carbon fibers, both HM and HS (pitch based), basalt fibers, Aramid fibers, liquid crystal fibers, Kevlar fibers, boron fibers, high performance polyethylene fibers and carbon nanofiber (CNF). In one embodiment, the fiber dispensing system comprises two racks **13** each rack containing a plurality of spools **11** containing fiber tows **12**. Further, the spools **11** are interchangeable to accommodate varying types of fiber tows **12** depending on the desired properties of the composite core member.

For example, a preferred composite core member formed by the B-stage forming process comprises a carbon/resin inner core surrounded by a glass/resin outer core layer. Preferably, high strength and high quality carbon is used. The resin matrix also protects the fibers from surface damage, and prevents cracking through a mass of fibers improving fracture resistance. The conductor core B-stage forming process **10** creates a system for pulling the fibers to achieve the optimum degree of bonding between fibers in order to create a composite member with optimal composite properties.

As previously mentioned, the components of the composite core are selected based on desired composite core characteristics. One advantage of the process is the ability to adjust composite components in order for a composite core to achieve the desired goals of a final ACCC cable, namely, a cable that can carry current without undue thermal expansion causing sag and without tensile strength reduction. It is preferable to combine types of fibers to combine the physical characteristics of each. Performance can be improved by forming a core with increased strength and stiffness, coupled with a more flexible outer layer. The process increases the optimal characteristics of the composite by preventing twisting of rovings leading to more uniform wetting and strength characteristics.

For example, in a preferred embodiment of the composite core member, the composite core comprises glass and carbon. Using the B-stage forming process, the racks **13** hold 126 spools **11** of glass and 16 spools **11** of carbon. The fiber tows **12** leading from spools **11** are threaded through a fiber tow guide **18** wherein fiber tow passageways are arranged to provide a configuration for formation of a core composite member having a uniform carbon core and outer glass layer. The carbon layer is characterized by high strength and stiffness and is a weak electrical conductor whereas the outer low modulus glass layer is more flexible and non-conductive. Having an outer glass layer provides an outer insulating layer between the carbon and the high conductivity aluminum wrapping in the final composite conductor product.

The fiber dispensing system dispenses fiber tangent from the fiber package pull. Tangent pull from the spool will not twist the fiber. The center pull method will twist fibers dispensed from the spool. As such, the center pull method results in an increased number of twisted fibers. Twisted fiber will occasionally lay on top of other twisted fiber and create a composite with multiple spots of dry fiber. It is preferable to use tangent pull to avoid dry spots and optimize wet out ability of the fibers.

The fiber tows **12** are threaded through a guidance system **18**. Preferably, the guide **18** comprises a polyethylene and steel bushings containing a plurality of passageways in a predetermined pattern guiding the fibers to prevent the fibers from crossing. Referring to FIG. **2**, the guide comprises a bushing with sufficiently spaced passageways for insertion of the fibers in a predetermined pattern. The passageways are contained within an inner square portion **40**. The passageways are arranged in rows of varying number wherein the larger diameter carbon fibers pass through the center two rows of passageways **42** and the smaller diameter glass fibers pass through the outer two rows **44** on either side of the carbon passageways **42**. A tensioning device, preferably on each spool, adjusts the tension of the pulled fibers and assures the fibers are pulled straight through the guide **18**.

At least two fibers are pulled through each passageway in the guide **18**. For example, a guide **18** comprising 26 passageways pulls 52 fibers through, wherein each passageway has two fibers. If a fiber of a pair breaks, a sensing system alerts the composite core B-stage forming process **10** that there is a broken fiber and stops the puller **34**. Alternatively, in one embodiment, a broken fiber alerts the process and the repair can be made on the fly without stopping the process depending on where the breakage occurs. To repair, a new fiber is pulled from the rack **13** and glued to the broken end of the new fiber. After the fiber is repaired, the conductor core B-stage forming machine **10** is started again.

In preferred form, the fibers are grouped in a parallel arrangement for a plurality of rows. For example, in FIG. **2**, there are six parallel rows of passageways. The outer two rows comprise 32 passageways, the two inner rows comprise 31 passageways, and the two center rows comprise 4 passageways each. Fibers are pulled at least two at a time into each passageway and pulled into zone **2**.

Zone **2** comprises an oven processing system that preheats the dry fibers to evacuate any moisture. The fibers of the present invention are preferably heated within the range of about 150 to 250° F. to evaporate moisture.

The oven processing system comprises an oven portion wherein the oven portion is designed to promote cross-circular air flow against the flow of material. FIG. **9** illustrates a typical embodiment of the oven system. An oven is generally designated **60**. The fibers pass through the oven from upstream to downstream direction, the air passes in the reverse direction. The oven processing system comprises a heat drive system housing **64** that houses a blower **68** powered by electric motor **70** located upstream from a heater assembly **66** to circulate air in a downstream direction through air flow duct **62**. The heat drive system housing houses a blower **68** upstream of the heater assembly **66**. The blower **68** propels air across the heater assembly **66** and through the oven system. The air flows downstream to a curved elbow duct **72**. The curved elbow duct **72** shifts air flow 90 degrees up into an inlet duct **78** and through the oven inlet **76**. Through the inlet air flow shifts 90 degrees to flow upstream through the oven **60** against the pull direction of the fibers. At the end of the oven **60**, the air flow shifts 90 degrees down through the oven outlet **80** through the outlet duct **74** through the motor **70** and back into the heat drive system housing **64**. The motor **70** comprises an electrical motor outside of the heat drive system to prevent overheating. The motor **70** comprises a pulley with a timing belt that moves the bladed blower **68**. Preferably, the system is computer controlled allowing continuous air circulation at a desired temperature. More preferably, the process allows for the temperature to change at any time according to the needs of the process.

For example, the computer senses a temperature below the required temperature and activates the heating element or disactivate the heater when the temperature is too high. The blower blows air across the heating element downstream. The system forces the air to travel in a closed loop circle continuously circulating through the oven keeping the temperature constant.

FIG. **10** is a more detailed view of a preferred embodiment of the heating element **66**. In one embodiment, the heater assembly comprises nine horizontal steel electrical heaters **82**. Each heater unit is separate and distinct from the other heater.

Each heater unit is separated by a gap. Preferably, after sensing a temperature differential, the computer activates the number of heaters to provide sufficient heat. If the system requires the computer activates one of nine heaters. Alternatively, depending on the needs of the process, the computer activates every other heater in the heater assembly. In another embodiment the computer activates all heaters in the heater assembly. In a further alternative, the computer activates a portion of the heaters in the heater assembly or turns all the heaters off.

In an alternate embodiment, electromagnetic fields penetrate through the process material to heat the fibers and drive off any moisture. In another embodiment pulsed microwaves heat the fibers and drive off any moisture. In another embodiment, electron beam processing uses electrons as ionizing radiation to drive off any excess moisture.

In another embodiment, the puller pulls the fibers from zone **2** to zone **3**, the fiber impregnation system. Zone **3** comprises a wet out tank **22**. In a preferred embodiment, the wet out tank **22** contains a device that allows the redirection of fibers during wet out. Preferably, the device is located in the center of the tank and moves the fibers vertically up and down perpendicular to the direction of the pull whereby the deflection causes the fibers to reconfigure from a round configuration to a flat configuration. The flat configuration allows the fibers to lay side by side and allows for the fibers to be more thoroughly wetted by the resin.

Various alternative techniques well known in the art can be employed to apply or impregnate the fibers with resin. Such techniques include for example, spraying, dipping, reverse coating, brushing and resin injection. In an alternate embodiment, ultrasonic activation uses vibrations to improve the wetting ability of the fibers.

Generally, any of the various known heat curable thermosetting polymeric resin compositions can be used with the invention. The resin may be for example, PEAR (PolyEther Amide Resin), Bismaleimide, Polyimide, liquid-crystal polymer (LCP), and high temperature epoxy based on liquid crystal technology or similar resin materials. Resins are selected based on the process and the physical characteristics desired in the composite core.

Further, the viscosity of the resin affects the rate of formation. To achieve the desired proportion of fiber/resin for formation of the composite core member, preferably the viscosity ranges within the range of about 200 to about 1500 Centipoise at 20° C. More preferably, the viscosity falls in the range of about 200 to about 600 Centipoise 20° C. The resin is selected to have good mechanical properties and excellent chemical resistance to prolonged exposure of at least 60 years and more preferably, at least 70 years of operation up to about 230° C. A particular advantage of the present invention is the ability for the process to accommodate use of low viscosity resins. In accordance with the present invention, it is preferable to achieve a fiber/resin ratio within the range of 62-75% by weight. More preferable is a fiber/resin ratio within the range of 72-75% by weight. Low viscosity resins will sufficiently wet the fibers for the composite core member. A preferred polymer provides resistance to a broad spectrum of aggressive chemicals and has very stable dielectric and insulating properties. It is further preferable that the polymer meets ASTME595 outgassing requirements and UL94 flammability tests and is capable of operating intermittently at temperatures ranging between 220 and 280° C. without thermally or mechanically damaging the strength member.

To achieve the desired fiber to resin ratio, the upstream side of the wet out tank comprises a number of redirectional wiping bars. As the fibers are pulled through the wet out tank the fibers are adjusted up and down against a series of wiping bars removing excess resin. Alternatively, the redirection system comprises a wiper system to wipe excess resin carried out of the tank by the fibers. Preferably, the excess resin is collected and recycled into the wet out tank **22**.

Alternatively, the wet out tank uses a series of squeeze out bushings to remove excess resin. During the wet out process each bundle of fiber contains as much as three times the desired resin for the final product. To achieve the right proportion of fiber and resin in the cross section of the composite core members, the amount of pure fiber is calculated. The squeeze out bushing in designed to remove a predetermined percentage of resin. For example, where the bushing passageway is twice as big as the area of the cross section of the fiber, a resin concentration greater than 50% by value won't be pulled through the bushing, the excess resin will be removed. Alternatively, the bushing can be designed to allow passage of 100% fiber and 20% resin.

Preferably, a recycle tray extends lengthwise under the wet out tank **22** to catch overflow resin. More preferably, the wet out tank has an auxiliary tank with overflow capability. Overflow resin is returned to the auxiliary tank by gravity through the piping. Alternatively, tank overflow is captured by an overflow channel and returned to the tank by gravity. In a further alternate, the process uses a drain pump system to recycle the resin back through the auxiliary tank and into the wet out tank. Preferably, a computer system controls the level of resin within the tank. Sensors detect low resin levels and activate a pump to pump resin into the tank from the auxiliary mixing tank into the processing tank. More preferably, there is a mixing tank located within the area of the wet out tank. The resin is mixed in the mixing tank and pumped into the resin wet out tank.

The pullers pull the fibers from zone **3** to zone **4**, the B-stage zone. Zone **4** comprises an oven processing system **24**. Preferably, the oven processing system is an oven with a computer system that controls the temperature of the air and keeps the air flow constant wherein the oven is the same as the oven in zone **2**.

The pullers pull the fibers from zone **3** to zone **4**. The oven circulates air in a circular direction downstream to upstream by a propeller heating system. The computer system controls the temperature at a temperature to heat the wet fiber to B-stage. Preferably, the process determines the temperature. B-stage temperature of the present invention ranges from within about 200 to 250° F. One advantage of the B-stage semi-cure process in the present invention is the ability to heat the resin to a semi-cure state in a short duration of time, approximately 1-1.5 minutes during the continuation of the process. The advantage is that the heating step does not affect the processing speed of the system. The B-stage process allows for the further tuning of the fiber/resin ratio by removing excess resin from the wet-out stage. Further, B-stage allows the fiber/resin matrix to be further compacted and configured during the process. Accordingly, the process differs from previous processes that use pre-preg semi-cure. Heating semi-cures the fibers to a tacky stage.

More specifically, in traditional composite processing applications, the wetted fibers are heated gradually to a semi-cure stage. However, the heating process generally takes periods of one hour or longer to reach the semi-cure stage. Moreover, the composite must be immediately wrapped and frozen to keep the composite at the semi-cure stage and prevent curing to a final stage. Accordingly, the processing is fragmented because it is necessary to remove the product from the line to configure the product.

In accordance with the present invention, the B-stage heating is dedicated to a high efficiency commercial application wherein semi-cure is rapid, preferably 1-1.5 minutes during a continuous process in line within the process.

Preferably, the resins are designed to allow rapid B-stage semi-curing that is held constant through the process allowing for shaping and configuring and further compaction of the product.

The pullers pull the fibers from B-stage zone **4** to zone **5** for the formation of the composite core member. Zone **5** comprises a next oven processing system **26** having a plurality of bushings. The bushings function to shape the cross section of the fiber tows **12**. Preferably, the bushings are configured in a series comprising a parallel configuration with each other. In this embodiment, there is a set of seven bushings spaced laterally within the oven processing system **26**. Preferably, the spacing of the bushings are adjusted according to the process. The bushings can be spaced equi-distance or variable distance from each other.

The series of bushings in zone **5** minimize friction due to the relatively thin bushing ranging within about ½ to ⅜ inch thick. Minimizing friction aids in maximizing the process speed.

Zones **4**, **5** and **6** of the present invention extends within the range of about 30-45 feet. Most preferably, the zones **4**, **5** and **6** extend at least 30 feet. This pulling distance and the decreased friction due to thin bushing plates aids in achieving a desired pull speed in the range of about 9 ft/min to about 50 ft/min. Most preferably about 20 ft/min. Processing speed is further increased due to the high fiber/resin ratio.

Referring to FIG. **3**, for example, the bushings **90** comprise a flat steel plate with a plurality of passageways through which the fiber tows **12** are pulled. The flat plate steel bushing **90** preferably ranges from ⅜ inch to ½ inch thick determined by the process. The bushings **90** have relatively thin walls to reduce friction and the amount of heat which must be added or removed by the heating and cooling process in order to achieve the temperature changes required to effect curing of the fiber resin matrix. The thickness of the bushing **90** is preferably the minimum thickness required to provide the structural strength necessary to constrain forces imposed upon the bushing **90** by the material passing therethrough. In particular, the thickness of the bushing **90** is preferably the minimum needed to limit deformation of the bushing wall to a tolerable level which will not interfere with the pulling of the material through the system.

Preferably, the design and size of the bushings **90** are the same. More preferably, the passageways within each bushing **90** diminish in size and vary in location within each successive bushing **90** in the upstream direction. FIG. **3** illustrates a preferred embodiment of a bushing **90**. The bushing **90** comprises two hooked portions **94** and an inner preferably square portion **92**. The inner square portion **92** houses the passageways through which the pulling mechanism pulls the fibers. The outer hooked portions **94** form a support system whereby the bushing **90** is placed within the oven in zone **5**. The outer hooked portion **94** connects with interlocking long steel beams within the oven that function to support the bushings **90**.

Zone **5** comprises a series of eight consecutive bushings. The bushings have two functions: (1) guide the fiber in the configuration for the final product; and (2) shape and compress the fibers. In one embodiment, the bushings **90** are placed apart within the oven supported on the hooked structures. The bushings **90** function to continually compress the fibers and form a composite core comprising, in this embodiment, carbon and glass while the process is under appropriate tension to achieve concentricity and uniform distribution of fiber without commingling of fibers.

The bushings **90** may be designed to form bundles of a plurality of geometries. For example, FIG. **5** illustrates the variations in cross sections in composite member. Each cross section results from different bushing **90** design.

The passageways in each successive bushing **90** diminish in size further compacting the fiber bundles. For example, FIG. **6** shows each bushing **90** superimposed on top of one another. Several changes are apparent with each consecutive bushing **90**. First, each overlayed bushing **90** shows that the size of each passageway decreases. Second, the superimposed figure shows the appearance of the center hole for compaction of the core element. Third, the figure shows the movement of the outer corner passageways towards the center position.

Referring to FIG. **4**, there are two bushings illustrated. The first bushing **100** illustrated, is in a similar configuration as the guide bushing **18**. The second bushing **104** is the first in the series of bushings that function to compress and configure the composite core. The first bushing **100** comprises an inner square portion **92** with a plurality of passageways **102** prearranged through which the fibers are pulled. The passageways **102** are designed to align the fibers into groups in bushing two **104** having four outer groups **106** of fibers and four inner groups **108** of fibers. The inner square portion of the bushing **100** comprises six rows of passageways **110**. The arrangement of the passageways **110** may be configured into any plurality of configurations depending on the desired cross section geometry of the composite core member. The top and bottom row, **112** and **114** respectively, contain the same number of passageways. The next to top and next to bottom rows, **116** and **118** respectively, contain the same number of passageways and the two inner rows **120** and **122** contain the same number of passageways.

In a preferred embodiment, the top and bottom rows contain 32 passageways each. The next level of rows contain 31 passageways each. The middle rows contain 4 passageways each. The pulling mechanism pulls two fibers through each passageway. Referring to FIG. **4** for example, the pulling mechanism pulls 126 glass fibers through rows **112**, **114**, **116** and **118**. Further, the pulling mechanism pulls 16 carbon fibers through rows **120** and **122**.

Referring to FIG. **7**, the next bushing **130**, bushing three in the series comprises an inner square portion **131** having four outer corner passageways **132*a***, **132*b***, **132*c*** and **132*d*** and four inner passageways **134*a***, **134*b***, **134*c*** and **134*d***. The fibers exit bushing two and are divided into equal parts and pulled through bushing three. Each passageway in bushing three comprises one quarter of the particular type of fiber pulled through bushing two. More specifically, the top two rows of the top and the bottom of bushing two are divided in half whereby the right half of the top two rows of fibers are pulled through the right outer corner of bushing three. The left half of the top two rows of fibers are pulled through the upper left corner **132*a*** of bushing three **130**. The right half of the top two rows of fibers are pulled through the upper right corner **132*b*** of bushing three **130**. The right half of the bottom two rows of fibers are pulled through the lower right corner **132*c*** of bushing three. The left half of the bottom two rows of fibers are pulled through the lower left corner **132*d*** of bushing three **130**. The inner two rows of bushing one are divided in half whereby the top right half of the top middle row of fibers is pulled through the inner upper right corner **134*b*** of bushing three **130**. The left half of the top middle row of fibers is pulled through the inner upper left corner **134*a*** of bushing three **130**. The right half of the lower middle row of fibers is pulled through the inner lower right corner **134***c* of bushing three **130**. The left half of the lower middle row of fibers is pulled through the inner lower left corner **134***d* of bushing three **130**. Accordingly, bushing three **130** creates eight bundles of impregnated fibers that will be continually compressed through the series of next bushings.

The puller pulls the fibers through bushing three **130** to bushing four **140**. Bushing four **140** comprises the same configuration as bushing three **130**. Bushing four **140** comprises a square inner portion **141** having four outer corner passageways **142***a*, **142***b*, **142***c* and **142***d* and four inner passageways **144***a*, **144***b*, **144***c* and **144***d*. Preferably, the four outer corner passageways **142***a-d* and the four inner passageways **144***a-d* are slightly smaller in size than the similarly configured passageways in bushing three **130**. Bushing four **140** compresses the fibers pulled through bushing three.

The puller pulls the fibers from bushing four **140** to bushing five **150**. Preferably, the four outer corner passageways **152***a*, **152***b*, **152***c* and **152***d* and the four inner passageways **154***a*, **154***b*, **154***c* and **154***d* are slightly smaller in size than the similarly configured passageways in bushing four **140**. Bushing five **150** compresses the fibers pulled through bushing four **140**.

For each of the successive bushings, each bushing creates a bundle of fibers with an increasingly smaller diameter. Preferably, each smaller bushing wipes off excess resin to approach the optimal and desired proportion of resin to fiber composition.

The puller pulls the fibers from bushing five **150** to bushing six **160**. Preferably, the four outer corner passageways **162***a*, **162***b*, **162***c* and **162***d* and the four inner passageways **164***a*, **164***b*, **164***c* and **164***d* are slightly smaller in size than the similarly configured passageways in bushing five **150**. Bushing six **160** compresses the fibers pulled through bushing five **150**.

Bushing seven **170** comprises an inner square **171** having four outer corner passageways **172***a*, **172***b*, **172***c* and **172***d* and one inner passageway **174**. The puller pulls the fibers from the four inner passageways **164** of bushing six **160** through the single inner passageway **174** in bushing seven **170**. The process compacts the product to a final uniform concentric core. Preferably, fibers are pulled through the outer four corners **172***a*, **172***b*, **172***c*, **172***d* of bushing seven **170** simultaneous with compacting of the inner four passageways **164** from bushing six **160**.

The puller pulls the fibers through bushing seven **170** to bushing eight **180**. The puller pulls the inner compacted core **184** and the outer four corners **182***a*, **182***b*, **182***c*, **182***d* migrate inwardly closer to the core **184**. Preferably, the outer fibers diminish the distance between the inner core and the outer corners by half the distance.

The puller pulls the fibers through bushing eight **180** to bushing nine **190**. Bushing nine **190** is the final bushing for the formation of the composite core. The puller pulls the four outer fiber bundles and the compacted core through a passageway **192** in the center of bushing nine **190**.

Preferably, bushing nine **190** compacts the outer portion and the inner portion creating an inner portion of carbon and an outer portion of glass fiber. FIG. **8** for example, illustrates a cross-section of a composite cable. The example illustrates a composite core member **200** having an inner reinforced carbon fiber composite portion **202** surrounded by an outer reinforced glass fiber composite portion **204**.

Temperature is kept constant throughout zone **5**. The temperature is determined by the process and is high enough to keep the resin in a semi-cured state. At the end of zone **5**, the product comprises the final level of compaction and the final diameter.

The puller pulls the fibers from zone **5** to zone **6** a curing stage preferably comprising an oven with constant heat and airflow as in zone **5**, **4** and **2**. The oven uses the same constant heating and cross circular air flow as in zone **5**, zone **4** and zone **2**. The process determines the curing heat. The curing heat remains constant throughout the curing process. In the present invention, the preferred temperature for curing ranges from about 350° F. to about 400° F. The curing process preferably spans within the range of about 8 to about 15 feet. More preferably, the curing process spans about 10 feet in length. The high temperature of zone **6** results in a final cure forming a hard resin.

Zone **6** may incorporate a bushing ten to assure that the final fiber composite cor member holds its shape. In addition, another bushing prevents bluming of the core during curing.

During the next stages the composite core member product is pulled through a series of heating and cooling phases. The post cure heating improves cross linking within the resin matrix improving the physical characteristics of the product. The pullers pull the fibers to zone **7**, a cooling device. Preferably, the mechanical configuration of the oven is the same as in zones **2**, **4**, **5** and **6**. More specifically, the device comprises a closed circular air system using a cooling device and a blower. Preferably, the cooling device comprises a plurality of coils. Alternatively, the coils may be horizontally structured consecutive cooling elements. In a further alternative, the cooling device comprises cooling spirals. The blower is placed upstream from the cooling device and continuously blows air in the cooling chamber in an upstream direction. The air circulates through the device in a closed circular direction keeping the air throughout at a constant temperature. Preferably, the cooling temperature ranges from within about 40 to about 180° F.

The pullers pull the composite member through zone **7** to zone **8**, the post-curing phase. The composite core member is heated to post-curing temperature to improve the mechanical properties of the composite core member product.

The pullers pull the composite core member through zone **8** to zone **9**, the post curing cooling phase. Once the composite core has been reheated, the composite core is cooled before the puller grabs the compacted composite core. Preferably, the composite core member cools for a distance ranging about 8 to about 15 feet by air convection before reaching the puller. Most preferably, the cooling distance is about 10 feet.

The pullers pull the composite core member through the zone **9** cooling phase into zone **10**, a winding system whereby the fiber core is wrapped around a wheel for storage. It is critical to the strength of the core member that the winding does not over stress the core by bending. In one embodiment, the core does not have any twist and can only bend a certain degree. In another embodiment, the wheel has a diameter of seven feet and handles up to 6800 feet of B-stage formed composite core member. The wheel is designed to accommodate the stiffness of the B-stage formed composite core member without forcing the core member into a configuration that is too tight. In a further embodiment, the winding system comprises a means for preventing the wheel from reversing flow from winding to unwinding. The means can be any device that prevents the wheel direction from reversing for example, a brake system.

In a further embodiment, the process includes a quality control system comprising a line inspection system. The quality control process assures consistent product. The quality control system may include ultrasonic inspection of composite core members; record the number of tows in the end product; monitor the quality of the resin; monitor the temperature of the ovens and of the product during various phases; measure formation; measure speed of the pulling process. For example, each batch of composite core member has supporting data to keep the process performing optimally. Alternatively, the quality control system comprises a marking system. The marking system wherein the marking system marks the composite core members with the product information of the particular lot. Further, the composite core members may be placed in different classes in accordance with specific qualities, for example, Class A is high grade, Class B and Class C.

The fibers used to process the composite core members can be interchanged to meet specifications required by the final composite core member product. For example, the process allows replacement of fibers in a composite core member having a carbon core and a glass fiber outer core with high grade carbon and E-glass. The process allows the use of more expensive better performing fibers in place of less expensive fibers due to the combination of fibers and the small core size required. In one embodiment, the combination of fibers creates a high strength inner core with minimal conductivity surrounded by a low modulus nonconductive outer insulating layer. In another embodiment, the outer insulating layer contributes to the flexibility of the composite core member and enables the core member to be wound, stored and transported.

Another embodiment of the invention, allows for redesign of the composite core cross section to accommodate varying physical properties and increase the flexibility of the composite core member. Referring again to FIG. 5, the different composite shapes change the flexibility of the composite core member. Changing the core design may enable winding of the core on a smaller diameter wheel. Further, changing the composite core design may affect the stiffness and strength of the inner core. As an advantage, the core geometry may be designed to achieve optimal physical characteristics desired in a final ACCC cable.

In another embodiment of the invention, the core diameter is greater than 0.375 inches. A core greater than 0.375 inches cannot bend to achieve a 7-foot wrapping diameter. The potential strength on the outside bend shape exceeds the strength of the material and the material will crack. A core diameter of ½ to ⅝ inch may require a wheel diameter of 15 feet and this is not commercially viable. To increase the flexibility of the composite core, the core may be twisted or segmented to achieve a wrapping diameter that is acceptable. One 360 degree twist of fiber orientation in the core for one revolution of core. Alternatively, the core can be a combination of twisted and straight fiber. The twist may be determined by the wheel diameter limit. If the limit is prohibited then twist by one revolution of diameter of the wheel. The tension and compression stresses in the core are balanced by one revolution.

Winding stress is reduced by producing a segmented core. FIG. 5 illustrates some examples of possible cross section configurations of segmented cores. The segmented core under the process is formed by curing the section as separate pieces wherein the separate pieces are then grouped together. Segmenting the core enables a composite member product having a core greater than 0.375 inches to achieve a desirable winding diameter without additional stress on the member product.

Variable geometry of the cross sections in the composite core members are preferably processed as a multiple stream. The processing system is designed to accommodate formation of each segment in parallel. Preferably, each segment is formed by exchanging the series of consecutive bushings for bushings having predetermined configurations for each of the passageways. In particular, the size of the passageways may be varied to accommodate more or less fiber, the arrangement of passageways may be varied in order to allow combining of the fibers in a different configuration in the end product and further bushings may be added within the plurality of consecutive bushings to facilitate formation of the varied geometric cross sections in the composite core member. At the end of the processing system the five sections in five streams of processing are combined at the end of the process to form the composite cable core. Alternatively, the segments may be twisted to increase flexibility and facilitate winding The final composite core is wrapped in lightweight high conductivity aluminum forming a composite cable. Preferably, the composite core cable comprises an inner carbon core having an outer insulating glass fiber composite layer and two layers of trapezoidal formed strands of aluminum.

In one embodiment, the inner layer of aluminum comprises a plurality of trapezoidal shaped aluminum segments wrapped in a counter-clockwise direction around the composite core member. Each trapezoidal section is designed to optimize the amount of aluminum and increase conductivity. The geometry of the trapezoidal segments allows for each segment to fit tightly together and around the composite core member.

In a further embodiment, the outer layer of aluminum comprises a plurality of trapezoidal shaped aluminum segments wrapped in a clockwise direction around the composite core member. The opposite direction of wrapping prevents twisting of the final cable. Each trapezoidal aluminum element fits tightly with the trapezoidal aluminum elements wrapped around the inner aluminum layer. The tight fit optimizes the amount of aluminum and decreases the aluminum required for high conductivity.

EXAMPLE

A particular embodiment of the invention is now described wherein the composite strength member comprises E-glass and carbon type 13 sizing. E-glass combines the desirable properties of good chemical and heat stability, and good electrical resistance with high strength. The cross-sectional shape or profile is illustrated in FIG. 8 wherein the composite strength member comprises a concentric carbon core encapsulated by a uniform layer of glass fiber composite. In a preferred embodiment the process produces a hybridized core member comprising two different materials.

The fiber structures in this particular embodiment are 126 ends of E-glass product, yield 900, Veterotex Amer and 16 ends of carbon Torayca T7DOS yield 24K. The resin used is an epoxy resin called ARALDITE MY 721 from Vantico.

In operation, the ends of 126 fiber tows of E-glass and 16 fiber tows of carbon are threaded through a fiber tow guide comprising two rows of 32 passageways, two rows inner of 31 passageways and two innermost rows of 4 passageways and into a preheating stage at 150° F. to evacuate any moisture. After passing through the preheating oven, the fiber tows are pulled through a wet out tank. In the wet out tank a device effectually moves the fibers up and down in a vertical direction enabling thorough wetting of the fiber tows. On the upstream side of the wet out tank is located a wiper system that removes excess resin as the fiber tows are pulled from the tank. The excess resin is collected by a resin overflow tray and added back to the resin wet out tank.

The fiber tows are pulled from the wet out tank to a B-state oven that semi-cures the resin impregnated fiber tows to a tack stage. At this stage the fiber tows can be further compacted and configured to their final form in the next phase. The fiber tows are pulled to a next oven at B-stage oven temperature to maintain the tack stage. Within the oven are eight consecutive bushings that function to compact and configure the fiber tows to the final composite core member form. Two fiber tow ends are threaded through each of the 134 passageways in the first bushing which are machined to pre-calculated dimensions to achieve a fiber volume of 72 percent and a resin volume of 28 percent in the final composite core member. The ends of the fiber tows exiting from passageways in the top right quarter comprising half of the two top rows are threaded through passageways **132** of the next bushing; the ends of the fiber tows exiting from passageways in the top left quarter comprising half of the top two rows are threaded through passageway **136** of the next bushing; the ends of the fiber tows exiting from passageways in the lower right quarter comprising half of the bottom two rows are threaded through passageway **140** of the next bushing; the ends of the fiber tows exiting from passageways in the lower left quarter comprising half of the bottom two rows are threaded through passageway **138** of the next bushing; the right and left quarters of passageways in the middle upper row are threaded through passageways **142** and **144** of the next bushing and the right and left quarters of passageways in the middle bottom row are threaded through passageways **134** and **146** respectively.

The fiber tows are pulled consecutively through the outer and inner passageways of each successive bushing further compacting and configuring the fiber bundles. At bushing seven, the fiber bundles pulled through the inner four passageways of bushing six are combined to form a composite core whereas the remaining outer passageways continue to keep the four bundles glass fibers separate. The four outer passageways of bushing seven are moved closer inward in bushing eight, closer to the inner carbon core. The fiber tows are combined with the inner carbon core in bushing nine forming a hybridized composite core member comprising an inner carbon core having an outer glass layer.

The composite core member is pulled from the bushing nine to a final curing oven at an elevated temperature of 380° F. as required by the specific resin. From the curing oven the composite core member is pulled through a cooling oven to be cooled to 150 to 180° F. After cooling the composite core member is pulled through a post curing oven at elevated temperature, preferably to heat the member to at least B-stage temperature. After post-curing the member is cooled by air to approximately 180° F. The member is cooled prior to grabbing by the caterpillar puller to the core winding wheel having 6000 feet of storage.

EXAMPLE

An example of an ACCC reinforced cable in accordance with the present invention follows. An ACCC reinforced cable comprising four layers of components consisting of an inner carbon/epoxy layer, a next glassfiber/epoxy layer and two layers of tetrahedral shaped aluminum strands. The strength member consists of an advanced composite T700S carbon/epoxy having a diameter of about 0.2165 inches, surrounded by an outer layer of R099-688 glassfiber/epoxy having a layer diameter of about 0.375 inches. The glassfiber/epoxy layer is surrounded by an inner layer of nine trapezoidal shaped aluminum strands having a diameter of about 0.7415 inches and an outer layer of thirteen trapezoidal shaped aluminum strands having a diameter of about 1.1080 inches. The total area of carbon is about 0.037 in^2, of glass is about 0.074 in^2, of inner aluminum is about 0.315 in^2 and outer aluminum is about 0.5226 in^2. The fiber to resin ratio in the inner carbon strength member is 70/30 by weight and the outer glass layer fiber to resin ratio is 75/25 by weight.

The specific specifications are summarized in the following table:

Glass Vetrotex roving R099-686 (900 Yield)	
Tensile Strength, psi	298,103
Elongation at Failure, %	3.0
Tensile Modulus, × 10^6 psi	11.2
Glass Content, %	57.2
Carbon (graphite) Carbon: Torayca T700S (Yield 24K)	
Tensile strength, Ksi	711
Tensile Modulus, Msi	33.4
Strain	2.1%
Density lbs/ft^3	0.065
Filament Diameter, in	2.8E−04
Epoxy Matrix System Araldite MY 721	
Epoxy value, equ./kg	8.6-9.1
Epoxy Equivalent, g/equ.	109-
Viscosity @ 50 C., cPs	3000-6000
Density @ 25 C. lb/gal.	1.1501.18
Hardener 99-023	
Viscosity @ 25 C., cPs	75-300
Density @ 25 C., lb/gal	1.19-1/22
Accelerator DY 070	
Viscosity @ 25 C., cPs	<50
Density @ 25 C., lb/gal	0.95-1.05

An ACCC reinforced cable having the above specifications is manufactured according to the following. The process used to form the composite cable in the present example is illustrated in FIG. **1**. First, 126 spools of glass fiber tows **12** and 8 spools of carbon are set up in the rack system **14** and the ends of the individual fiber tows **12**, leading from spools **11**, are threaded through a fiber tow guide **18**. The fibers undergo tangential pulling to prevent twisted fibers. A puller **16** at the end of the apparatus pulls the fibers through the apparatus. Each dispensing rack **14** has a small brake to individually adjust the tension for each spool. The tows **12** are pulled through the guide **18** and into a preheating oven **20** at 150° F. to evacuate moisture.

The tows **12** are pulled into wet out tank **22**. Wet out tank **22** is filled with an epoxy resin called ARALDITE MY 721 MY 721/Hardener 99-023/Accelerator DY070 to impregnate the fiber tows **12**. Excess resin is removed from the fiber tows **12** during wet out tank **22** exit. The fiber tows **12** are pulled from the wet out tank **22** to a B-stage oven **24** and are heated to 200° F. Fiber tows **12** maintained separated by the guide **18**, are pulled into a second B-stage oven **26** also at 200° F. comprising a plurality of consecutive bushings to compress and configure the tows **12**. In the second B-stage oven **26**, the fiber tows **12** are directed through a plurality of passageways provided by the bushings. The consecutive passageways continually compress and configure the fiber tows **12** into the final uniform composite core member.

The first bushing has two rows of 32 passageways, two inner rows of 31 passageways each and two inner most rows of 4 passageways each. The 126 glass fiber tows are pulled through the outer two rows of 32 and 31 passageways, respectively. The carbon fiber tows are pulled through the inner two rows of 4 passageways eaten. The next bushing splits the top two rows in half and the left portion is pulled through the left upper and outer corner passageway in the second bushing. The right portion is pulled through the right upper and outer corner passageway in the second bushing. The bottom two rows are split in half and the right portion is pulled through the lower right outer comer of the second bushing and the left portion is pulled through the lower left outer corner of the second bushing. Similarly, the two inner rows of carbon are split in half and the fibers of the two right upper passageways are pulled through the inner upper right corner of the second bushing. The fibers of the left upper passageways are pulled through the inner upper left corner of the second bushing. The fibers of the right lower passageways are pulled through the inner lower right corner of the second bushing and the fibers of the left lower passageways are pulled through the inner lower left corner of the second bushing.

The fiber bundles are pulled through a series of seven bushings continually compressing and configuring the bundles into one hybridized uniform concentric core member.

The composite core member is pulled from the second B-stage oven **26** to a next oven processing system **28** at 330 to 370° F. wherein the composite core member is cured and pulled to a next cooling system **30** at 30 to 100° F. for cooling. After cooling, the composite core is pulled to a next oven processing system **32** at 330 to 370° F. for post curing. The pulling mechanism pulls the product through a 10 foot air cooling area at about 180° F.

Nine trapezoidal shaped aluminum strands each having an area of about 0.0350 or about 0.315 sq. in. total area on the core are wrapped around the composite core after cooling. Next, thirteen trapezoidal shaped aluminum strands each strand having an area of about 0.0402 or about 0.5226 sq. in. total area on the core are wrapped around the inner aluminum layer.

It is to be understood that the invention is not limited to the exact details of the construction, operation, exact materials, or embodiments shown and described, as modifications and equivalents will be apparent to one skilled in the art without departing from the scope of the invention.

We claim:

1. A composite core for an electrical cable comprising:

an inner core comprising a plurality of substantially continuous reinforcing fibers of at least a first type, the first fiber type having a tensile strength that exceeds the tensile strength of glass fibers;

an outer core comprising a plurality of substantially continuous reinforcing fibers of at least a second type, the second fiber type having a tensile strength of or similar to glass fibers; and

a resin matrix, wherein the fibers of the inner and the outer cores are embedded therein;

wherein, the fibers of the inner core are different from the fibers of the outer core, and wherein the fibers of the inner and the outer cores are oriented substantially parallel to the longitudinal axis.

2. A composite core as claimed in claim **1** wherein, the first fiber type is carbon.

3. A composite core as claimed in claim **1**, wherein the second fiber type is glass.

4. A composite core as claimed in claim **1** wherein, the first reinforcing fiber type in the inner core comprises a modulus of elasticity in the range of about 22 (151 GPa) to 37 Msi (255 GPa) coupled with a coefficient of thermal expansion in the range of about −0.7 to about 0 m/m/° C. and a tensile strength of at least about 350 Ksi (2413 MPa) and the second reinforcing fiber type in the outer core comprises a tensile strength in the range of at least about 180 Ksi (1241 MPa) coupled with a coefficient of thermal expansion in the range of about 5×10^{-6} to about 10×10^{-6} m/m/° C.

5. A composite core as claimed in claim **1** wherein, the composite material of the inner core and the outer core is selected to meet physical characteristics in the end composite core including a tensile strength of at least 160 Ksi (1103 MPa), a modulus of elasticity in the range of at least about 7 Msi (48 GPa) to about 30 Msi (206 GPa), an operating temperature in the range of about 90 to about 230° C. and a thermal expansion coefficient at least in the range of about 0 to about 6×10^{-6} m/m/° C.

6. A composite core as claimed in claim **1** comprising a fiber/resin volume fraction in the range of at least about 50%.

7. A composite core as claimed in claim **1** comprising a fiber/resin ratio of at least about 62% by weight.

8. A composite core as claimed in claim **1** wherein, the inner core comprises carbon fibers and the outer core comprises glass fibers.

9. A composite core as set forth in claim **1** wherein, said outer core and said inner core form a segmented concentric core.

10. A composite core as claimed in claim **1** wherein, at least one layer of a plurality of aluminum segments is wrapped around the core.

11. A composite core for an electrical cable comprising:

a plurality of reinforcing fibers in a thermosetting resin matrix to form the core, said core having at least 50% fiber volume fraction, the plurality of reinforcing fibers consisting of two or more different types of fibers, a first fiber type having a modulus of elasticity in the range of about 22 (151 GPa) to 37 Msi (255 GPa) and a tensile strength at least about 350 Ksi (2413 MPa) and a second fiber type having a modulus of elasticity in the range of about 6 Msi to about 11.2 Msi and a tensile strength of at least about 180 Ksi (1241 MPa); wherein, the fibers are arranged within the resin matrix having the higher tensile strength fibers in the center of the core.

12. A composite core as claimed in claim **11** wherein, the first reinforcing fiber type is carbon.

13. A composite core as claimed in claim **11** wherein, the second reinforcing fiber type is glass.

14. A composite core as claimed in claim **11** wherein, the proportion and type of fibers are selected to meet physical characteristics in the end composite core including a tensile strength in the range of at least 160 Ksi (1103 MPa), a modulus of elasticity in the range of at least about 7 (48 GPa) to about 30 Msi (206 GPa), an operating temperature in the range of about 90 to about 230° C. and a thermal expansion coefficient at least in the range of about 0 to about 6×10^{-6} m/m/° C.

15. A composite core as claimed in claim **11** comprising a fiber resin ratio of at least about 62% by weight.

16. A composite core as claimed in claim **11** wherein the first fiber type forms an inner core and the second fiber type forms an outer core that surrounds the inner core.

17. A composite core as claimed in claim **16** wherein, the inner core comprises carbon fibers and the outer core comprises glass fibers.

18. A composite core as set forth in claim **11** wherein, the core is segmented.

19. A composite core as claimed in claim **11** wherein, at least one layer of a plurality of aluminum segments is wrapped around the core.

20. A composite core for an electrical cable comprising:

an inner core consisting of a plurality of substantially continuous reinforcing fibers, the fibers having a tensile strength that exceeds the tensile strength of glass fibers;

an outer core surrounding the inner core consisting at least in part of a plurality of substantially continuous reinforcing glass fibers; and

a cured resin matrix, wherein the fibers of the inner and the outer cores are embedded therein;

wherein, the fibers of the inner and the outer cores are oriented substantially parallel to the longitudinal axis.

21. A composite core as claimed in claim **20** wherein, the fibers of the inner core are carbon.

22. A composite core as claimed in claim **20** wherein, the inner core comprises carbon and basalt fibers.

23. A composite core as claimed in claim **20** wherein, the fibers of the inner core have a modulus of elasticity in the range of about 22 to about 37 Msi.

24. A composite core as claimed in claim **20** comprising a fiber/resin volume fraction in the range of at least about 50%.

25. A composite core as claimed in claim **20** comprising a fiber resin ratio of at least about 62% by weight.

26. A composite core as claimed in claim **20** wherein, at least one layer of a plurality of aluminum segments is wrapped around the core.

27. A composite core for an electrical cable comprising:

an inner core comprising a plurality of reinforcing carbon fibers and at least a portion of a plurality of reinforcing fibers having a tensile strength in excess of glass fibers;

an outer core surrounding the inner core comprising a plurality of glass fibers; and

a cured resin matrix, wherein the fibers of the inner and the outer cores are embedded therein;

wherein, the fibers of the inner and outer cores are oriented substantially parallel to the longitudinal axis.

28. The composite core as claimed in claim **27**, wherein the fiber having a tensile strength in excess of glass fibers is basalt.

29. An electrical cable comprising:

a composite core further comprising:

an inner core comprising a plurality of substantially continuous reinforcing fibers of at least a first type, the first type having a tensile strength that exceeds the tensile strength of glass fibers, wherein the fibers are substantially parallel to the longitudinal axis;

an outer core comprising a plurality of substantially continuous reinforcing fibers of at least a second type, the second type having a tensile strength of or similar to glass fibers, wherein the fibers are substantially parallel to the longitudinal axis; and

a cured resin matrix, wherein the fibers of the inner and the outer cores are embedded therein; and

at least one layer of conductor surrounding said outer core.

30. An electrical cable as claimed in claim **29** wherein, the composite material of the inner core and the outer core is selected to meet physical characteristics in the end composite core including a tensile strength of at least 160 Ksi (1103 MPa), a modulus of elasticity in the range of at least about 7 Msi (48 GPa) to about 30 Msi (206 GPa), an operating temperature in the range of about 90 to about 230° C. and a thermal expansion coefficient at least in the range of about 0 to about 6×10^{-6} m/m/° C.

31. An electrical cable as claimed in claim **29** wherein, the composite core comprises a fiber/resin volume fraction in the range of at least about 50%.

32. An electrical cable as claimed in claim **29** wherein, the composite core comprises a fiber/resin ratio of at least about 62% by weight.

33. An electrical cable as claimed in claim **29** wherein, the fibers of the inner core are carbon and the fibers of the outer core are glass.

34. An electrical cable as claimed in claim **29** wherein, the conductor surrounding the core comprises a plurality of aluminum segments.

35. An electrical cable as set forth in claim **29** wherein, the composite core is segmented.

36. A method of transmitting electrical power comprising:

using a cable comprising a composite core and at least one layer of aluminum conductor surrounding the composite core, the composite core further comprising:

an inner core comprising a plurality of substantially continuous reinforcing fibers of at least a first type, the first type having a tensile strength that exceeds the tensile strength of glass fibers, wherein the fibers are substantially parallel to the longitudinal axis;

an outer core comprising a plurality of substantially continuous reinforcing fibers of at least a second type, the second type having a tensile strength of or similar to glass fibers, wherein the fibers are substantially parallel to the longitudinal axis; and

a cured resin matrix, wherein the fibers of the inner and the outer cores are embedded therein; and

transmitting power across the composite cable.

* * * * *

EXHIBIT B

US 7,368,162 C1 (7555th)

ALUMINUM CONDUCTOR COMPOSITE CORE REINFORCED CABLE AND METHOD OF MANUFACTURE

Clem Hiel, Rancho Palos Verdes, Calif., and George Korzlenowski, Woodland Hills, Calif., assignors to CTC Cable Corporation, Irvine, Calif.

Reexamination Request No. 90/009,493, Jul. 18, 2009.

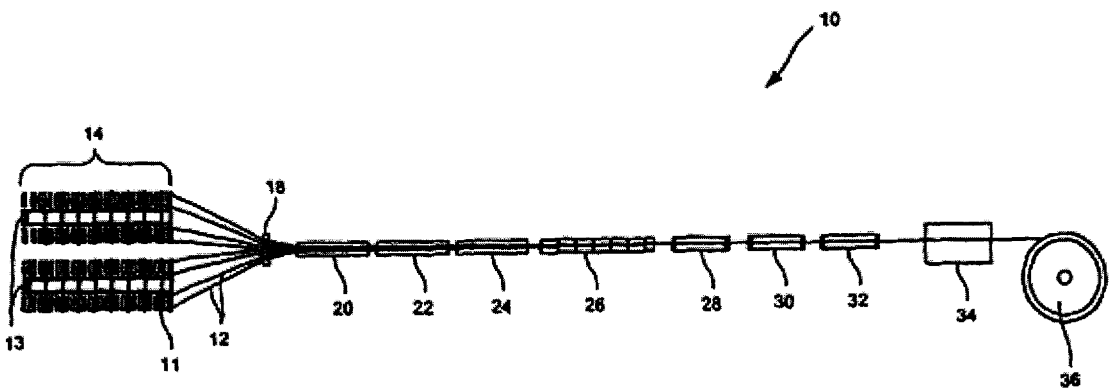
Reexamination Certificate for Patent 7,368,162, issued May 6, 2008, Appl. No. 511,881, Oct. 19, 2004.

PCT No. PCT/US03/12520, § 371 Date Nov. 6, 2003, PCT Pub. No. WO03/09100, PCT Pub. Date Nov. 6, 2003

Provisional application No. 60/374,879, filed on Apr. 23, 2002.

Int. Cl. B32B *27/04;* **H02G** *3/00* (2006.01)

U.S. Cl. 428—300.7



AS A RESULT OF REEXAMINATION, IT HAS BEEN DETERMINED THAT:

The patentability of claims **29-36** is confirmed.

Claims **1**, **11**, **20** and **27** are determined to be patentable as amended.

Claims **2-10**, **12-19**, **21-26** and **28**, dependent on an amended claim, are determined to be patentable.

New claims **37-83** are added and determined to be patentable.

1. A composite core for an electrical cable comprising:
an inner core comprising a plurality of substantially continuous reinforcing fibers of at least a first type, the first fiber type having a tensile strength that exceeds the tensile strength of glass fibers;
an outer core comprising a plurality of substantially continuous reinforcing fibers of at least a second type, the second fiber type having a tensile strength of or similar to glass fibers; and
a resin matrix, wherein the fibers of the inner and the outer cores are embedded therein;
wherein, the fibers of the inner core are different from the fibers of the outer core, and wherein the fibers of the inner and the outer cores are oriented substantially parallel to the longitudinal axis *and wherein the composite core is adapted for use as a strength member in an electrical cable.*

EXHIBIT C

US007368162C2

(12) **EX PARTE REEXAMINATION CERTIFICATE** (9008th)

United States Patent

Hiel et al.

(10) **Number: US 7,368,162 C2**
(45) **Certificate Issued: May 8, 2012**

(54) **ALUMINUM CONDUCTOR COMPOSITE CORE REINFORCED CABLE AND METHOD OF MANUFACTURE**

(75) Inventors: **Clem Hiel**, Rancho Palos Verdes, CA (US); **George Korzienowski**, Woodland Hills, CA (US)

(73) Assignee: **Partners for Growth II, L.P.**, San Francisco, CA (US)

Reexamination Request:
No. 90/011,740, Jun. 13, 2011

Reexamination Certificate for:

Patent No.:	**7,368,162**
Issued:	**May 6, 2008**
Appl. No.:	**10/511,881**
Filed:	**Oct. 19, 2004**

Reexamination Certificate C1 7,368,162 issued Jun. 8, 2010

Certificate of Correction issued Jun. 8, 2010.

(22) PCT Filed: **Apr. 23, 2003**

(86) PCT No.: **PCT/US03/12520**

§ 371 (c)(1), (2), (4) Date: **Nov. 6, 2003**

(87) PCT Pub. No.: **WO03/091008**

PCT Pub. Date: **Nov. 6, 2003**

Related U.S. Application Data

(60) Provisional application No. 60/374,879, filed on Apr. 23, 2002.

(51) **Int. Cl.**
B32B 27/04 (2006.01)
H02G 3/00 (2006.01)

(52) **U.S. Cl.** .... **428/300.7**; 174/102 R; 174/70 R; 174/106 R; 174/113 C; 428/297.4; 428/298.1; 428/299.1; 428/299.4; 428/300.4

(58) **Field of Classification Search** .... None
See application file for complete search history.

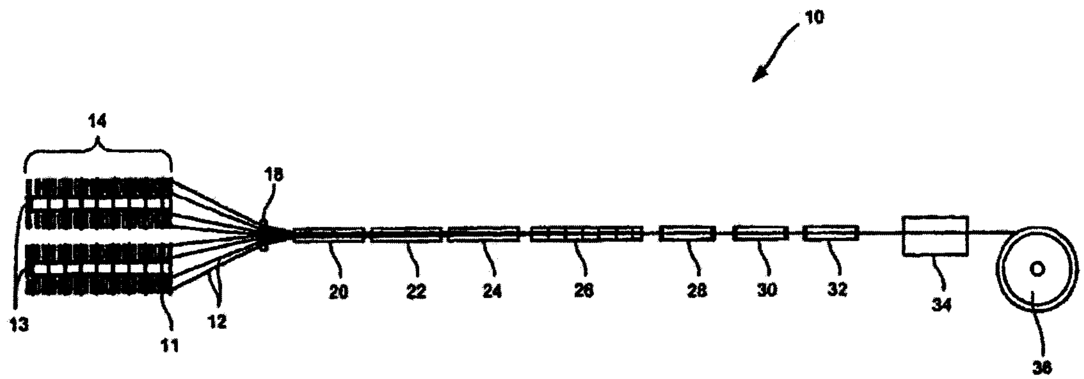
(56) **References Cited**

To view the complete listing of prior art documents cited during the proceeding for Reexamination Control Number 90/011,740, please refer to the USPTO's public Patent Application Information Retrieval (PAIR) system under the Display References tab.

Primary Examiner—Norca L Torres Velazquez

(57) **ABSTRACT**

This invention relates to an aluminum conductor composite core reinforced cable (ACCC) and method of manufacture. An ACCC cable having a composite core surrounded by at least one layer of aluminum conductor. The composite core comprises at least one longitudinally oriented substantially continuous reinforced fiber type in a thermosetting resin matrix having an operating temperature capability within the range of about 90 to about 230° C., at least 50% fiber volume fraction, a tensile strength in the range of about 160 to about 240 Ksi, a modulus of elasticity in the range of about 7 to about 30 Msi and a thermal expansion coefficient in the range of about 0 to about 6×10^{-6} m/m/C. According to the invention, a B-stage forming process may be used to form the composite core at improved speeds over pultrusion processes wherein the speeds ranges from about 9 ft/min to about 50 ft/min.



EX PARTE REEXAMINATION CERTIFICATE ISSUED UNDER 35 U.S.C. 307

THE PATENT IS HEREBY AMENDED AS INDICATED BELOW.

Matter enclosed in heavy brackets [ ] appeared in the patent, but has been deleted and is no longer a part of the patent; matter printed in italics indicates additions made to the patent.

AS A RESULT OF REEXAMINATION, IT HAS BEEN DETERMINED THAT:

Claims **1**, **11**, **20**, **27**, **29-36**, **58-62** and **70-80** are determined to be patentable as amended.

Claims **2-10**, **12-19**, **21-26**, **28**, **37-57**, **63-69** and **81-83**, dependent on an amended claim, are determined to be patentable.

1. A composite core for an *overhead* electrical cable comprising:

an inner core comprising a plurality of substantially continuous reinforcing fibers of at least a first type, the first fiber type having a tensile strength that exceeds the tensile strength of glass fibers;

an outer core comprising a plurality of substantially continuous reinforcing fibers of at least a second type, the second fiber type having a tensile strength of or similar to glass fibers; and

a resin matrix, wherein the fibers of the inner and the outer cores are embedded therein;

wherein, the fibers of the inner core are different from the fibers of the outer core, and wherein the fibers of the inner and the outer cores are oriented substantially parallel to the longitudinal axis and wherein the composite core is adapted for use as a strength member in an *overhead* electrical cable.

11. A composite core for an *overhead* electrical cable comprising:

a plurality of reinforcing fibers in a thermosetting resin matrix to form the core, said core having at least 50% fiber volume fraction, the plurality of reinforcing fibers consisting of two or more different types of fibers, a first fiber type having a modulus of elasticity in the range of about 22 (151 GPa) to 37 Msi (255 GPa) and a tensile strength of at least about 350 Ksi (2413 MPa) and a second fiber type having a modulus of elasticity in the range of about 6 Msi to about 11.2 Msi and a tensile strength of at least about 180 Ksi (1241 MPa);

wherein, the fibers are arranged within the resin matrix having the higher tensile strength fibers in the center of the core, and wherein the composite core is adapted for use as a strength member in an *overhead* electrical cable.

20. A composite core for an *overhead* electrical cable comprising:

an inner core consisting of a plurality of substantially continuous reinforcing fibers, the fibers having a tensile strength that exceeds the tensile strength of glass fibers;

an outer core surrounding the inner core consisting at least in part of a plurality of substantially continuous reinforcing glass fibers; and

a cured resin matrix, wherein the fibers of the inner and the outer cores are embedded therein;

wherein, the fibers of the inner and the outer cores are oriented substantially parallel to the longitudinal axis, and wherein the composite core is adapted for use as a strength member in an *overhead* electrical cable.

27. A composite core for an *overhead* electrical cable comprising:

an inner core comprising a plurality of reinforcing carbon fibers and at least a portion of a plurality of reinforcing fibers having a tensile strength in excess of glass fibers;

an outer core surrounding the inner core comprising a plurality of glass fibers; and

a cured resin matrix, wherein the fibers of the inner and the outer cores are embedded therein;

wherein, the fibers of the inner and outer cores are oriented substantially parallel to the longitudinal axis, and wherein the composite core is adapted for use as a strength in an *overhead* electrical cable.

29. An *overhead* electrical cable comprising:

a composite core further comprising:

an inner core comprising a plurality of substantially continuous reinforcing fibers of at least a first type, the first type having a tensile strength that exceeds the tensile strength of glass fibers, wherein the fibers are substantially parallel to the longitudinal axis;

an outer core comprising a plurality of substantially continuous reinforcing fibers of at least a second type, the second type having a tensile strength of or similar to glass fibers, wherein the fibers are substantially parallel to the longitudinal axis; and

a cured resin matrix, wherein the fibers of the inner and the outer cores are embedded therein; and

at least one layer of conductor surrounding said outer core.

30. An *overhead* electrical cable as claimed in claim **29** wherein, the composite material of the inner core and the outer core is selected to meet physical characteristics in the end composite core including a tensile strength of at least 160 Ksi (1103 MPa), a modulus of elasticity in the range of at least about 7 Msi (48 GPa) to about 30 Msi (206 GPa), an operating temperature in the range of about 90 to about 230° C. and a thermal expansion coefficient at least in the range of about 0 to about 6×10^{-6} m/m/° C.

31. An *overhead* electrical cable as claimed in claim **29** wherein, the composite core comprises a fiber/resin volume fraction in the range of at least about 50%.

32. An *overhead* electrical cable as claimed in claim **29** wherein, the composite core comprises a fiber/resin ratio of at least about 62% by weight.

33. An *overhead* electrical cable as claimed in claim **29** wherein, the fibers of the inner core are carbon and the fibers of the outer core are glass.

34. An *overhead* electrical cable as claimed in claim **29** wherein, the conductor surrounding the core comprises a plurality of aluminum sigments.

35. An *overhead* electrical cable as set forth in claim **29** wherein, the compsoite core is sgemented.

36. A method of transmitting electrical power comprising:

using [a] *an overhead* cable comprising a composite core and at least one layer of aluminum conductor surrounding the composite core, the composite core further comprising:

an inner core comprising a plurality of substantially continuous reinforcing fibers of at least a first type, the first type having a tensile strength that exceeds the tensile strength of glass fibers, wherein the fibers are substantially parallel to the longitudinal axis;

an outer core comprising a plurality of substantially continuous reinforcing fibers of at least a second type, the second type having a tensile strength of or similar to glass fibers, wherein the fibers are substantially parallel to the longitudinal axis; and

a cured resin matrix, wherein the fibers of the inner and the outer cores are embedded therein; and

transmitting power across the *overhead* composite cable.

58. An *overhead* electrical cable as claimed in claim **29**, wherein the outer core is non-conductive and insulates the inner core.

59. An *overhead* electrical cable as claimed in claim **29**, wherein the composite core has a tensile strength about 160 Ksi (1103 MPa).

60. An *overhead* electrical cable as claimed in claim **29**, wherein the composite core has a modulus of elasticity within the range of about 7 Msi (48 GPa) to about 30 Msi (206 GPa).

61. An *overhead* electrical cable as claimed in claim **29**, wherein the composite core has coefficient of thermal expansion of from about 0×10^{-6} to about 6×10^{-6} m/m/°C.

62. An *overhead* electrical cable as claimed in claim **29** wherein the composite core has a length of at least about 6000 feet.

70. An *overhead* electrical cable, comprising:

a composite core strength member, the composite core strength member comprising:

a plurality of reinforcing fibers in a thermosetting resin matrix to form the core, said core having at least 50% fiber volume fraction, the plurality of reinforcing fibers consisting of two or more different types of fibers, a first fiber type having a modulus of elasticity in the range of about 22 (151 GPa) to 37 Msi (255 GPa) and a tensile strength of at least about 350 Ksi (2413 MPa) and a second fiber type having a modulus of elasticity in the range of about 6 Msi to about 11.2 Msi and a tensile strength of at least about 180 Ksi (1241 MPa); wherein, the fibers are arranged within the resin matrix having the higher tensile strength fibers in the center of the core;

at least one layer of conductor surrounding said composite core.

71. An *overhead* electrical cable as claimed in claim **70**, wherein the composite core has a tensile strength above 160 Ksi (1103 MPa).

72. An *overhead* electrical cable as claimed in claim **70**, wherein the composite core has a modulus of elasticity within the range of about 7 Msi (48 GPa) to about 30 Msi (206 GPa).

73. An *overhead* electrical cable as claimed in claim **70**, wherein the composite core has a length of at least about 6000 feet.

74. An *overhead* electrical cable as claimed in claim **70**, wherein the at least one layer of conductor comprises an aluminum conductor.

75. An *overhead* electrical cable as claimed in claim **70**, wherein the at least one layer of conductor comprises a plurality of trapezoidal shaped aluminum strands.

76. An *overhead* electrical cable as claimed in claim **70**, wherein the first reinforcing fiber type is carbon.

77. An *overhead* electrical cable as claimed in claim **76**, wherein the second reinforcing fiber type is glass.

78. An *overhead* electrical cable as claimed in claim **70**, wherein the first fiber type forms an inner core and the second fiber type forms an outer core that surrounds the inner core.

79. An *overhead* electrical cable as claimed in claim **78**, wherein the outer core is non-conductive and insulates the inner core.

80. A composite core strength member for an *overhead* electrical cable, comprising:

a plurality of reinforcing fibers in a thermosetting resin matrix to form the composite core strength member, said composite core strength member having at least 50% fiber volume fraction, the plurality of reinforcing fibers consisting of two or more different types of fibers, a first fiber type having a modulus of elasticity in the range of about 22 (151 GPa) to 37 Msi (255 GPa) and a tensile strength of at least about 350 Ksi (2413 MPa) and a second fiber type having a modulus of elasticity in the range of about 6 Msi to about 11.2 Msi and a tensile strength of at least about 180 Ksi (1241 MPa); wherein,the fibers are arranged within the resin matrix having the higher tensile strength fibers in the center of the core, and

wherein the composite core strength member is adapted for use as a strength member in an *overhead* electrical cable, and wherein the outside diameter of the composite core strength member is smaller than that of a steel core having the same tensile strength as the composite core strength member thereby allowing the composite core strength member to be wound with an increased volume of conductive material without changing the outside diameter of the *overhead* electrical cable, thereby providing increased ampacity thereover.

* * * * *

EXHIBIT D

US007211319B2

(12) **United States Patent**
Hiel et al.

(10) **Patent No.: US 7,211,319 B2**
(45) **Date of Patent: *May 1, 2007**

(54) **ALUMINUM CONDUCTOR COMPOSITE CORE REINFORCED CABLE AND METHOD OF MANUFACTURE**

(75) Inventors: **Clement Hiel**, Rancho Palos Verdes, CA (US); **George Korzeniowski**, Woodland Hills, CA (US)

(73) Assignee: **CTC Cable Corporation**, Irvine, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **10/691,447**

(22) Filed: **Oct. 22, 2003**

(65) **Prior Publication Data**

US 2004/0131851 A1 Jul. 8, 2004

Related U.S. Application Data

(63) Continuation-in-part of application No. PCT/US03/12520, filed on Apr. 23, 2003.

(60) Provisional application No. 60/374,879, filed on Apr. 23, 2002.

(51) **Int. Cl.**
B32B 27/04 (2006.01)
B32B 27/12 (2006.01)

(52) **U.S. Cl.** **428/300.7**; 428/297.4; 428/299.4; 428/299.1; 428/298.1; 428/300.4; 428/378

(58) **Field of Classification Search** .... 428/375, 428/378, 392, 297.4, 298.1, 299.4, 299.1, 428/300.4, 300.7, 301.4; 174/102 R, 106 R, 174/70 R, 113 C; 385/101, 102, 103, 104, 385/107, 111, 113
See application file for complete search history.

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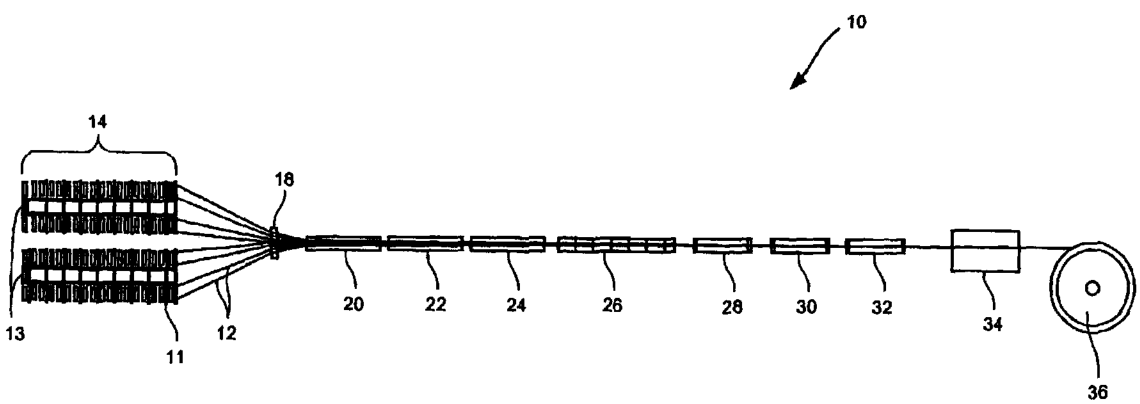
Primary Examiner—Jill Gray
(74) *Attorney, Agent, or Firm*—The McIntosh Group

(57) **ABSTRACT**

This invention relates to an aluminum conductor composite core reinforced cable (ACCC) and method of manufacture. An ACCC cable has a composite core surrounded by at least one layer of aluminum conductor. The composite core comprises a plurality of fibers from at least one fiber type in one or more matrix materials. The composite core can have a maximum operating temperature capability above 100° C. or within the range of about 45° C. to about 230° C., at least 50% fiber to resin volume fraction, a tensile strength in the range of about 160 Ksi to about 370 Ksi, a modulus of elasticity in the range of about 7 Msi to about 37 Msi and a coefficient of thermal expansion in the range of about -0.7×10^{-6} m/m/° C. to about 6×10^{-6} m/m/° C. According to the invention, a B-stage forming process may be used to form the composite core at improved speeds over pultrusion processes wherein the speeds ranges from about 9 ft/min to about 60 ft/min.

29 Claims, 11 Drawing Sheets



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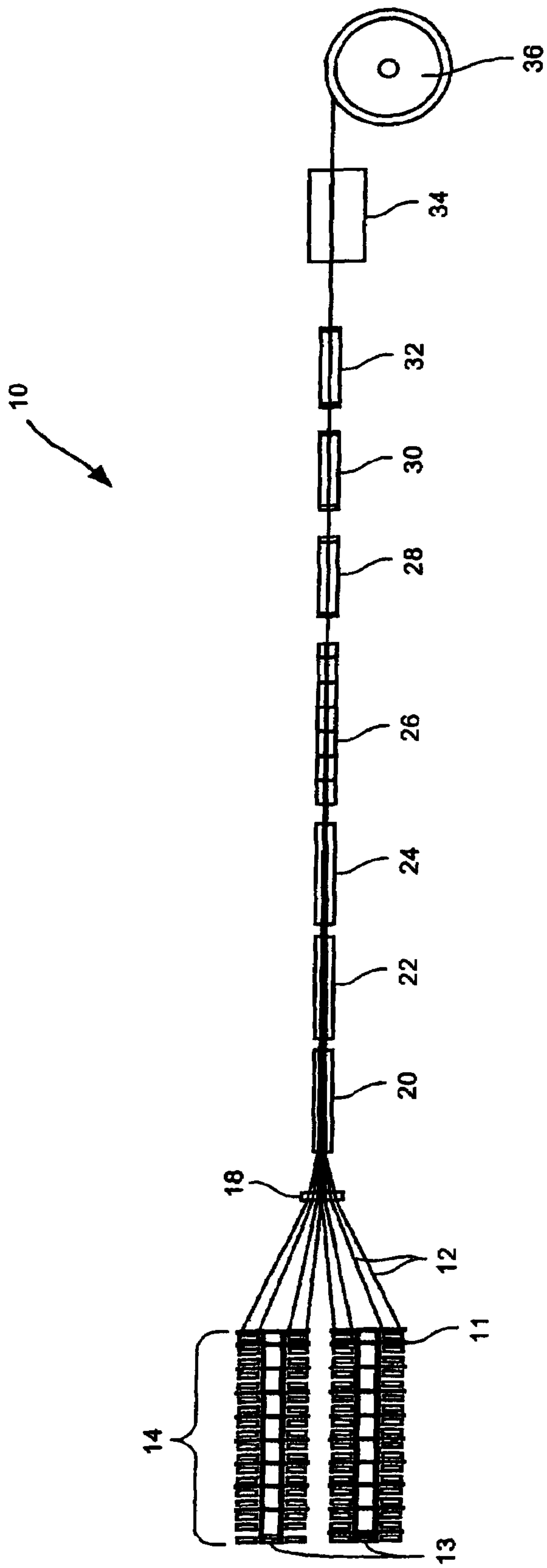

FIG. 1

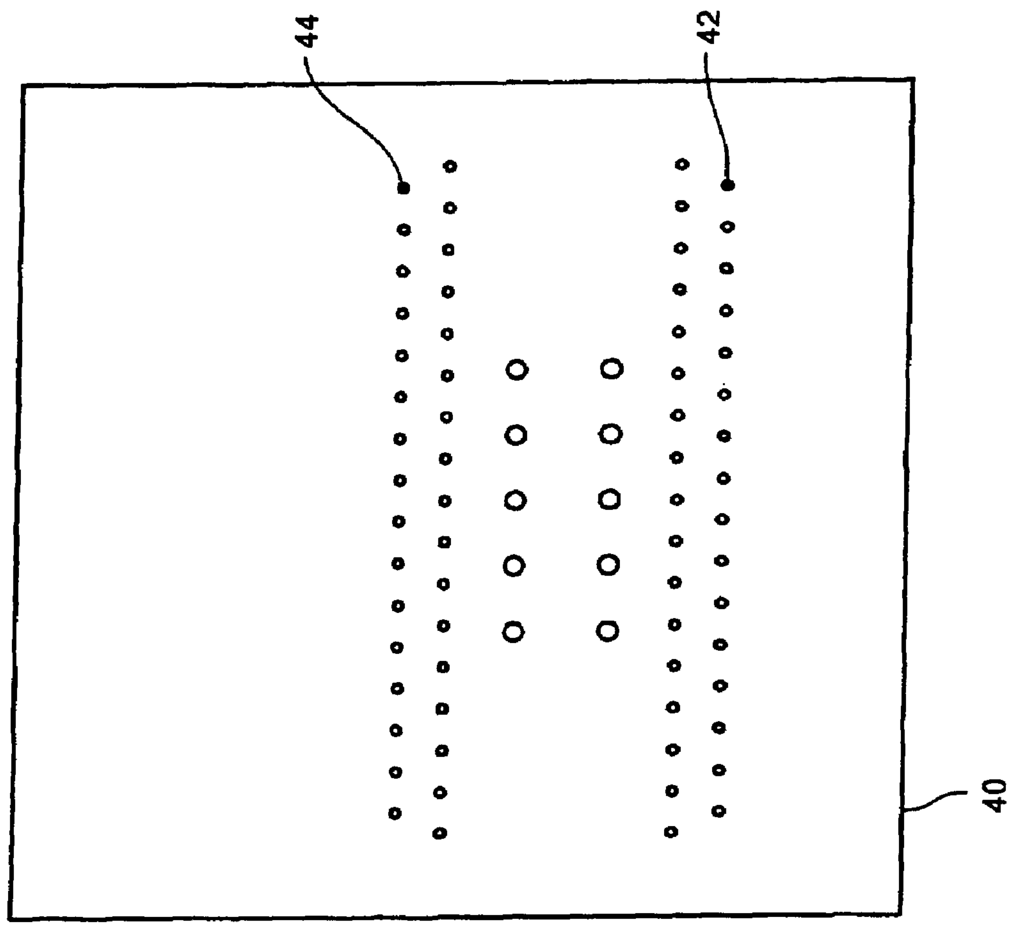

FIG. 2

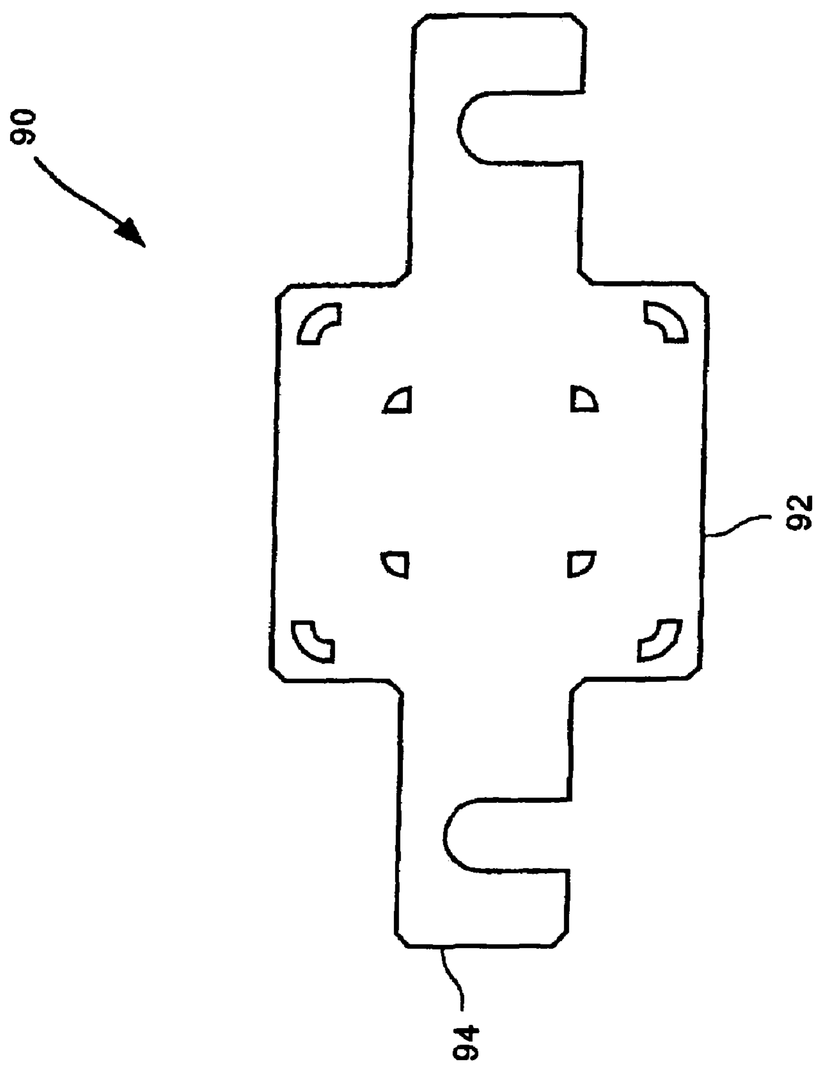

FIG. 3

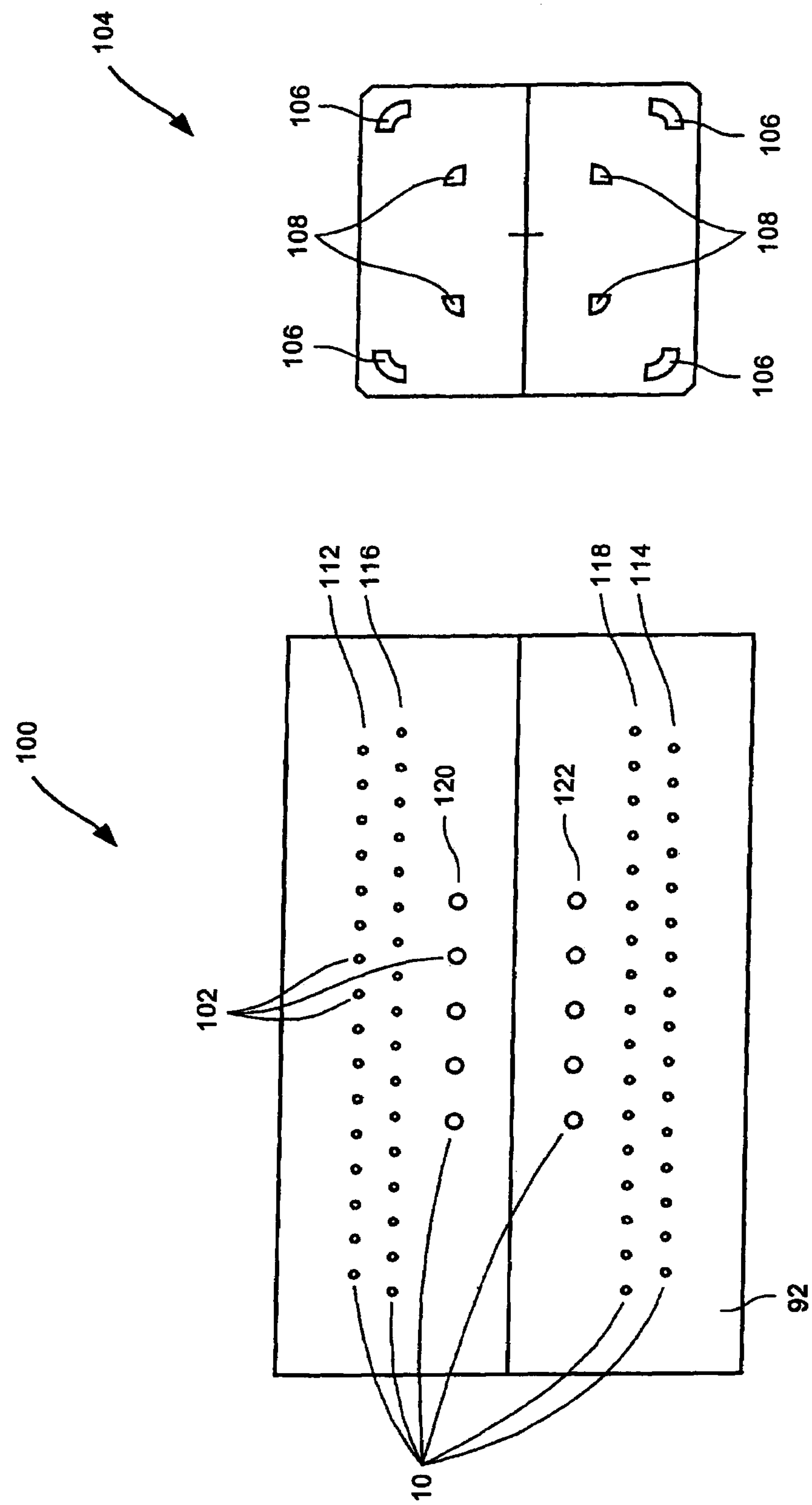
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FIG. 4

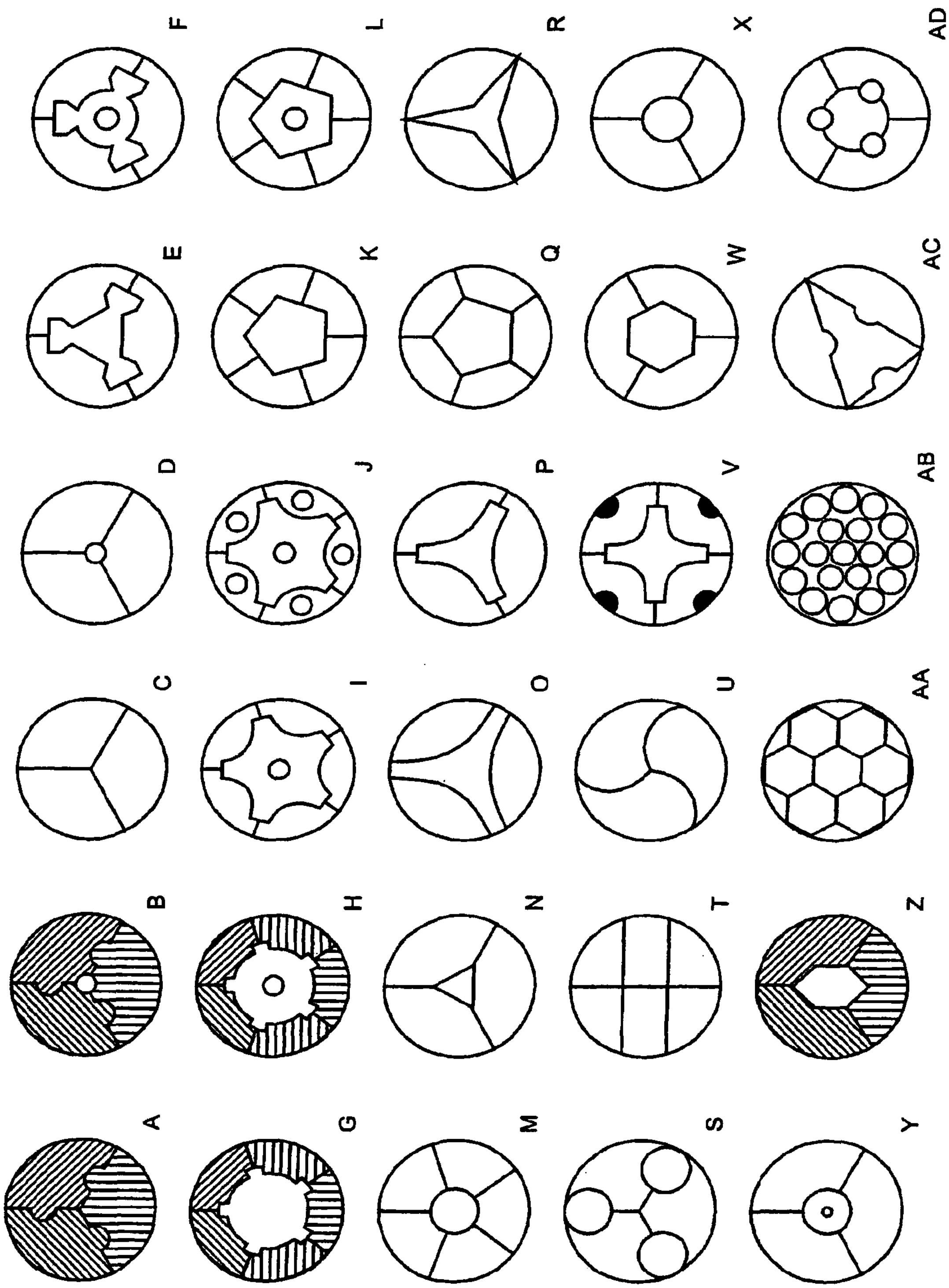

FIG. 5

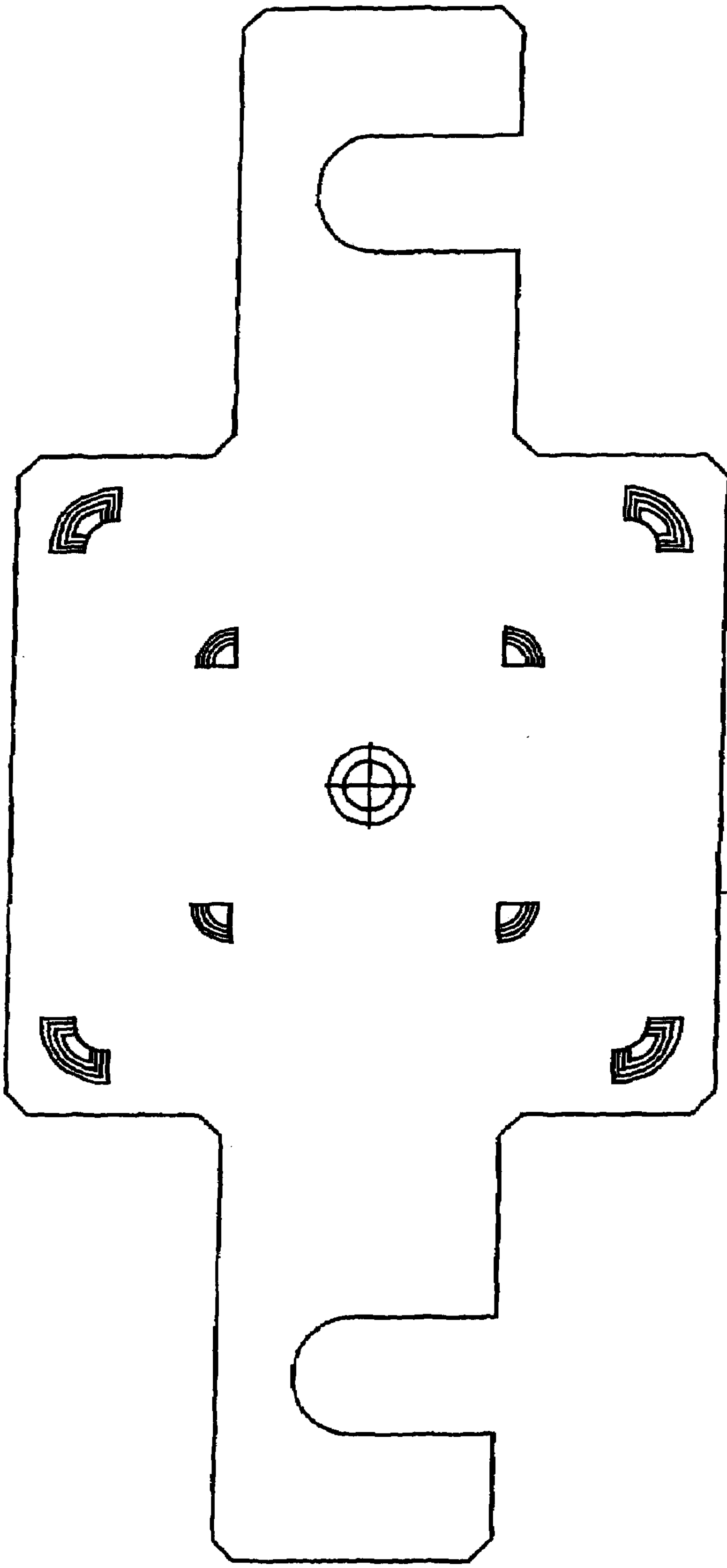

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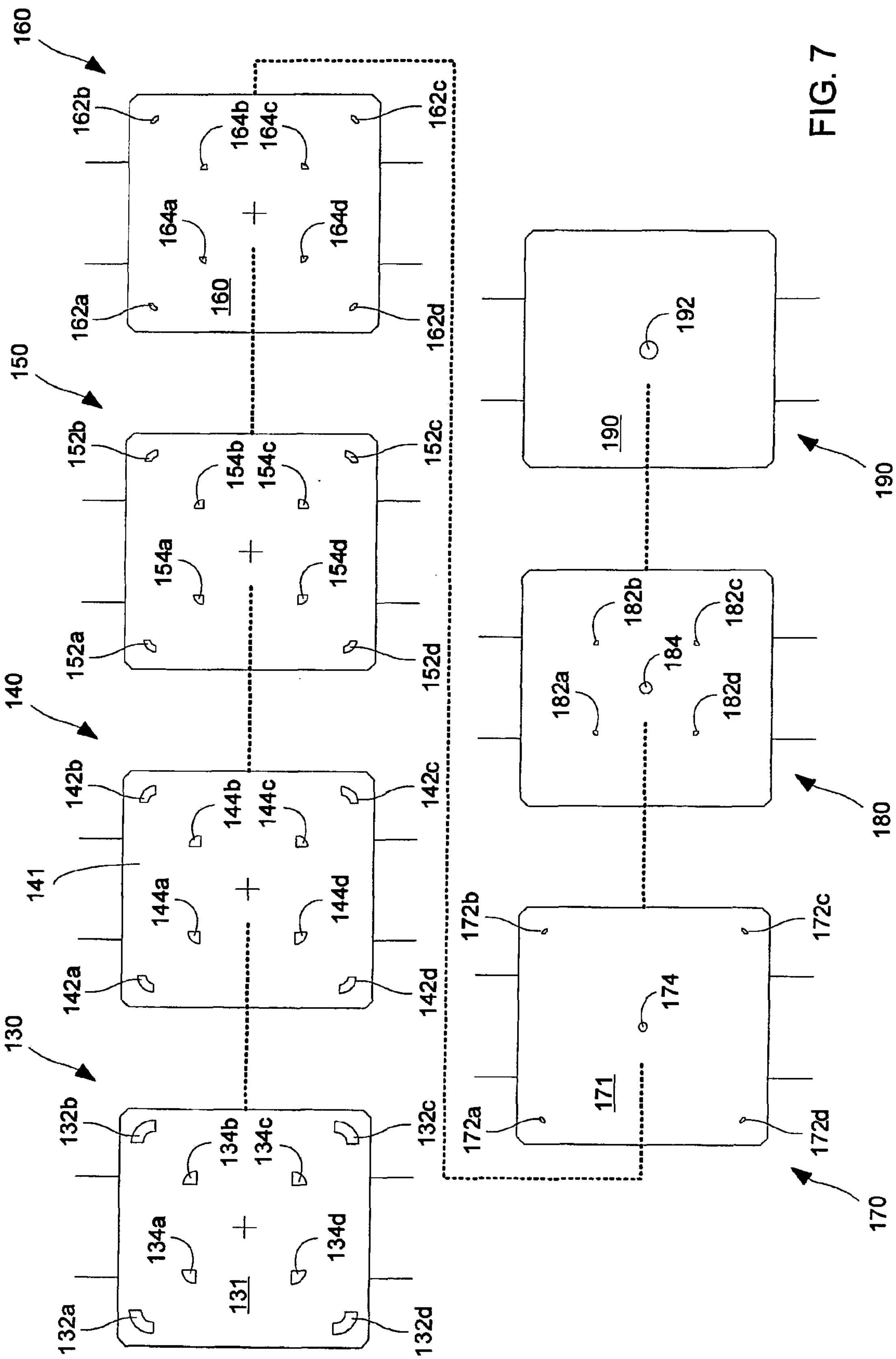
FIG. 6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172d
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FIG. 7

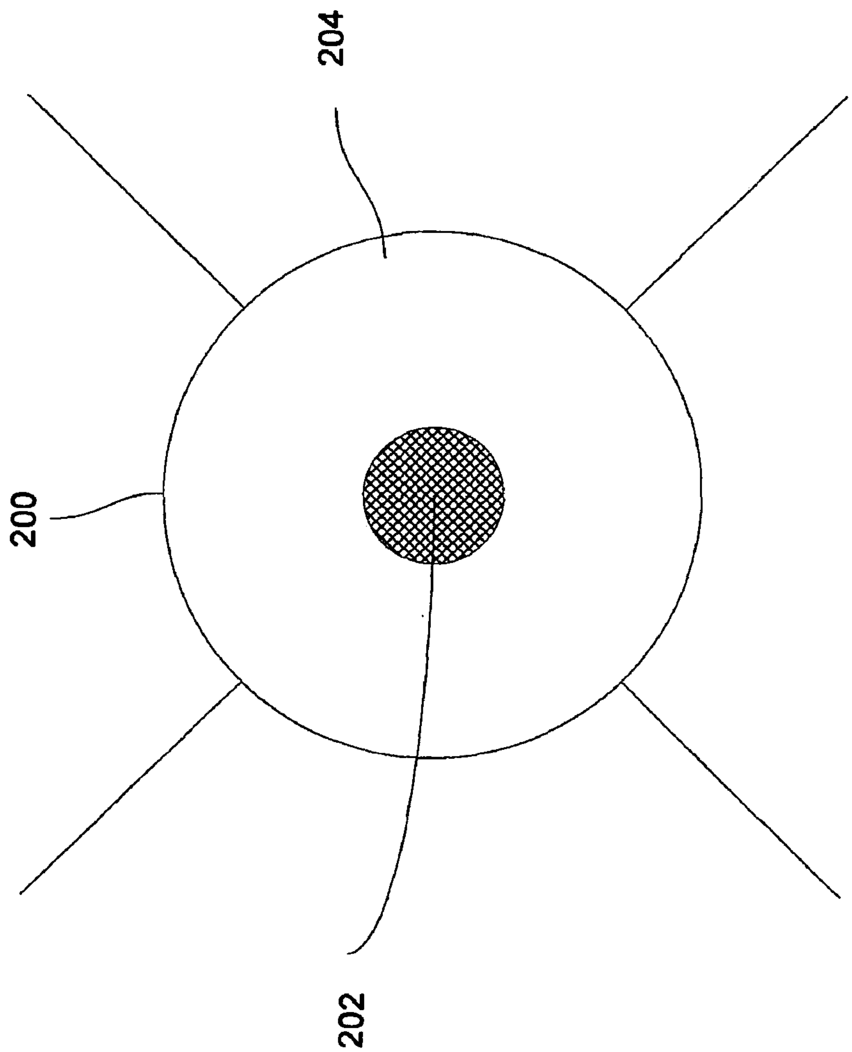


FIG. 8

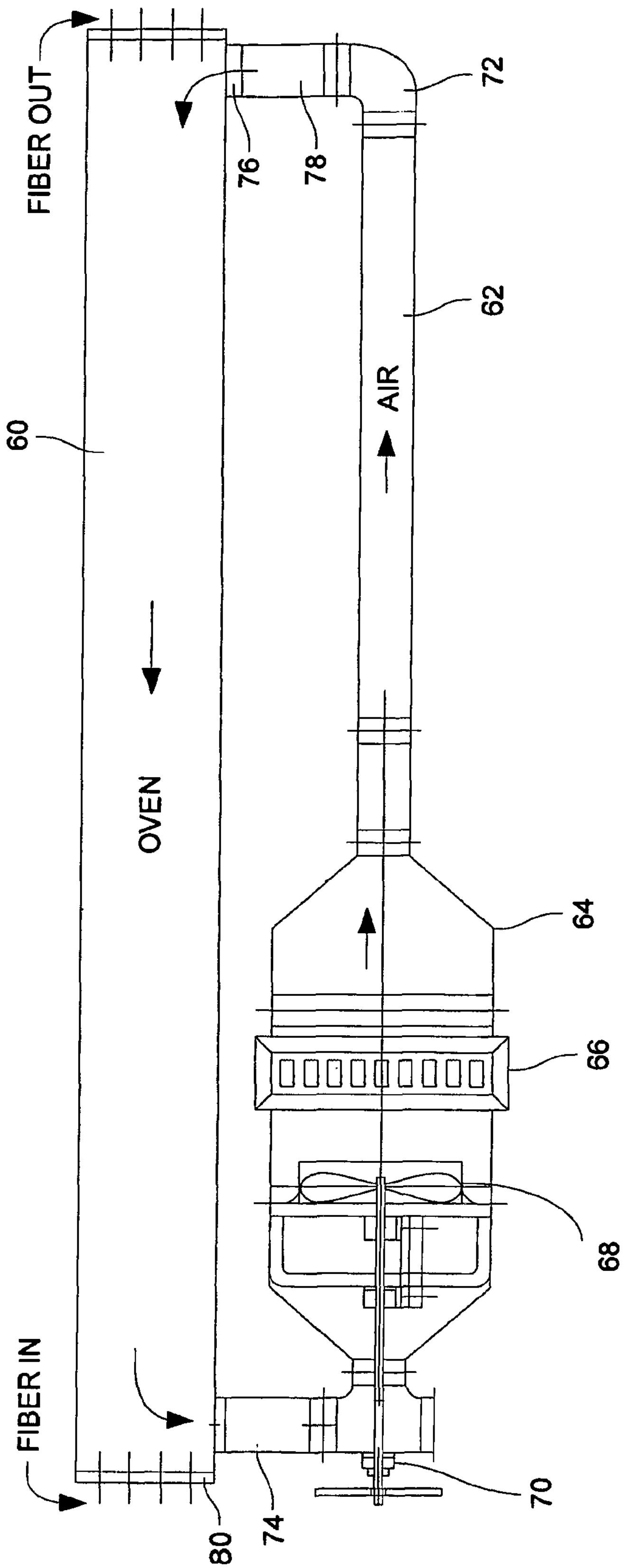


FIG. 9

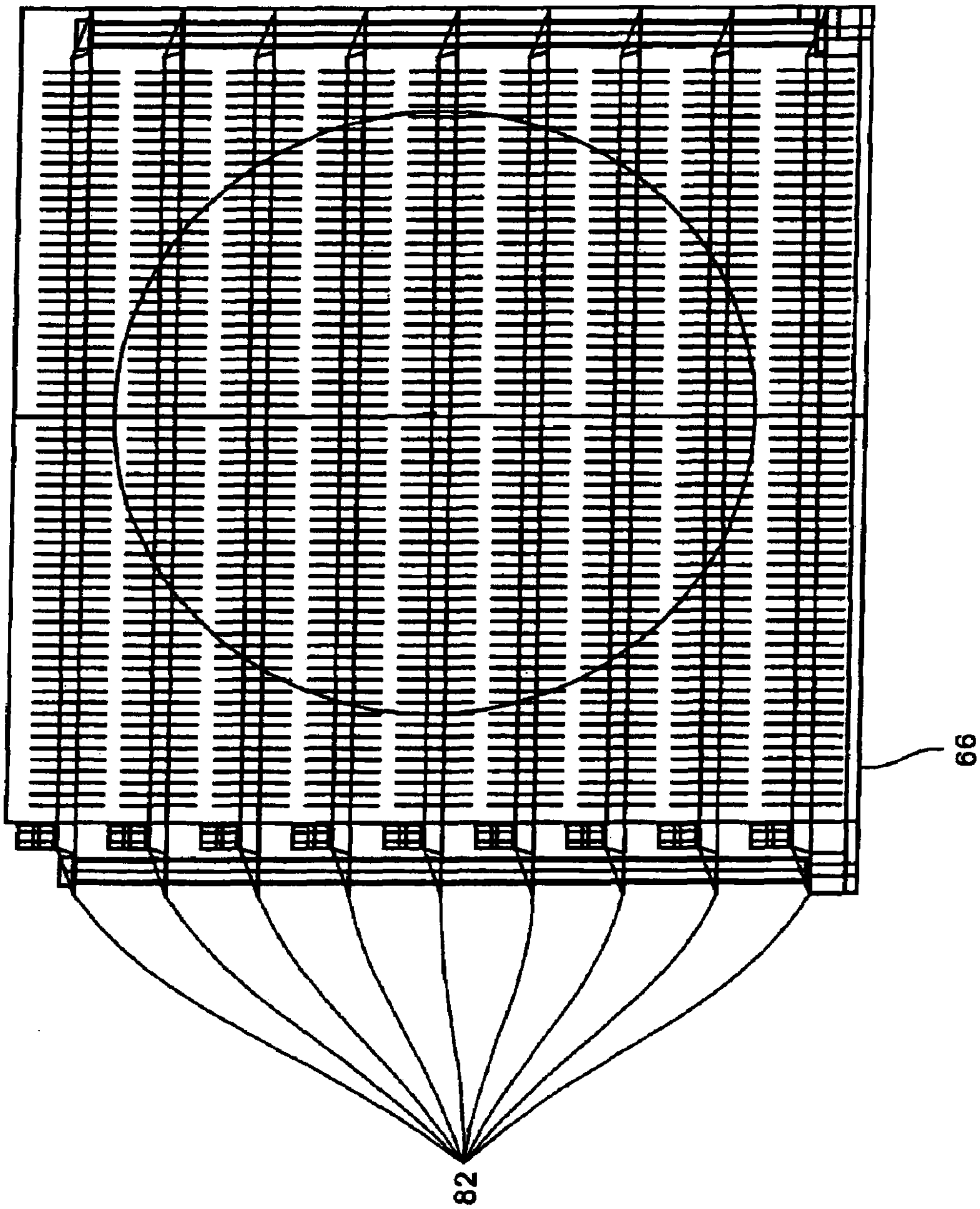


FIG. 10

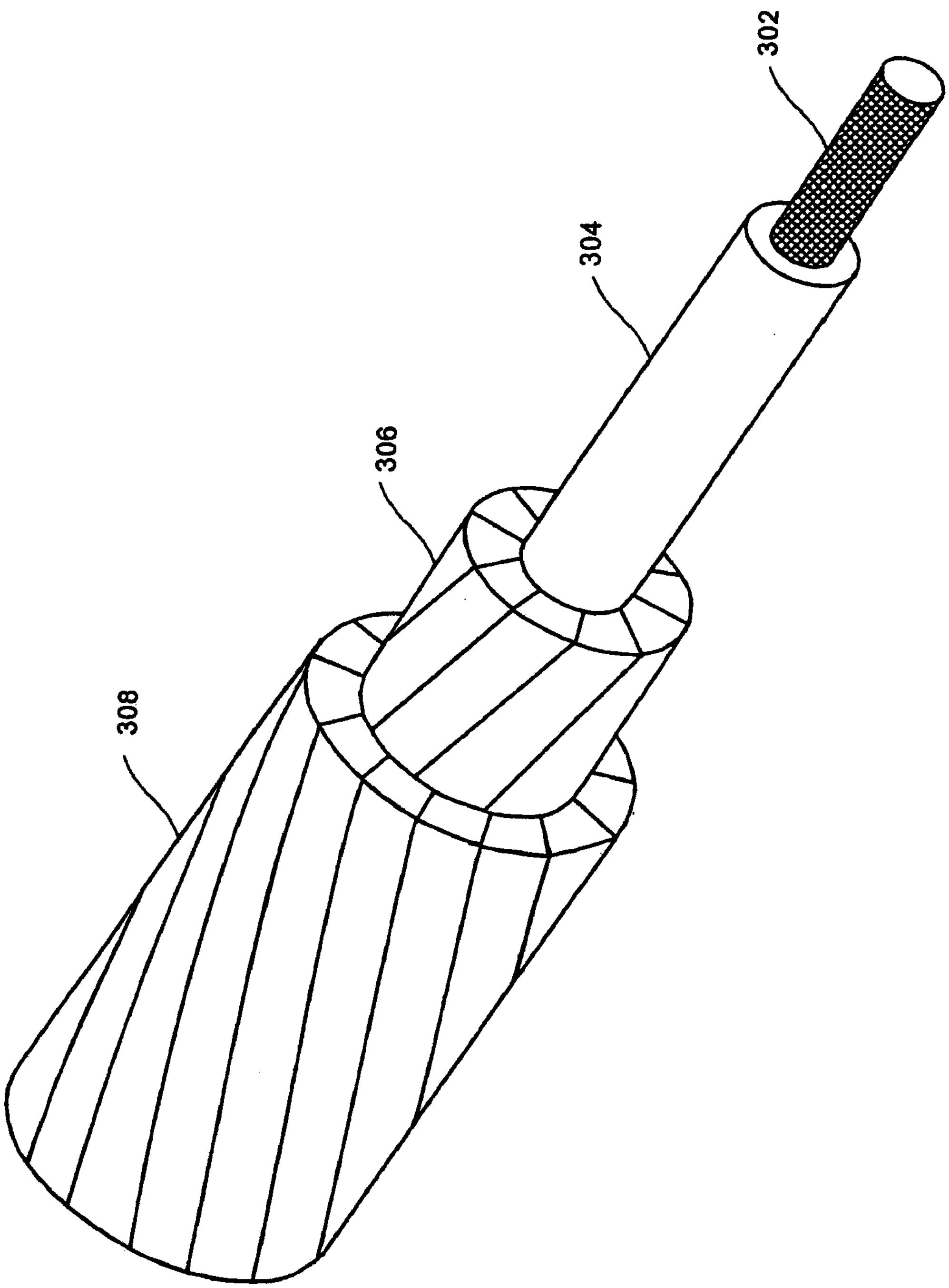


FIG. 11

ALUMINUM CONDUCTOR COMPOSITE CORE REINFORCED CABLE AND METHOD OF MANUFACTURE

CROSS REFERENCES TO RELATED APPLICATIONS

In relation to this Continuation in Part Application, applicants claim priority of earlier PCT filing PCT/US03/12520 filed in the International Receiving Office of the United States Patent and Trademark Office on 23 Apr. 2003, the entire disclosure of which is incorporated by reference herein, which claims priority from U.S. provisional application Ser. No. 60/374,879 filed in the United States Patent and Trademark Office on 23 Apr. 2002, the entire disclosure of which is incorporated by reference herein.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

Not Applicable

REFERENCE TO A "MICROFICHE APPENDIX"

Not Applicable

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an aluminum conductor composite core (ACCC) reinforced cable and method of manufacture. More particularly, the present invention relates to a cable for providing electrical power having a composite core, formed by fiber reinforcements and a matrix, surrounded by aluminum conductor capable of carrying increased ampacity and operating at elevated temperatures.

2. Description of the Related Art

In a traditional aluminum conductor steel reinforced cable (ACSR) the aluminum conductor transmits the power and the steel core is designed to carry the transfer load. Conductor cables are constrained by the inherent physical characteristics of the components; these components limit ampacity. Ampacity is a measure of the ability to send power through the cable. Increased current or power on the cable causes a corresponding increase in the conductor's operating temperature. Excessive heat will cause the cable to sag below permissible levels. Typical ACSR cables can be operated at temperatures up to 100° C. on a continuous basis without any significant change in the conductor's physical properties related to sag. Above 100° C., ACSR cables suffer from thermal expansion and a reduction in tensile strength. These physical changes create excessive line sage. Such line sag has been identified as one of the possible causes of the power blackout in the Northeastern United States in 2003. The temperature limits constrain the electrical load rating of a typical 230-kV line, strung with 795 kcmil ACSR "Drake" conductor, to about 400 MVA, corresponding to a current of 1000 A. Therefore, to increase the load carrying capacity of transmission cables, the cable itself must be designed using components having inherent properties that allow for increased ampacity without inducing excessive line sag.

Although ampacity gains can be obtained by increasing the conductor area that surrounds the steel core of the transmission cable, increasing conductor volume increases the weight of the cable and contributes to sag. Moreover, the increased weight requires the cable to use increased tension in the cable support infrastructure. Such large weight increases typically would require structural reinforcement or replacement of the electrical transmission towers and utility poles. Such infrastructure modifications are typically not financially feasible. Thus, there is financial motivation to increase the load capacity on electrical transmission cables while using the existing transmission structures and liens.

Prior art applications disclose a composite core comprised of a single type of glass fiber and thermoplastic resin. The object is to provide an electrical transmission cable which utilizes a reinforced plastic composite core as a load bearing element in the cable and to provide a method of carrying electrical current through an electrical transmission cable which utilizes an inner reinforced plastic core. The composite core fails in these objectives. A one fiber system comprising glass fiber does not have the required stiffness to attract transfer load and keep the cable from sagging. Secondly, a composite core comprising glass fiber and thermoplastic resin does not meet the operating temperatures required for increased ampacity, namely, between 90° C. and 230° C.

Physical properties of composite cores are further limited by processing methods. Previous processing methods cannot achieve a high fiber to resin ratio by volume or weight. These processes do not allow for creation of a fiber rich core that will achieve the strength required for electrical cables. Moreover, the processing speed of previous processing methods is limited by inherent characteristics of the process itself. For example, traditional pultrusion dies are approximately 36 inches long, having a constant cross section. The longer dies create increased friction between the composite and the die slowing processing time. The processing times in such systems for epoxy resins range from about 3 inches/minute to about 12 inches/minute. Processing speeds using polyester and vinyl ester resins can produce composites at up to 72 inches/minute. With thousands of miles of cables needed, these slow processing speeds fail to meet the need in a financially acceptable manner.

It is therefore desirable to design an economically feasible cable that facilitates increased ampacity without corresponding cable sag. It is further desirable to process composite cores using a process that allows configuration and tuning of the composite cores during processing and allows for processing at speeds up to 60 ft/min.

BRIEF SUMMARY OF THE INVENTION

An aluminum conductor composite core (ACCC) reinforced cable can ameliorate the problems in the prior art. The ACCC cable is an electrical cable with a composite core made from one or more fiber type reinforcements and embedded in a matrix. The composite core is wrapped in an electrical conductor. An ACCC reinforced cable is a high-temperature, low-sag conductor, which can be operated at temperatures above 100° C. while exhibiting stable tensile strength and creep elongation properties. In exemplary embodiments, the ACCC cable can operate at temperatures above 100° C. and in some embodiments up to or near 230° C. An ACCC cable with a similar outside diameter may increase the line rating over a prior art cable by at least 50% without any significant changes in the weight of the conductor.

In an ACCC cable, the core of the distribution and transmission cable is replaced with a composite strength member comprising a plurality of fibers selected from one or more fiber types and embedded in a matrix. The important characteristics of the ACCC cable are a relatively high modulus of elasticity and a relatively low coefficient of thermal expansion, which help increase the ampacity of the conductor cable. It is further desirable to design composite cores having long term durability. The composite strength member may operate at least sixty years, and more preferably seventy years, at elevated operating temperatures above 90° C. and possibly up to 230° C.

Further, the invention allows for formation of a composite core having a smaller core size. The smaller core size acts as the only load bearing member in the ACCC cable. This smaller core size allows the cable to accommodate an increased volume of aluminum without changing the conductor outside diameter. The ACCC cable can have the same or greater strength and the same or less weight as a conductor cable with a steel core, but can include more conductor around the core. With more conductor, the ACCC cable can carry increased ampacity.

To achieve the desired ampacity gains, a composite core according to the invention may combine fibers having a low modulus of elasticity for lower stiffness with fibers having a high modulus of elasticity for increased stiffness or strength. By combining fibers, new property sets are obtained, including different modulus of elasticity, thermal expansion, density, and cost. Sag versus temperature calculations show improved ampacity over ACSR cables when a high-strength and high-stiffness composite is combined with a lower strength and lower stiffness composite.

Composite cores according to the invention meet certain physical characteristics dependent upon the selection of fiber types and matrix material. Composite cores according to the invention have substantially low coefficient of thermal expansions, substantially high tensile strength, and ability to withstand substantially high operating temperatures, ability to withstand low ambient temperatures, substantially high dielectric properties, and sufficient flexibility to permit winding on a transportation wheel or a transportation drum. In particular, composite cores according to the present invention may have: a tensile strength above 160 Ksi, and more preferably within the range of about 160 Ksi to about 380 Ksi; a modulus of elasticity above 7 Msi, and more preferably within the range of about 7 Msi to about 37 Msi; an operating temperature capability above 45° C., and more preferably within the range of about 90° C. to about 230° C.; and, a coefficient of thermal expansion below 6×10^{-6} m/m/° C., and more preferably within the range of about -0.7×10^{-4} m/m/° C. to about 6×10^{-4} m/m/° C. These ranges may be achieved by a single fiber type or by a combination of fiber types. Practically, most cores within the scope of this invention comprise two or more fiber types, but a single fiber type may be able to achieve the above ranges. In addition, depending on the physical characteristics desired in the final composite core, the composite core can accommodate variations in the relative amounts of fibers, fiber types, or matrix type.

Composite cores of the present invention can be formed by a B-stage forming process wherein fibers are wetted with resin and continuously pulled through a plurality of zones within the process. The B-stage forming process relates generally to the manufacture of composite core members and relates specifically to an improved apparatus and process for making resin impregnated fiber composite core members. More specifically, according to an exemplary embodiment, a multi-phase B-stage process forms, from fiber and resin, a composite core member with superior strength, higher ampacity, lower electrical resistance and lighter weight. The process enables formation of composite core members having a fiber to resin ratio that maximizes the flexural strength, the compressive strength, and the tensile strength. In a further embodiment, the composite core member is wrapped with high conductivity aluminum or other conductor resulting in an ACCC cable having high strength and high stiffness characteristics.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

These and other features of the invention are best understood by referring to the detailed description of the invention, read in light of the accompanying drawings, in which:

FIG. **1** is a schematic diagram of a B-stage forming process used for forming fiber composite core members in accordance with the present invention.

FIG. **2** is a schematic diagram of a bushing showing sufficiently spaced passageways for insertion of the fibers in a predetermined pattern to guide the fibers through the B-stage forming process in accordance with the present invention.

FIG. **3** is a schematic view of the structure of a bushing; said view showing the passageways used to shape and compacts the bundles of fibers in accordance with the present invention.

FIG. **4** is schematic comparison of two different bushings showing a reduction in the passageways from one bushing to the next to shape and compact the fibers into bundles in forming the composite core in accordance with the present invention.

FIG. **5** shows a cross-sectional view of thirty possible composite core cross-section geometries according to the invention.

FIG. **6** is a multi-dimensional cross-sectional view of a plurality of bushings overlaid on top of one another showing the decreasing passageway size with respective bushings.

FIG. **7** is a multi-phase schematic view of a plurality of bushings showing migration of the passageways and diminishing size of the passageways with each successive bushing in accordance with the invention.

FIG. **8** is a cross sectional view of one embodiment of a composite core according to the invention.

FIG. **9** is a schematic view of an oven process having cross circular air flow to keep the air temperature constant in accordance with the invention.

FIG. **10** is a cross-sectional view of the heating element in the oven represented in FIG. **9** showing each heater in the heating element in accordance with the invention.

FIG. **11** is a schematic view of one embodiment of an aluminum conductor composite core (ACCC) reinforced cable showing an inner composite core and an outer composite core surrounded by two layers of aluminum conductor according to the invention.

To clarify, each drawing includes reference numerals. These reference numerals follow a common nomenclature. The reference numeral will have three digits. The first digit represents the drawing number where the reference numeral was first used. For example, a reference numeral used first in drawing one will have a numeral like **1XX**, while a numeral first used in drawing four will have a numeral like 4XX. The second two numbers represent a specific item within a drawing. One item in FIG. **1** may be **101** while another item may be **102**. Like reference numerals used in later drawing represent the same item. For example, reference numeral **102** in FIG. **3** is the same item as shown in FIG. 1. In addition, the drawings are not necessarily drawn to scale but are configured to clearly illustrate the invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which exemplary embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that the disclosure will fully convey the scope of the invention to those skilled in the art.

An ACCC Reinforced Cable

The present invention relates to a reinforced composite core member made from a plurality of fiber reinforcements from one or more fiber types embedded in a matrix. A further embodiment of the invention uses the composite core in an aluminum conductor composite core reinforced (ACCC) cable. These ACCC cables can provide for electrical power distribution wherein electrical power distribution includes distribution and transmission cables. FIG. **11** illustrates an embodiment of an ACCC reinforced cable **300**. This one embodiment in FIG. **11** illustrates an ACCC reinforced cable having a carbon fiber reinforcement and epoxy resin composite inner core **302** and a glass fiber reinforcement and epoxy resin composite outer core **304**, surrounded by a first layer of aluminum conductor **306** wherein a plurality of trapezoidal shaped aluminum strands helically surround around the composite core and having a second layer of aluminum conductor **308** wherein a plurality of trapezoidal shaped aluminum strands helically surround around the first aluminum layer **306**.

Composite cores of the present invention can comprise the following characteristics: at least one type of fiber, variable relative amounts of each fiber type, fiber types of substantially small diameter, fiber types of a substantially continuous length, composite cores having a high packing density, fiber tows having relative spacing within the packing density, a fiber to resin volume fraction 60% or lower, a fiber to resin weight fraction 72% or lower by weight, adjustable volume fraction, substantially low coefficient of thermal expansion, a substantially high tensile strength, ability to withstand a substantially high range of operating temperatures, ability to withstand substantially low ambient temperatures, having the potential to customize composite core resin properties, substantially high dielectric properties, having the potential of a plurality of geometric cross section configurations, and sufficient flexibility to permit winding of continuous lengths of composite core.

A composite core of the following invention can have a tensile strength above 160 Ksi, and more preferably within the range of about 160 Ksi to about 380 Ksi; a modulus of elasticity above 7 Msi, and more preferably within the range of about 7 Msi to about 37 Msi; an operating temperature capability above 45° C., and more preferably within the range of about 45° C. to about 230° C.; and, a coefficient of thermal expansion below 6×10^{-6} m/m/° C, and more preferably within the range of about -0.7×10^{-6} m/m/° C. to about 6×10^{-6} m/m/° C.

To achieve a composite core in the above stated ranges, different matrix materials and fiber types may be used. The matrix and the fiber properties are explained further below. First, matrix materials embed the fibers. In other words, the matrix bundles and holds the fibers together as a unit—a load member. The matrix assists the fibers to act as a single unit to withstand the physical forces on the ACCC cable. The matrix material may be any type of inorganic or organic material that can embed and bundle the fibers into a composite core. The matrix can include, but is not limit to, materials such as glue, ceramics, metal matrices, resins, epoxies, foams, elastomers, or polymers. One skilled in the art will recognize other materials that may be used as matrix materials.

While other materials may be used, an exemplary embodiment of the invention uses epoxy resins. Throughout the remainder of the invention the term resin or epoxy may be used to identify the matrix. However, the use of the terms epoxy and resin are not meant to limit the invention to those embodiments, but all other types of matrix material are included in the invention. The composite core of the present invention may comprise resins having physical properties that are adjustable to achieve the objects of the present invention. The present invention may use any suitable resin. Suitable resins may include thermosetting resins, thermoplastic resins or thermoplastically modified resins, toughened resins, elastomerically modified resins, multifunctional resins, rubber modified resins, Cyanate Esters, or Polycyanate resins. Some thermosetting and thermoplastic resins may include, but are not limited to, phenolics, epoxies, polyesters, high-temperature polymers (polyimides), nylons, fluoropolymers, polyethelenes, vinyl esters, and the like. One skilled in the art will recognize other resins that may be used in the present invention.

Depending on the intended cable application, suitable resins are selected as a function of the desired cable properties to enable the composite core to have long term durability at high temperature operation. Suitable resins may also be selected according to the process for formation of the composite core to minimize friction during processing, to increase processing speed, and to achieve the appropriate fiber to resin ratio in the final composite core.

The composite core of the present invention comprises resins having good mechanical properties and chemical resistance. These resins may be able to function with prolonged environmental exposure for at least about 60 years of usage. More preferably, the composite core of the present invention can comprise resins having good mechanical properties and chemical resistance at prolonged exposure for at least about 70 years of usage. Further, the composite core of the present invention comprises resins that may operate anywhere above 45° C. and possibly up to 230° C. More preferably, the resin can operate well around 180° C. or above.

An embodiment of an epoxy system may include a low viscosity multifunctional epoxy resin using an anhydride hardener and an imidazol accelerator. An example of this type of epoxy system may be the Araldite® MY 721/Hardener 99-023/Accelerator DY 070 hot curing epoxy matrix system by Vantico Inc. and specified in the like titled data sheet dated September 2002. The resin has a chemical description of N,N,N',N'-Tetraglycidyl4,4'-methylenebisbenzenamine. The hardener is described as 1 H-Imidazole, 1-methyl-1-Methylimidazole. This exemplary resin epoxy system can have the following properties: a tensile elongation around 1.0% to 1.5%; a flexural strength around 16.5 Kpsi to 19.5 Kpsi; a tensile strength around 6.0 Kpsi to 7.0 Kpsi; a tensile modulus around 450 Kpsi to 500 Kpsi; a flexural elongation around 4.5% to 6.0%. Another embodiment of an epoxy resin system may be a multifunctional epoxy with a cycloaliphatic-amine blend hardener. An example of this type of epoxy system may be the JEFFCO 1401-16/4101-17 epoxy system for infusion by JEFFCO Products Inc. and specified in the like titled data sheet dated July 2002. This exemplary resin epoxy system can have the following properties: a Shore D Hardness around 88D; an ultimate tensile strength of 9,700 pounds; an elongation at tensile strength around 4.5% to 5.0%; an ultimate elongation around 7.5% to 8.5%; a flexural strength around 15.25 Kpsi; and an ultimate compressive strength around 14.5 Kpsi. These embodiments of the epoxy resin system are exemplary and are not meant to limit the invention to these particular epoxy resin systems. One skilled in the art will recognize other epoxy systems that will produce composite cores within the scope of this invention.

The composite core of the present invention can comprise a resin that is tough enough to withstand splicing operations without allowing the composite body to crack. The composite core of the present invention can comprise resins having a neat resin fracture toughness above 0.87 INS-lb/in and possible up to about 1.24 INS-lb/in.

The composite core of the present invention can comprise a resin having a low coefficient of thermal expansion. A low coefficient of thermal expansion reduces the amount of sag in the resulting cable. A resin of the present invention may have a coefficient of thermal expansion below about 4.2×10^{-5} m/m/° C. and possibly lower than 1.5×10^{-5} m/m/° C. The composite core of the present invention can comprise a resin having an elongation greater than about 2.1% or more preferably greater than 4.5%.

Second, the composite core comprises a plurality of fiber reinforcements from one or more fiber types. Fiber types may be selected from: carbon (graphite) fibers—both HM and HS (pitch based), Kevlar fibers, basalt fibers, glass fibers, Aramid fibers, boron fibers, liquid crystal fibers, high performance polyethylene fibers, or carbon nanofibers or nanotubes. Several types of carbon, boron, Kevlar and glass fibers are commercially available. Each fiber type may have subtypes that can be variously combined to achieve a composite with certain characteristics. For instance, carbon fibers may be any type from the Zoltek Panex®, Zoltek Pyron®, Hexcel, or Thornel families of products. These carbon fibers may come from a PAN Carbon Fiber or a Polyacrylonitrile (PAN) Precursor. There are hundreds of different types of carbon fibers, and one skilled in the art would recognize the numerous carbon fibers that may be used in the present invention. There are also numerous different types of glass fibers. For instance, an A-Glass, B-Glass, C-Glass, D-Glass, E-Glass, S-Glass, AR-Glass, or R-Glass may be used in the present invention. Fiberglass and paraglass may also be used. As with carbon fibers, there are hundreds of different types of glass fibers, and one skilled in the art would recognize the numerous glass fibers that may be used in the present invention. It is noted that these are only examples of fibers that may meet the specified characteristics of the invention, such that the invention is not limited to these fibers only. Other fibers meeting the required physical characteristics of the invention may be used. One skilled in the art will recognize other fibers that may be used in the present invention. In addition, examples of cores using carbon and glass fibers will be explained. These descriptions are not meant to limit the invention to those fiber types. Rather, one skilled in the art will recognize from the description that other fibers may be used in the invention, and those different fibers may have similar or different properties depending on the desired composite core.

To achieve these physical characteristics, composite cores in accordance with the present invention may comprise only one type of fiber. The composite core may be a uniform section or layer that is formed from one fiber type and one matrix type. For instance, the composite core may be a carbon fiber embedded in resin. The core may also be a glass fiber embedded in a polymer, and the core may also be basalt embedded in a vinyl ester. However, most cables, within the scope of this invention, may comprise at least two distinct fiber types.

The two fiber types may be general fiber types, fiber classes, fiber type subtypes, or fiber type genera. For instance, the composite core may be formed using carbon and glass. Yet, when an embodiment mentions two or more fiber types, the fiber types need not be different classes of fibers, like carbon and glass. Rather, the two fiber types may be within one fiber class or fiber family. For instance, the core may be formed from E-glass and S-glass, which are two fiber types or fiber subtypes within the glass fiber family or fiber class. In another embodiment, the composite may comprise two types of carbon fibers. For instance, the composite may be formed from IM6 carbon fiber and IM7 carbon fiber. One skilled in the art will recognize other embodiments that would use two or more types of fibers.

The combination of two or more fiber types into the composite core member offers substantial improvements in strength to weight ratio over materials, such as steel, commonly used for cables in an electrical power transmission and distribution system. Combining fiber types also may allow the composite core to have sufficient stiffness and strength but maintain some flexibility.

Composite cores of the present invention may comprise fiber tows having relatively high yield or small K numbers. A fiber tow is a bundle of continuous microfibers, wherein the composition of the tow is indicated by its yield or K number. For example, a 12K carbon tow has 12,000 individual microfibers, and a 900 yield glass tow has 900 yards of length for every one pound of weight. Ideally, microfibers wet out with resin such that the resin coats the circumference of each microfiber within the bundle or tow. Wetting may be affected by tow size, the number of microfibers in the bundle, and also by individual microfiber size. Larger tows are more difficult to wet around individual fibers in the bundle due to the number of fibers contained within the bundle. Smaller fiber diameter increases the distribution of resin around each fiber within each fiber tow. Wetting and infiltration of the fiber tows in composite materials is of critical importance to the performance of the resulting composite. Incomplete wetting results in flaws or dry spots within the fiber composite that reduce strength and durability of the composite product. Fiber tows may also be selected in accordance with the size of fiber tow that the process can handle.

One process for forming composite cores in accordance with the present invention is called the B-stage forming process. Fiber tows of the present invention for carbon may be selected from 2K and up, but more preferably from about 4K to about 50K. Glass fiber tows may be 50 yield and up, but more preferably from about 115 yield to about 1200 yield.

For glass fibers, individual fiber size diameters in accordance with the present invention may be below 15 μm, or more preferably within the range of about 8 μm to about 15 μm, and most preferably about 10 μm in diameter. Carbon fiber diameters may be below 10 μm, or more preferably within the range of about 5 μm to about 10 μm, and most preferably about 7 μm. For other types of fibers, a suitable size range is determined in accordance with the desired physical properties. The ranges are selected based on optimal wet-out characteristics and feasibility of use. For example, fibers less than about 5 μm are so small in diameter that they pose certain health risks to those that handle the fibers. In contrast, fibers approaching 25 μm in diameter are difficult to work with because they are stiffer and more brittle.

Composite cores of the present invention may comprise fiber tows that are substantially continuous in length. In practice, carbon fiber tows comprising the present invention may be between about 1000 and 3000 meters in length, depending on the size of the fiber spool. However, glass fiber lengths can be up to 36 km in length. It is most preferable to select the longest fibers that the processing equipment will accommodate due to less splicing of fibers to form a continuous composite core. When the material on a fiber tow spool ends, fiber ends may be glued or mechanically connected end-to-end forming a substantially continuous fiber tow length.

Composite cores of the present invention may comprise fibers having a high packing efficiency relative to prior art cores, such as steel, for conductor cables. Traditional steel conductor cables generally comprise several round steel wires. Due to the round shape of the wires, the wires cannot pack tightly together and can only achieve a maximum packing efficiency of about 74%. The only way that a steel core could have 100% packing efficiency would be to have a solid steel rod as opposed to several round steel wires. Using a solid steel rod is not possible because the final cable would be inflexible. The steel rod would bend slightly to the point of yield, which may only be a few inches. However, if the rod is bent past the point of yield, it will remain bent and not return to its original shape. In the present invention, individual fibers can be oriented, coated with resin, and cured to form a composite core member having 100% packing efficiency. Higher packing efficiency yields a composite core with strength that is greater for a given volume than a steel core. In addition, higher packing efficiency allows for formation of a composite core with a smaller diameter. The smaller diameter core can allow an increased amount of aluminum conductor material to be wrapped around the composite core without changing the outside diameter of the conductor.

Composite cores of the present invention can comprise fiber types that are substantially heat resistant. Higher operating temperatures occur when higher amperage is sent through a conductor during increased demand periods. Heat resistant fiber types enable an ACCC cable to operate at higher operating temperatures. An ACCC cable may transmit the higher amperages that can cause the higher conductor temperatures. The fiber types in the present invention may withstand operating temperatures above 45° C. and may possibly withstand temperatures as high as 230° C. More preferably, the fibers in the present invention have the ability to withstand operating temperatures above 100° C., and most preferably, withstand temperatures around 180° C. or above. Moreover, fiber types in the present invention can withstand an ambient temperature above 45° C. and more preferably within the range between about 45° C. to about 90° C. That is, under no load conditions, the composite core may be able to withstand temperatures as low as about 45° C. without suffering impairment of the core's physical characteristics.

A relative amount of each type of fiber can vary depending on the desired physical characteristics of the composite core. For example, fibers having a higher modulus of elasticity enable formation of a high strength and high-stiffness composite core. As an example, carbon fibers have a modulus of elasticity from 15 Msi and up, but more preferably, from about 22 Msi to about 37 Msi; glass fibers are considered low modulus fibers having a modulus of

elasticity from 3 Msi and up. As one skilled in the art will recognize, other fibers may be chosen that can achieve the desired physical properties for the composite core.

Composite cores of the present invention can comprise fibers having relatively high tensile strengths. The degree of sag in an overhead voltage power transmission cable varies as the square of the span length and inversely with the tensile strength of the cable. An increase in the tensile strength can effectively reduce sag in an ACCC cable. As an example, carbon or graphite fibers may be selected having a tensile strength above 350 Ksi and more preferably within the range of about 350 Ksi to about 750 Ksi, but most preferably, within the range between 710 Ksi to 750 Ksi. Also as an example, glass fibers can be selected having a tensile strength above 180 Ksi, and more preferably within the range of about 180 Ksi to about 220 Ksi. The tensile strength of the composite core can be adjusted by combining glass fibers having a lower tensile strength with carbon fibers having a higher tensile strength. The properties of both types of fibers may be combined to form a new cable having a more desirable set of physical characteristics.

Composite cores of the present invention can have various fiber to resin volume fractions. The volume fraction is the area of fiber divided by the total area of the cross section. A composite core of the present invention may comprise fibers embedded in a resin having at least a 50% volume fraction. The fiber to resin ratio affects the physical properties of the composite core member. In particular, the strength, electrical conductivity, and coefficient of thermal expansion are functions of the fiber to resin volume. Generally, a higher volume fraction of fibers in the composite results in a higher tensile strength for the resulting composite. The weight of the fiber will determine the ratio of fiber to resin by weight. In accordance with the invention, the more preferred volume fraction of fiber to resin composite is 60% or lower or most preferably from about 50% to about 60%. The volume fraction can be adjusted to yield a fiber to resin ratio of 72% or lower by weight, or more preferably from 65% to 72%, and most preferably 65% by weight.

Any layer or section of the composite core may have a different fiber to resin ratio by weight relative to the other layers or sections. These differences may be accomplished by selecting the choosing an appropriate number of fibers for the appropriate resin type to achieve the desired fiber to resin ratio. For example, a composite core member having a carbon fiber and epoxy layer surrounded by an outer glass and epoxy layer may comprise 126 spools of glass fiber and an epoxy resin having a viscosity of about 2000 cPs to about 6000 cPs at 50° C. This fiber to resin selection can yield a fiber to resin ratio of about 75/25 by weight. Preferably, the resin may be modified to achieve the desired viscosity for the forming process. The exemplary composite may also have 16 spools of carbon fiber and an epoxy resin having a viscosity of about 2000 cPs to about 6000 cPs at 50° C. This selection can yield a fiber to resin ratio of about 70/30 by weight. Changing the number of spools of fiber changes the fiber to resin by weight ratio, and thereby can change the physical characteristics of the composite core. Alternatively, the resin may be adjusted to increase or decrease the resin viscosity to improve wetting.

Composite cores may have various geometries. Some of the different embodiments of the various geometries will be explained below. However, the invention is not limited to these embodiments of the geometries. First, fibers may have various alignments or orientations. Continuous towing can longitudinally orient the fibers along the cable. The core may have a longitudinal axis running along the length of the cable. In the art, this longitudinal axis is referred to as the 0° orientation. In most cores, the longitudinal axis runs along the center of the core. Fibers can be arranged to parallel this longitudinal axis; this orientation is often referred to as a 0° orientation or unidirectional orientation. However, other orientations may be possible.

The fibers in the composite core may be arranged in various ways within the core. Besides the 0° orientation, the fibers may have other arrangements. Some of the embodiments may include off-axis geometries. One embodiment of the composite core may have the fibers helically wound about the longitudinal axis of the composite core. The winding of the fibers may be at any angle from near 0° to near 90° from the 0° orientation. The winding may be in the + and − direction or in the + or − direction. In other words, the fibers may be wound in a clockwise or counterclockwise direction. In an exemplary embodiment, the fibers would be helically wound around the longitudinal axis at an angle to the longitudinal axis. In some embodiments, the core may not be formed in radial layers. Rather, the core may have two or more flat layers that are compacted together into a core. In this configuration, the fibers may have other fiber orientation besides 0° orientation. The fibers may be laid at an angle to the 0° orientation in any layer. Again, the angle may be any angle + or − from near 0° to near 90°. In some embodiments, one fiber or group of fibers may have one direction while another fiber or group of fibers may have a second direction. Thus, the present invention includes all multidirectional geometries. One skilled in the art will recognize other possible angular orientations.

In some other embodiments, the fibers may be interlaced or braided. In this embodiment, one set of fibers may be helically wound in one direction while a second set of fibers is wound in the opposite direction. As the fibers are wound, one set of fibers may change position with the other set of fibers. In other words, the fibers would be woven or criss-crossed. These sets of helically wound fibers also may not be braided or interlaced but may form concentric layers in the core. In another embodiment, a braided sleeve may be placed over the core and embedded in the final core configuration. Also, the fibers may be twisted upon themselves or in groups of fibers. One skilled in the art will recognize other embodiments where the fiber orientation is different. Those different embodiments are included within the scope of the invention.

Other geometries are possible beyond the orientation of the fibers. The composite core may be formed in different layers and sections. A two layered composite core is provided as an example in FIG. **11**. Several other core arrangements are possible. First, a composite core formed from more than two layers is possible. A first layer may have a first fiber type and a first type of matrix. Other layers may have different fiber types and different matrices from the first layer. The different layers may be bundled and compacted into a final composite core. As an example, the composite core may consist of a layer made from carbon and epoxy, a glass fiber and epoxy layer, and then a basalt fiber and epoxy layer. In another example, the inner lay may be basalt, followed by a carbon layer, followed by a glass layer, and finally be another basalt layer. All of these different arrangements can produce different physical properties for the composite core. One skilled in the art will recognized the numerous other layer configurations that are possible.

Still another core arrangement may include different sections in the core instead of layers. FIG. **5** shows numerous possible cross sectional views of these types of composite cores. These cross sections demonstrate that the composite core may be arranged in two or more sections without those sections being layered. Thus, depending on the physical characteristics desired, the composite core can have a first section of core with a certain composite and one or more other sections with a different composite. These sections can each be made from a plurality of fibers from one or more fiber types embedded in one or more types of matrices. The different sections may be bundled and compacted into a final core configuration.

In any of these different arrangements, the layers or sections may have different fibers or different matrices. For example, one section of the core may be a carbon fiber embedded in a thermosetting resin. Another section may be a glass fiber embedded in a thermoplastic section. Each of the sections may be uniform in matrix and fiber type. However, the sections and layers may also be hybridized. In other words, any section or layer may be formed from two or more fiber types. Thus, the section or layer may be, as an example, a composite made from glass fiber and carbon fiber embedded in a resin. Thus, the composite cores of the present invention can form a composite core with only one fiber type and one matrix, a composite core with only one layer or section with two or more fiber types and one or more matrices, or a composite core formed from two or more layers or sections each with one or more fiber types and one or more matrix types. One skilled in the art will recognize the other possibilities for the geometry of the composite core.

As explained above, some embodiments of the composite core may combine two or more types of fibers to take advantage of the inherent physical properties of each fiber type to create different composite cores. For example, two or more fiber type reinforcements may be combined to form a high strength and high stiffness composite core but with added flexibility. Also, the physical characteristics of the composite core may be adjusted by changing the fiber to resin ratio of each component. In one example, the composite core may be 0.1104 sq. in. in cross sectional area for a core of 0.375 inches in diameter and comprise a layer of carbon fiber and a layer of glass fiber. The carbon fiber and matrix section or inner layer may be 0.0634 sq. in. in cross sectional area. The glass fiber and matrix section or layer may be 0.0469 sq. in. in cross sectional area. This composite core may comprise an inner core with a fiber to resin ratio of about 70/30 by weight and an outer layer having a fiber to resin ratio of about 75/25 by weight. This fiber and core arrangement produces a high strength core, which is also flexible. Other fibers and other geometries may produce composite cores with different physical properties.

The physical characteristics of the composite core may also be adjusted by adjusting the area percentage of each component within the composite core member. For example, by reducing the total area of carbon in the composite core mentioned earlier from 0.0634 sq. in. and increasing the area of the glass layer from 0.0469 sq. in., the composite core member product can have reduced stiffness and increased flexibility. Alternatively, a third fiber, for example basalt, may be introduced into the composite core. The additional fiber changes the physical characteristics of the end product. For example, by substituting basalt for some carbon fibers, the core may have increased dielectric properties and a relatively small decrease in core stiffness.

In accordance with the present invention, the composite core is designed based on the desired physical characteristics of an ACCC reinforced cable. An exemplary embodiment is provided below. The composite core can be designed having an inner strengthening core member comprising a high-strength composite surrounded by an outer low-stiffness layer. The high-strength composite can have a greater than 50% volume fraction and mechanical properties exceeding the mechanical properties of glass fibers. The outer layer of low-stiffness composite can have mechanical properties in the range of glass fiber. The mechanical properties of fibers similar to glass fibers can add flexibility to the composite core.

Fibers forming the first layer of a high-strength composite can be selected with a tensile strength within the range of about 350 Ksi to about 750 Ksi; a modulus of elasticity within the range of about 22 Msi to about 37 Msi; a coefficient of thermal expansion within the range of about −0.7×110 m/m/° C. to about 0 m/m/° C.; a yield elongation percent within the range of about 1.5% to 3%; a dielectric within the range of about 0.31 W/m·K to about 0.04 W/m·K; and a density within the range of about 0.065 lb/in^3 to about 0.13 lb/in^3.

Fibers forming the outer layer of a low-stiffness layer can have a tensile strength within the range about 180 Ksi to 220 Ksi; a modulus of elasticity within the range of about 6 Msi to 7 Msi; a coefficient of thermal expansion within the range of about 5×10^{-6} m/m/° C. to about 10×10^{-6} m/m/° C.; a yield elongation percent within the range of about 3% to about 6%; a dielectric within the range of about 0.034 W/m·K to about 0.04 W/m·K; and a density from 0.060 lbs/in^3 and up, but more preferably from about 0.065 lbs/in^3 to about 0.13 lbs/in.

The layers may be bundled in a single core. These layers of differing composites form a hybridized composite core. Although other arrangements of the layers are possible, preferably, the layers would be concentric. Thus, the layers form a hybridized, concentric core with two uniform layers each created from one fiber type and one matrix material.

In the exemplary embodiment, the composite core can have the following physical characteristics. The core can have a tensile strength in the range within the range of about 160 Ksi to about 380 Ksi. More preferably, the core has a tensile strength of about 300 Ksi and above. The core can have a modulus of elasticity within the range of about 7 Msi to about 37 Msi, more preferably, about 16 Msi. The core can withstand operating temperature in the range of about 45° C. and possibly up to about 230° C. More preferably, the composite core is able to withstand an operating temperature around 180° C. and above. The composite core can have a coefficient of thermal expansion of about 0 m/m/° C. to about 6×10^{-6} m/m/° C., more preferably, about 2.5×10^{-6} m/m/° C. A composite core member having an inner layer and an outer layer in accordance with the ranges set forth above can have increased ampacity over other prior art conductor cables of similar diameter by about 1% to about 200%. This ampacity gain may also be achieved even if the prior art cable has a similar conductor configuration.

Sag versus temperature is determined by considering the modulus of elasticity, the coefficient of thermal expansion, the weight of the composite strength member, and the conductor weight. An ACCC cable can achieve ampacity gains and operating temperatures between 45° C. and 230° C. because the higher modulus of elasticity and lower coefficient of thermal expansion in the composite cores. To design an ACCC cable with increased ampacity ability, the composite core should prevent sag at the higher operating temperatures that may accompany ampacity gains. Sag versus temperature calculations require input of the modulus of elasticity, coefficient of thermal expansion, the weight of the composite strength member, and the conductor weight. Accordingly, these physical characteristics are taken into account in designing the composite core. The composite core of the present invention can have both a high modulus of elasticity and a low coefficient of thermal expansion. Also, the fibers can have high dielectric properties. Thus, an ACCC cable of the present invention can operate at higher operating temperatures without a corresponding increase in sag.

As another example of the composite core, it may be feasible to make a composite core comprising interspersed high modulus of elasticity fibers and low modulus of elasticity fibers. Depending on the strain to failure ratio, this type of core may be a single section or layer of hybridized composite or it may be formed in several sections of single fiber composite. Carbon fibers can be selected for their high modulus of elasticity within the range of about 22 Msi to about 37 Msi, a low coefficient of thermal expansion within the range of about -0.7×10^{-6} m/m/° C. to about 0 m/m/° C., and an elongation percent within the range of about 1.5% to about 3%. Glass fibers are selected for a low modulus of elasticity, a low coefficient of thermal expansion within the range of about 5×10^{-6} m/m/° C. to about 10×10^{-6} m/m/° C., and an elongation percent within the range of about 3% to about 6%. The strain capability of this exemplary composite is a function of the inherent physical properties of the components and the volume fraction of components. In accordance with the present invention, the resins can be customized to achieve certain properties for processing and to achieve desired physical properties in the end product. As such, the fiber and customized resin strain to failure ratio can be determined. For example, carbon fiber and epoxy has a strain to failure ratio of 2.1% and glass fiber and epoxy has a strain to failure ratio of 1.7%. Accordingly, the composite core can be designed to have the stiffness of the carbon fiber and epoxy and the flexibility of the glass fiber and epoxy. This combination of fibers and resin can create a composite core that is flexible and has a low coefficient of thermal expansion.

Alternatively, another high-strength composite having mechanical properties in excess of glass fiber could be substituted for at least a portion of the carbon fibers and another fiber having the mechanical property range of glass fiber could be substituted for glass fiber. For example, basalt has the following properties: a high tensile strength in the range of about 701.98 Ksi (compared to the range of about 180 to about 500 Ksi for glass fibers), a high modulus of elasticity in the range of about 12.95 Msi, a low coefficient of thermal expansion in the range of about 8.0 ppm/C (compared to about 5.4 ppm/C for glass fibers), and an elongation percent in the range of about 3.15% (compared the range of about 3% to about 6% for glass fibers). The basalt fibers can provide increased tensile strength, a modulus of elasticity between carbon and glass fiber, and an elongation percent close to that of carbon fibers. A further advantage is that basalt has superior dielectric properties to carbon. The composite core can comprise an inner strength member that is non-conductive. By designing a high-strength composite core having fibers of inherent physical characteristics surrounded by low modulus fiber outer core, a new property set for the composite core is obtained.

The composite core may also include other surface applications or surface treatments to the composite core. For instance, the composite core may include any chemical or material application to the core that protects the core from environmental factors, protects the core from wear, or prepares the core for further processing. Some of these types of treatments may include, but are not limited to, gel coats, protective paintings, finishes, abrasive coatings, or the like.

Some of the material applications may include, but are not limited to, surface veils applied to the core, mats applied to the core, or protective or conductive tapes wrapped around the core. The tape may include dry or wet tapes. The tapes may include, but are not limited to, paper or paper-product tapes, metallic tape (like aluminum tape), polymeric tapes, rubber tapes, or the like. Any of these products may protect the core from environmental forces like moisture, heat, cold, UV radiation, or corrosive elements. Other applications and treatments to the core will be recognized by one skilled in the art and are included in the present invention.

The final ACCC reinforced cable is created by surrounding the composite core with an electrical conductor. Putting the conductor around the core is explained in more detail below.

The composite cables made in accordance with the present invention exhibit physical properties wherein these certain physical properties may be controlled by changing parameters during the composite core forming process. More specifically, the composite core forming process is adjustable to achieve desired physical characteristics in a final ACCC cable.

A Method of Manufacture of a Composite Core for an ACCC reinforced Cable

Several forming processes to create the composite core may exist, but an exemplary process is described hereinafter. This exemplary process is a high-speed manufacturing process for composite cores. Many of the processes, including the exemplary process, can be used to form the several different composite cores with the several different core structures mentioned or described earlier. However, the description that follows chooses to describe the high-speed processing in terms of creating a carbon fiber core with a glass fiber outer layer, having unidirectional fibers, and a uniformly layered, concentric composite core. The invention is not meant to be limited to that one embodiment, but encompasses all the modifications needed to use the high-speed process to form the composite cores mentioned earlier. These modifications will be recognized by one skilled in the art.

In accordance with the invention, a multi-phase B-stage forming process produces a composite core member from substantially continuous lengths of suitable fiber tows and heat processible resins. After producing an appropriate core, the composite core member can be wrapped with high conductivity material.

A process for making composite cores for ACCC cables according to the invention is described as follows. Referring to FIG. **1**, the conductor core B-stage forming process of the present invention is shown and designated generally by reference number **10**. The B-stage forming process **10** is employed to make continuous lengths of composite core members from suitable fiber tows or rovings and resins. The resulting composite core member comprises a hybridized concentric core having an inner and outer layer of uniformly distributed substantially parallel fibers.

In starting the operation, the pulling and winding spool mechanism is activated to commence pulling. The unimpregnated initial fiber tows, comprising a plurality of fibers extending from the exit end of the cooling portion in zone **9**, serve as leaders at the beginning of the operation to pull fiber tows **12** from spools **11** through fiber tow guide **18** and the composite core processing system.

In FIG. **1**, multiple spools of fiber tows **12** are contained within a rack system **14** and are provided with the ends of the individual fiber tows **12**, leading from spools **11**, being threaded through a fiber tow guide **18**. The fibers can be unwound, either using tangent pulling or center pulling, but preferably using tangent pulling to prevent twisted fibers. Preferably, a puller **16** at the end of the apparatus pulls the fibers through the apparatus. Each dispensing rack **14** can comprise a device allowing for the adjustment of tension for each spool **11**. For example, each rack **14** may have a small brake at the dispensing rack to individually adjust the tension for each spool. Tension adjustment minimizes caternary and cross-over of the fiber when it travels and aids in the wetting process. The tows **12** are pulled through the guide **18** and into a preheating oven **20** that evacuates moisture. The preheating oven **20** uses continuous circular air flow and a heating element to keep the temperature constant. The preheating oven is preferably above 100° C.

The tows **12** are pulled into a wet out system **22**. The wet out system may be any process or device that can wet the fibers or impregnate the fibers with resin. Wet out systems may include incorporating the resin in a solid form that will be liquefied during later heating. For instance, a thermoplastic resin may be formed as several fibers. These fibers may be interspersed with the carbon and glass fibers of the exemplary embodiment. When heat is applied to the bundle of fibers, the thermoplastic fibers liquefy or melt and impregnate or wet the carbon and glass fibers. In another embodiment, the carbon and glass fibers may have a bark or skin surrounding the fiber; the bark holds or contains a thermoplastic or other type resin in a powder form. When heat is applied to the fibers, the bark melts or evaporates, the powdered resin melts, and the melted resin wets the fibers. In another embodiment, the resin is a film applied to the fibers and then melted to wet the fibers. In still another embodiment, the fibers are already impregnated with a resin—these fibers are known in the art as pre-preg tows. If the pre-preg tows are used, no wet out tank or device is used. An embodiment of the wet out system is a wet out tank. Hereinafter, a wet out tank will be used in the description, but the present invention is not meant to be limited to that embodiment. Rather, the wet out system may be any device to wet the fibers. The wet out tank **22** is filled with resin to impregnate the fiber tows **12**. Excess resin is removed from the fiber tows **12** during wet out tank **22** exit. The fiber tows **12** are pulled from the wet out tank **22** to a secondary system, a B-stage oven **24**. The B-stage oven heats the resin to a temperature changing the liquid stage of resin to a semi-cure stage. B-stage cure resin is in a tacky stage which permits the fiber tows **12** to be bent, compacted, bundled, and configured. The tackiness of the resin is controlled mainly by the resin heating temperature, which may come from either the tooling, the fiber, or the oven. Fiber tows **12** separated by the guide **18** are pulled into a second B-stage oven **26** comprising a plurality of consecutive dies to compact and configure the tows **12**. Two or more dies may be an implement to compact, to drive air out of the composite, and to shape the fibers into a composite core. An embodiment of the set of dies is a set of bushings. A bushing may be a rigid plate with a plurality of passageways that accept the impregnated fibers. Hereinafter, bushing will be used interchangeably with dies, but the invention is not limited to that one embodiment. In the second B-stage oven **26**, the fiber tows **12** are directed through a plurality of passageways provided by the bushings. In an exemplary embodiment, the composite core is made from two sets of fiber tows—inner segments are formed from carbon while the outer segments are formed from glass. The consecutive passageways continually compact and configure the inner fiber tows **12** into the inner composite segments. These inner segments are compacted together to form the inner carbon core. The outer fiber tows are also continually compacted and configured into the outer layer, glass segments. After the inner core is formed, the outer segments may be deposited onto and compacted with the inner core. The compaction of all the segments creates a uniformly distributed, layered, and concentric final composite core with the requisite outside diameter.

Preferably, the composite core member is pulled from the second B-stage oven **26** to a next oven processing system **28** wherein the composite core member is cured and pulled to a next cooling system **30** for cooling. After cooling, the composite core may be pulled to a next oven processing system **32** for post curing at elevated temperature. The post-curing process promotes increased cross-linking within the resin resulting in improved physical characteristics of the composite member. The process generally can allow an interval between the heating and cooling process and the pulling apparatus **36** to cool the product naturally or by convection such that the pulling device **34** used to grip and pull the product will not damage the product. The pulling mechanism pulls the product through the process with precision controlled speed.

Referring now more particularly to FIG. **1**, in an exemplary embodiment, the process continuously pulls fiber from left to right of the system through a series of phases referred to herein as zones. Each zone performs a different processing function. In this particular embodiment, the process comprises 9 temperature and compacting zones. The process originates at a series of fiber dispensing racks **14** whereby a caterpuller **34** can continuously pull the fibers **12** through each zone. One advantage to the caterpuller system is that it functions as a continuous pulling system driven by an electrical motor as opposed to the traditional reciprocation system. The caterpuller system uses a system of two belts traveling on the upper and lower portions of the product squeezing the product there between. Accordingly, the caterpuller system embodies a simplified uniform pulling system functioning at precision controlled speed using only one device instead of a multiplicity of interacting parts functioning to propel the product through the process. Alternatively, a reciprocation system may be used to pull the fibers through the process.

The process starts with zone **1**. Zone **1** may comprise a type of fiber dispensing system. In one embodiment, the fiber dispensing system comprises two racks **13** each rack containing a plurality of spools **11** containing fiber tows **12**. Further, the spools **11** are interchangeable to accommodate varying types of fiber tows **12** depending on the desired properties of the composite core member.

For example, an exemplary composite core member formed by the B-stage forming process comprises a carbon and resin inner core surrounded by a glass and resin outer core layer. Preferably, high strength and high quality carbon is used. The resin also protects the fibers from surface damage, and prevents cracking through a mass of fibers improving fracture resistance. The conductor core B-stage forming process **10** creates a system for pulling the fibers to achieve the optimum degree of bonding between fibers in order to create a composite member with optimal composite properties.

As previously mentioned, the components of the composite core are selected based on desired composite core characteristics. One advantage of the present process is the ability to adjust composite components in order for a composite core to achieve the desired goals of a final ACCC cable. It is preferable to combine types of fibers to combine the physical characteristics of each. Performance can be improved by forming a core with increased strength and stiffness, coupled with a more flexible outer layer. The process can increase the optimal characteristics of the composite by preventing twisting of rovings leading to more uniform wetting and strength characteristics.

For example, in an exemplary embodiment of the composite core member, the composite core comprises glass and carbon. Using the B-stage forming process, the racks **13** may hold 126 spools 11 of glass and 16 spools 11 of carbon. The fiber tows **12** leading from spools **11** are threaded through a fiber tow guide **18** wherein fiber tow passageways are arranged to provide a configuration for formation of a core composite sections having an inner carbon core and outer glass layer. The carbon layer is characterized by high strength and stiffness and is a weak electrical conductor whereas the outer low modulus glass layer is more flexible and non-conductive. Having an outer glass layer provides an outer insulating layer between the carbon and the high conductivity aluminum wrapping in the final composite conductor product.

The fiber dispensing system dispenses fibers from the fiber package pull. Preferably, a tangent pull method may be used because it does not twist the fiber. The center pull method can twist fibers dispensed from the spool. As such, the center pull method can result in an increased number of twisted fibers. Twisted fiber can occasionally lay on top of other twisted fiber and create a composite with spots of dry fiber. It is preferable to use tangent pull method to avoid dry spots and optimize wet out ability of the fibers.

The fiber tows **12** are threaded through a guidance system **18**. The guide **18** can comprise polyethylene and steel dies or bushings containing a plurality of passageways in a predetermined pattern guiding the fibers to prevent the fibers from crossing. Referring to FIG. **2**, the guide may comprise a bushing with sufficiently spaced passageways for insertion of the fibers in a predetermined pattern. The passageways can be contained within an inner square portion **40**. The passageways may be arranged in rows of varying number. The larger diameter carbon fibers can pass through the center two rows of passageways **42** and the smaller diameter glass fibers pass through the outer two rows **44** on either side of the carbon passageways **42**. A tensioning device, preferably on each spool, can adjust the tension of the pulled fibers and may assure the fibers are pulled straight through the guide **18**.

At least two fibers are pulled through each passageway in the guide **18**. For example, a guide **18** comprising 26 passageways pulls 52 fibers through. If a fiber of a pair breaks, a sensing system can alert the composite core B-stage forming process **10** that there is a broken fiber and may stop the puller **34**. Alternatively, in one embodiment, a broken fiber can alert the process and the repair can be made without stopping the process. To repair, a new fiber can be pulled from the rack **13** and glued or mechanically coupled or connected to the broken end of the new fiber. After the fiber is repaired, the conductor core B-stage forming machine **10** may be started again.

In an exemplary example, the fibers are grouped in a parallel arrangement for a plurality of rows. For example, in FIG. **2**, there are six parallel rows of passageways. The outer two rows comprise 32 passageways, the two inner rows comprise 31 passageways, and the two center rows comprise 4 passageways each. Fibers are pulled at least two at a time into each passageway and pulled into zone **2**.

Zone **2** comprises an oven processing system that preheats the dry fibers to evacuate any moisture. The fibers of the present invention may be heated within the range of about 150° F. to 300° F. to evaporate moisture.

The oven processing system comprises an oven portion wherein the oven portion is designed to promote cross-circular air flow against the flow of material. FIG. **9** illustrates a typical embodiment of the oven system. An oven is generally designated **60**. The fibers pass through the oven from upstream to downstream direction, the air passes in the reverse direction. The oven processing system comprises an air-heating drive system housing **64** that houses a blower **68**, powered by electric motor **70**, located upstream from a heater assembly **66** to circulate air in a downstream direction through an air flow duct **62**. The heat drive system housing houses a blower **68** upstream of the heater assembly **66**. The blower **68** propels air across the heater assembly **66** and through the oven system. The air flows downstream to a curved elbow duct **72**. The curved elbow duct **72** shifts the air flow 90 degrees up into an inlet duct **78** and through the oven inlet **76**. Through the inlet, the air flow shifts 90 degrees to flow upstream through the oven **60** against the pull direction of the fibers. At the end of the oven **60**, the air flow shifts 90 degrees down through the oven outlet **80** then through the outlet duct **74** then through the blower **68** and back into the heat drive system housing **64**. In one embodiment, a valve is placed between the outlet duct **74** and the blower **68**. This valve may function to fully or partially restrict the air flow in either direction. In a further embodiment, a louver or vent to the outside air is set between the valve and the blower. The louver can open to let in cooler air from the environment to help cool the over temperature quickly. The motor **70** comprises an electrical motor outside of the heat drive system to prevent overheating. The motor **70** comprises a pulley with a timing belt that moves the bladed blower **68**. Preferably, the system is computer controlled allowing continuous air circulation at a desired temperature. More preferably, the process allows for the temperature to change at any time according to the needs of the process.

For example, the computer may sense the temperature is not at the required temperature and can activate or deactivate the heater **66**. The blower **68** blows air across the heating element **66** downstream. The system forces the air to travel in a closed loop circle continuously circulating through the oven **60** keeping the temperature constant.

FIG. **10** is a more detailed view of an exemplary embodiment of the heating element **66**. In one embodiment, the heater assembly **66** comprises nine horizontal steel electrical heaters **82**. Each heater unit is separate and distinct from the other heater. Each heater unit is separated by a gap. Preferably, after sensing a temperature differential, the computer activates the number of heaters to provide sufficient heat. If the system requires the computer activates one of nine heaters. Alternatively, depending on the needs of the process, the computer activates every other heater in the heater assembly. In another embodiment the computer activates all heaters in the heater assembly. In a further alternative, the computer activates a portion of the heaters in the heater assembly or turns all the heaters off.

In an alternate embodiment, electromagnetic fields penetrate through the process material to heat the fibers and drive off any moisture. In another embodiment pulsed microwaves heat the fibers and drive off any moisture. In another embodiment, an electron beam uses electrons as ionizing radiation to drive off any excess moisture.

In another embodiment, the caterpuller can pull the fibers through zone **3**, the fiber impregnation system. Zone **3** comprises a wet out system **22**. There are several embodiments of a wet out system. Some of these embodiments will be explained below. However, the present invention is not limited to those described embodiments. In an exemplary embodiment, a pass-through tank is used. The pass-through tank has an enclosed tank where the fiber rovings enter through a bushing at one end of the tank and pass through the resin until exiting another bushing at the other end of the tank. A pass-through tank **22** can contain a device that allows the redirection of fibers during wet out. Preferably, a set of redirection bars may be located in the center of the tank and move the fibers vertically up or down compared to the direction of the pull, whereby the deflection causes the fibers to reconfigure from a round configuration to a flat configuration. The flat configuration allows the fibers to lie side by side and allows for the fibers to be more thoroughly wetted by the resin.

Various alternative techniques well known in the art can be employed to apply or impregnate the fibers with resin. Such techniques include for example, spraying, dipping, reverse coating, brushing, and resin injection. In an alternate embodiment, ultrasonic activation uses vibrations to improve the wetting ability of the fibers. In another embodiment, a dip tank may be used to wet out the fibers. A dip tank has the fibers drop into a tank filled with resin. When the fibers emerge from the tank filled with resin, the fibers are wetted. Still another embodiment may include an injection die assembly. In this embodiment, the fibers enter a pressurized tank filled with resin. The pressure within the tank helps wet the fibers. The fibers can enter the die for forming the composite while still within the pressurized tank. One skilled in the art will recognize other types of tanks and wet out systems that may be used.

Generally, any of the various known resin compositions can be used with the invention. In an exemplary embodiment, a heat curable thermosetting polymeric may be used. The resin may be for example, PEAR (PolyEther Amide Resin), Bismaleimide, Polyimide, liquid-crystal polymer (LCP), vinyl ester, high temperature epoxy based on liquid crystal technology, or similar resin materials. One skilled in the art will recognize other resins that may be used in the present invention. Resins are selected based on the process and the physical characteristics desired in the composite core.

Further, the viscosity of the resin affects the rate of formation. To achieve the desired proportion of fiber to resin for formation of the composite core member, preferably, the viscosity range of the resin is within the range of about 50 Centipoise to about 3000 Centipoise at 20° C. More preferably, the viscosity falls in the range of about 50 Centipoise to about 600 Centipoise at 20° C. The resin is selected to have good mechanical properties and excellent chemical resistance to prolonged environmental exposure of at least 60 years and more preferably, at least 70 years at operation up to about 230° C. A particular advantage of the present invention is the ability for the process to accommodate use of low viscosity resins. In accordance with the present invention, it is preferable to achieve a fiber to resin ratio within the range of 62–75% by weight. It is more preferable to have a fiber to resin ratio within the range of 69–75% by weight. Low viscosity resins will sufficiently wet the fibers for the composite core member. A preferred polymer provides resistance to a broad spectrum of aggressive chemicals and has very stable dielectric and insulating properties. It is further preferable that the polymer meets ASTME595 outgassing requirements and UL94 flammability tests and is capable of operating intermittently at temperatures ranging between 220° C. and 280° C. without thermally or mechanically damaging the strength of the member.

To achieve the desired fiber to resin wetting ratio, the upstream side of the wet out tank can comprises a device to extract excess resin from the fibers. In one embodiment, a set of wipers may be placed after the end of the wet out system, preferably made from steel chrome plated wiping bars. The wipers can be Dr. Blades or other device for removing excess resin.

Alternatively, the wet out tank uses a series of squeeze out bushings to remove excess resin. During the wet out process each bundle of fiber contains as much as three times the desired resin for the final product. To achieve the right proportion of fiber and resin in the cross section of the composite core members, the amount of pure fiber is calculated. The squeeze out bushing or wipers is designed to remove excess resin and control the fiber to resin ratio by volume. For example, where the bushing passageway is twice as big as the area of the cross section of the fiber, a resin to fiber ration by volume of 50% won't be pulled through the bushing, the excess resin will be removed. Alternatively, the bushing and wipers can be designed to allow passage of any ratio of fiber to resin by volume. In another embodiment, the device may be a set of bars that extract the resin. These resin extraction devices may also be used with other wet out systems. In addition, one skilled in the art will recognize other devices that may be used to extract excess resin. Preferably, the excess resin is collected and recycled into the wet out tank **22**.

Preferably, a recycle tray extends lengthwise under the wet out tank **22** to catch overflow resin. More preferably, the wet out tank has an auxiliary tank with overflow capability. Overflow resin is returned to the auxiliary tank by gravity through the piping. Alternatively, tank overflow can be captured by an overflow channel and returned to the tank by gravity. In a further alternate, the process can use a drain pump system to recycle the resin back from the auxiliary tank and into the wet out tank. Preferably, a computer system controls the level of resin within the tank. Sensors detect low resin levels and activate a pump to pump resin into the tank from the auxiliary mixing tank into the processing tank. More preferably, there is a mixing tank located within the area of the wet out tank. The resin is mixed in the mixing tank and pumped into the resin wet out tank.

The pullers pull the fibers from zone **3** to zone **4**, the B-stage zone. Zone **4** comprises an oven processing system **24**. Preferably, the oven processing system is an oven with a computer system that controls the temperature of the air and keeps the air flow constant wherein the oven is the same as the oven in zone **2**.

The pullers pull the fibers from zone **3** to zone **4**. The oven circulates air in a circular direction downstream to upstream by a propeller heating system. The computer system controls the temperature to heat the wet fiber to B-stage. Preferably, the process determines the temperature. B-stage temperature of the present invention ranges from within about 150° F. to about 300° F. This temperature is maintained within the range in both the first B-stage oven and the second B-stage oven. One advantage of the B-stage semi-cure process in the present invention is the ability to heat the resin to a semi-cure state in a short duration of time, approximately 1–1.5 minutes during the continuation of the process. The advantage is that the heating step does not affect the processing speed of the system. The B-stage process allows for the further tuning of the fiber to resin ratio by removing excess resin from the wet-out stage. Further, B-stage allows the fiber to resin to be further compacted and configured during the process. Accordingly, the process differs from previous processes that use pre-preg semi-cure. Heating the core can semi-cure the resin and bring it to a tacky stage.

More specifically, in traditional composite processing applications, the wetted fibers are heated gradually to a semi-cure stage. However, the heating process generally takes periods of one hour or longer to reach the semi-cure stage. Moreover, the composite must be immediately wrapped and frozen to keep the composite at the semi-cure stage and prevent curing to a final stage. Accordingly, the processing is fragmented because it is necessary to remove the product from the line to configure the product.

In accordance with the present invention, the B-stage heating is dedicated to a high efficiency commercial application wherein semi-cure is rapid, preferably 1–1.5 minutes during a continuous process. Preferably, the resins are designed to allow rapid B-stage semi-curing that is held constant through the process allowing for shaping and configuring and further compaction of the product.

The pullers pull the fibers from B-stage zone **4** to zone **5** for the formation of the composite core member. Zone **5** comprises a next oven processing system **26** having a plurality of dies. As stated above, this B-stage oven is kept at a temperature from about 150° F. to about 300° F. The dies or bushings function to shape the cross section of the fiber tows **12**. Preferably, the bushings are configured in a series comprising a parallel configuration with each other. In an exemplary embodiment, there is a set of seven bushings spaced laterally within the oven processing system **26**. Preferably, the spacing of the bushings is adjusted according to the process. The bushings can be spaced equidistance or variable distance from each other.

The series of bushings in zone **5** can minimize friction due to the relatively thin bushings ranging within about ⅜to about ¾ inch thick. Minimizing friction aids in maximizing the process speed.

Zones **4**, **5** and **6** of the present invention extend within the range of about 30–45 feet. Most preferably, the zones **4**, **5** and **6** extend at least 30 feet. The pulling distance and the decreased friction due to thin bushing plates helps the process reach speeds in the range of about 9 ft/min to about 60 ft/min. In an exemplary embodiment, the processing speed is about 20 ft/min. Processing speed is further increased due to the high fiber to resin ratio.

Referring to FIG. **3**, for example, the bushings **90** comprise a flat steel plate with a plurality of passageways through which the fiber tows **12** are pulled. The flat plate steel bushing **90** preferably ranges from ⅜ inch to ½ inch thick determined by the process. The bushings **90** have relatively thin walls to reduce friction between the die and the fast traveling fiber. The oven is long enough to allow the fiber to stay in the controllable B-stage temperature for a longer period of time. Thus, the length of the oven is related to the speed of processing. The thickness of the bushing **90** is preferably the minimum needed to compact the B-staged package into the final shape.

Preferably, the design and size of the bushings **90** are the same. More preferably, the passageways within each bushing **90** diminish in size and vary in location within each successive bushing **90** in the upstream direction. FIG. **3** illustrates an exemplary embodiment of a bushing **90**. The bushing **90** comprises two hooked portions **94** and an inner preferably square portion **92**. The inner square portion **92** houses the passageways through which the pulling mechanism pulls the fibers. The outer hooked portions **94** form a support system whereby the set of bushings **90** is placed within the oven in zone **5**. The outer hooked portion **94** connects with interlocking long steel beams within the oven that function to support the bushings **90**.

Zone **5** comprises a series of numerous consecutive bushings. The bushings have two functions: (1) guide the fiber in the configuration for the final product; and (2) shape and compact the B-staged fibers. In one embodiment, the bushings **90** are placed apart within the oven supported on the hooked structures. The bushings **90** function to continually compact the fibers and form a composite core comprising, in this embodiment, carbon and glass while the process is under appropriate tension to achieve concentricity and uniform distribution of fiber without commingling of fibers. The bushings **90** may be designed to form bundles of a plurality of geometries. For example, FIG. **5** illustrates the variations in cross sections that may be achieved in the composite member. Each cross section results from different bushing **90** designs.

The passageways in each successive bushing **90** diminish in size further compacting the fiber bundles. For example, FIG. **6** shows each bushing **90** superimposed on top of one another. Several changes are apparent with each consecutive bushing **90**. First, each overlaid bushing **90** shows that the size of each passageway decreases. Second, the superimposed figure shows the appearance of the center hole for compaction of the core element. Third, the figure shows the movement of the outer corner passageways towards the center position.

Referring to FIG. **4**, there are two bushings illustrated. The first bushing **100** illustrated, is in a similar configuration as the guide bushing **18**. The second bushing **104** is the first in the series of bushings that function to compact and configure the composite core. The first bushing **100** comprises an inner square portion **92** with a plurality of passageways **102** prearranged through which the fibers are pulled. The passageways **102** are designed to align the fibers into groups in bushing two **104** having four outer groups **106** of fibers and four inner groups **108** of fibers. The inner square portion of the bushing **100** comprises six rows of passageways **110**. The arrangement of the passageways **110** may be configured into any plurality of configurations depending on the desired cross section geometry of the composite core member. The top and bottom row, **112** and **114** respectively, contain the same number of passageways. The next to top and next to bottom rows, **116** and **118** respectively, contain the same number of passageways and the two inner rows **120** and **122** contain the same number of passageways.

In an exemplary embodiment, the top and bottom rows contain 32 passageways each. The next level of rows contains 31 passageways each. The middle rows contain 4 passageways each. The pulling mechanism pulls two fibers through each passageway. Referring to FIG. **4** for example, the pulling mechanism pulls **126** glass fibers through rows **112**, **114**, **116** and **118**. Further, the pulling mechanism pulls **16** carbon fibers through rows **120** and **122**.

Referring to FIG. **7**, the next bushing, bushing three in the series comprises an inner square portion **131** having four outer corner passageways **132*a***, **132*b***, **132*c*** and **132*d*** and four inner passageways **134*a***, **134*b***, **134*c*** and **134*d***. The fibers exit bushing two and are divided into equal parts and pulled through bushing three. Each passageway in bushing three comprises one quarter of the particular type of fiber pulled through bushing two. More specifically, the top two rows of the top and the bottom of bushing two are divided in half whereby the right half of the top two rows of fibers are pulled through the right outer corner of bushing three. The left half of the top two rows of fibers are pulled through the upper left corner **132*a*** of bushing three **130**. The right half of the top two rows of fibers are pulled through the upper right corner **132*b*** of bushing three **130**. The right half of the bottom two rows of fibers are pulled through the lower right corner **132*c*** of bushing three. The left half of the bottom two rows of fibers are pulled through the lower left corner **132*d*** of bushing three **130**. The inner two rows of bushing one are divided in half whereby the top right half of the top middle row of fibers is pulled through the inner upper right corner **134*b*** of bushing three **130**. The left half of the top middle row of fibers is pulled through the inner upper left corner **134*a*** of bushing three **130**. The right half of the lower middle row of fibers is pulled through the inner lower right corner **134*c*** of bushing three **130**. The left half of the lower middle row of fibers is pulled through the inner lower left corner **134*d*** of bushing three **130**. Accordingly, bushing three **130** creates eight bundles of impregnated fibers that will be continually compacted through the succeeding bushings.

The puller pulls the fibers through bushing three **130** to bushing four **140**. Bushing four **140** comprises the same configuration as bushing three **130**. Bushing four **140** comprises a square inner portion **141** having four outer corner passageways **142*a***, **142*b***, **142*c*** and **142*d*** and four inner passageways **144*a***, **144*b***, **144*c*** and **144*d***. Preferably, the four outer corner passageways **142*a–d*** and the four inner passageways **144*a–d*** are slightly smaller in size than the similarly configured passageways in bushing three **130**. Bushing four **140** compacts the fibers pulled through bushing three.

The puller pulls the fibers from bushing four **140** to bushing five **150**. Preferably, the four outer corner passageways **152*a***, **152*b***, **152*c*** and **152*d*** and the four inner passageways **154*a***, **154*b***, **154*c*** and **154*d*** are slightly smaller in size than the similarly configured passageways in bushing four **140**. Bushing five **150** compacts the fibers pulled through bushing four **140**.

For each of the successive bushings, each bushing creates a bundle of fibers with an increasingly smaller diameter. Preferably, each smaller bushing wipes off excess resin to approach the optimal and desired proportion of resin to fiber composition.

The puller pulls the fibers from bushing five **150** to bushing six **160**. Preferably, the four outer corner passageways **162*a***, **162*b***, **162*c*** and **162*d*** and the four inner passageways **164*a***, **164*b***, **164*c*** and **164*d*** are slightly smaller in size than the similarly configured passageways in bushing five **150**. Bushing six **160** compacts the fibers pulled through bushing five **150**.

Bushing seven **170** comprises an inner square **171** having four outer corner passageways **172*a***, **172*b***, **172*c*** and **172*d*** and one inner passageway **174**. The puller pulls the fibers from the four inner passageways **164** of bushing six **160** through the single inner passageway **174** in bushing seven **170**. The process compacts the product to a final uniform concentric core. Preferably, fibers are pulled through the outer four corners **172*a***, **172*b***, **172*c***, **172*d*** of bushing seven **170** simultaneous with compacting of the inner four passageways **164** from bushing six **160**.

The puller pulls the fibers through bushing seven **170** to bushing eight **180**. The puller pulls the inner compacted core **184** and the outer four corners **182*a***, **182*b***, **182*c***, **182*d*** migrate inwardly closer to the core **184**. Preferably, the outer fibers diminish the distance between the inner core and the outer corners by half the distance.

The puller pulls the fibers through bushing eight **180** to bushing nine **190**. Bushing nine **190** is the final bushing for the formation of the composite core. The puller pulls the four outer fiber bundles and the compacted core through a passageway **192** in the center of bushing nine **190**.

Preferably, bushing nine **190** compacts the outer portion and the inner portion creating an inner portion of carbon and an outer portion of glass fiber. FIG. **8** for example, illustrates a cross-section of a composite cable. The example illustrates a composite core member **200** having an inner reinforced carbon fiber composite portion **202** surrounded by an outer reinforced glass fiber composite portion **204**.

Temperature is kept constant throughout zone **5**. The temperature is determined by the process and is high enough to keep the resin in a semi-cured state. At the end of zone **5**, the product comprises the final level of compaction and the final diameter.

The puller pulls the fibers from zone **5** to zone **6** a curing stage preferably comprising an oven with constant heat and airflow as in zone **5**, **4** and **2**. The oven uses the same constant heating and cross circular air flow as in zone **5**, zone **4** and zone **2**. The process determines the curing heat. The curing heat remains constant throughout the curing process. In the present invention, the preferred temperature for curing ranges from about 300° F. to about 400° F. The curing process preferably spans within the range of about 8 feet to about 15 feet. More preferably, the curing process spans about 10 feet in length. The high temperature of zone **6** results in a final cure forming a hard resin. Zone **6** may incorporate a bushing ten to assure that the final fiber composite core member holds its shape. In addition, another bushing prevents blooming of the core during curing.

During the next stages the composite core member product is pulled through a series of heating and cooling phases. The post cure heating improves cross linking within the resin improving the physical characteristics of the product. The pullers pull the fibers to zone **7**, a cooling device. Preferably, the mechanical configuration of the oven is the same as in zones **2**, **4**, **5** and **6**. More specifically, the device comprises a closed circular air system using a cooling device and a blower. Preferably, the cooling device comprises a plurality of coils. Alternatively, the coils may be horizontally structured consecutive cooling elements. In a further alternative, the cooling device comprises cooling spirals. The blower is placed upstream from the cooling device and continuously blows air in the cooling chamber in an upstream direction. The air circulates through the device in a closed circular direction keeping the air throughout at a constant temperature. Preferably, the cooling temperature ranges from within about 30° F. to about 180° F.

The pullers pull the composite member through zone **7** to zone **8**, the post-curing phase. The composite core member is heated to post-curing temperature to improve the mechanical properties of the composite core member product. The temperature in this oven is kept in the range from about 300° F. to about 400° F.

The pullers pull the composite core member through zone **8** to zone **9**, the post curing cooling phase. Once the composite core has been reheated, the composite core is cooled before the puller grabs the compacted composite core. Preferably, the composite core member cools for a distance ranging from about 8 feet to about 15 feet by air convection before reaching the puller. Most preferably, the cooling distance is about 10 feet.

The pullers pull the composite core member through the zone **9** cooling phase into zone **10**, a winding system whereby the fiber core is wrapped around a wheel for storage or transportation. It is critical to the strength of the core member that the winding does not over stress the core by bending. In one embodiment, the core does not have any twist, but the fibers are unidirectional. A standard winding wheel has a diameter of 3.5 feet with the ability to store up to 40,000 feet of core material. The wheel is designed to accommodate the stiffness of the composite core member without forcing the core member into a configuration that is too tight. The winding wheel must also meet the requirements for transportation. Thus, the wheel must be sized to fit under bridges and be carried on semi-trailer beds or train beds. In a further embodiment, the winding system comprises a means for preventing the wheel from reversing flow from winding to unwinding. The means can be any device that prevents the wheel direction from reversing for example, a clutch or a brake system.

In a further embodiment, the process includes a quality control system comprising a line inspection system. The quality control process assures consistent product. The quality control system may include ultrasonic inspection of composite core members; record the number of tows in the end product; monitor the quality of the resin; monitor the temperature of the ovens and of the product during various phases; measure formation; or measure speed of the pulling process. For example, each batch of composite core member has supporting data to keep the process performing optimally. Alternatively, the quality control system may also comprise a marking system. The marking system may include a system to mark the composite core members with the product information of the particular lot. Further, the composite core members may be placed in different classes in accordance with specific qualities, for example, Class A, Class B and Class C.

The fibers used to process the composite core members can be interchanged to meet specifications required by the final composite core member product. For example, the process allows replacement of fibers in a composite core member having a carbon core and a glass fiber outer core with high grade carbon and E-glass. The process allows the use of more expensive better performing fibers in place of less expensive fibers due to the combination of fibers and the small core size required. In one embodiment, the combination of fibers creates a high strength inner core with minimal conductivity surrounded by a low modulus nonconductive outer insulating layer. In another embodiment, the outer insulating layer contributes to the flexibility of the composite core member and enables the core member to be wound, stored and transported on a transportation wheel.

Changing the composite core design may affect the stiffness and strength of the inner core. As an advantage, the core geometry may be designed to achieve optimal physical characteristics desired in a final ACCC cable. Another embodiment of the invention, allows for redesign of the composite core cross section to accommodate varying physical properties and increase the flexibility of the composite core member. Referring again to FIG. **5**, the different composite shapes change the flexibility of the composite core member. The configuration of the fiber type and matrix material may also alter the flexibility. The present invention includes composite cores that can be wound on a winding wheel. The winding wheel or transportation wheel may be a commercially available winding wheel or winding drum. These wheels are typically formed of wood with an inside diameter of 3.5 feet or less. These wheels are not made in larger diameters commercially. However, special wheels can be made. However, these wheels with larger diameters still must be able to be transported. Thus, the wheel diameters and widths are limited by transportation requirements. The wheel must be able to fit under bridges and be carried on a semi-trailer or a train bed. The composite core of the present invention can be wound onto one of these winding wheels.

Stiffer cores may require a wheel diameter 7 feet or greater diameter, and these size winding wheels are not commercially viable. In addition, a winding wheel that size may not meet the transportation standards to pass under bridges or fit on semi-trailers. Thus, stiff cores are not practical. To increase the flexibility of the composite core, the core may be twisted or segmented to achieve a wrapping diameter that is acceptable. In one embodiment, the core may include one 360 degree twist of the fiber for every one revolution of core around the wheel to prevent cracking. Twisted fiber is included within the scope of this invention and includes fibers that are twisted individually or fibers that are twisted as a group. In other words, the fibers may be twisted as a roving, bundle, or some portion of the fibers. Alternatively, the core can be a combination of twisted and straight fiber. The twist may be determined by the wheel diameter limit. The tension and compaction stresses on the fibers are balanced by the single twist per revolution.

Winding stress is reduced by producing a segmented core. FIG. **5** illustrates some examples of possible cross section configurations of segmented cores. The segmented core under the process is formed by curing the section as separate pieces wherein the separate pieces are then grouped together. Segmenting the core enables a composite member product having a core greater than 0.375 inches to achieve a desirable winding diameter without additional stress on the member product.

Variable geometry of the cross sections in the composite core members may be possessed as a multiple stream. The processing system is designed to accommodate formation of each segment in parallel. Preferably, each segment is formed by exchanging the series of consecutive bushings for bushings having predetermined configurations for each of the passageways. In particular, the size of the passageways may be varied to accommodate more or less fiber, the arrangement of passageways may be varied in order to allow combining of the fibers in a different configuration in the end product and further bushings may be added within the plurality of consecutive bushings to facilitate formation of the varied geometric cross sections in the composite core member. At the end of the processing system the five sections in five streams of processing are combined at the end of the process to form the composite cable core that form a unitary (one-piece) body. Alternatively, the segments may be twisted to increase flexibility and facilitate winding.

The final composite core can be wrapped in lightweight high conductivity aluminum forming a composite cable. While aluminum is used in the title of the invention and in this description, the conductor may be formed from any highly conductive substance. In particular, the conductor may be any metal or metal alloy suitable for electrical cables. While aluminum is most prevalent, copper may also be used. It may also be conceivable to use a precious metal, such as silver, gold, or platinum, but these metals are very expensive for this type of application. In an exemplary embodiment, the composite core cable comprises an inner carbon core having an outer insulating glass fiber composite layer and two layers of trapezoidal formed strands of aluminum.

In one embodiment, the inner layer of aluminum comprises a plurality of trapezoidal shaped aluminum segments helically wound or wrapped in a counter-clockwise direction around the composite core member. Each trapezoidal section is designed to optimize the amount of aluminum and increase conductivity. The geometry of the trapezoidal segments allows for each segment to fit tightly together around the composite core member.

In a further embodiment, the outer layer of aluminum comprises a plurality of trapezoidal shaped aluminum segments helically wound or wrapped in a clockwise direction around the composite core member. An opposite direction of wrapping prevents twisting of the final cable. Each trapezoidal aluminum element fits tightly with the trapezoidal aluminum elements wrapped around the inner aluminum layer. The tight fit optimizes the amount of aluminum and decreases the aluminum required for high conductivity.

EXAMPLE

A particular embodiment of the invention is now described wherein the composite strength member comprises E-glass and carbon type **13** sizing. E-glass combines the desirable properties of good chemical and heat stability, and good electrical resistance with high strength. The cross-sectional shape or profile is illustrated in FIG. **8** wherein the composite strength member comprises a concentric carbon core encapsulated by a uniform layer of glass fiber composite. In an exemplary embodiment the process produces a hybridized core member comprising two different materials.

The fiber structures in this particular embodiment are 126 ends of E-glass product, yield 900, Veterotex Amer and 16 ends of carbon Torayca T7DOS yield 24K. The resin used is Aralite MY 721 from Vantico or is JEFFCO 1401-16/4101-17 made by JEFFCO Products.

In operation, the ends of 126 fiber tows of E-glass and 16 fiber tows of carbon are threaded through a fiber tow guide comprising two rows of 32 passageways, two rows inner of 31 passageways and two innermost rows of 4 passageways and into a preheating stage at 150° F. to evacuate any moisture. After passing through the preheating oven, the fiber tows are pulled through a wet out tank. In the wet out tank a device effectually moves the fibers up and down in a vertical direction enabling thorough wetting of the fiber tows. On the upstream side of the wet out tank is located a wiper system that removes excess resin as the fiber tows are pulled from the tank. The excess resin is collected by a resin overflow tray and added back to the resin wet out tank.

The fiber tows are pulled from the wet out tank to a B-state oven that semi-cures the resin impregnated fiber tows to a tack stage. At this stage the fiber tows can be further compacted and configured to their final form in the next phase. The fiber tows are pulled to a next oven at B-stage oven temperature to maintain the tack stage. Within the oven are eight consecutive bushings that function to compact and configure the fiber tows to the final composite core member form. Two fiber tow ends are threaded through each of the 134 passageways in the first bushing which are machined to pre-calculated dimensions to achieve a fiber volume of 72 percent and a resin volume of 28 percent in the final composite core member. The ends of the fiber tows exiting from passageways in the top right quarter comprising half of the two top rows are threaded through passageways **132** of the next bushing; the ends of the fiber tows exiting from passageways in the top left quarter comprising half of the top two rows are threaded through passageway **136** of the next bushing; the ends of the fiber tows exiting from passageways in the lower right quarter comprising half of the bottom two rows are threaded through passageway **140** of the next bushing; the ends of the fiber tows exiting from passageways in the lower left quarter comprising half of the bottom two rows are threaded through passageway **138** of the next bushing; the right and left quarters of passageways in the middle upper row are threaded through passageways **142** and **144** of the next bushing and the right and left quarters of passageways in the middle bottom row are threaded through passageways **134** and **146** respectively.

The fiber tows are pulled consecutively through the outer and inner passageways of each successive bushing further compacting and configuring the fiber bundles. At bushing seven, the fiber bundles pulled through the inner four passageways of bushing six are combined to form a composite core whereas the remaining outer passageways continue to keep the four bundles glass fibers separate. The four outer passageways of bushing seven are moved inward in bushing eight, closer to the inner carbon core. The fiber tows are combined with the inner carbon core in bushing nine forming a hybridized composite core member comprising an inner carbon core having an outer glass layer.

The composite core member is pulled from bushing nine to a final curing oven at an elevated temperature of 380° F. as required by the specific resin. From the curing oven the composite core member is pulled through a cooling oven to be cooled to 150° F. to 180° F. After cooling, the composite core member is pulled through a post curing oven at elevated temperature, preferably to heat the member to at least B-stage temperature. After post-curing, the member is cooled by air to approximately 180° F. The member is cooled prior to grabbing by the caterpuller. The core is finally fed onto a winding wheel having around 6000 feet of storage.

EXAMPLE

An example of an ACCC reinforced cable in accordance with the present invention follows. An ACCC reinforced cable comprising four layers of components consisting of an inner carbon fiber and epoxy layer, a next glass fiber and epoxy layer and two layers of tetrahedral shaped aluminum strands. The strength member consists of a high-strength composite T700S carbon fiber and epoxy having a diameter of about 0.2165 inches, surrounded by an outer layer of R099-**688** glass fiber and epoxy having a layer diameter of about 0.375 inches. The glass fiber and epoxy layer is surrounded by an inner layer of nine trapezoidal shaped aluminum strands having a diameter of about 0.7415 inches and an outer layer of thirteen trapezoidal shaped aluminum strands having a diameter of about 1.1080 inches. In the cross section, the total area of carbon is about 0.037 in^2, of glass is about 0.074 in^2, of inner aluminum is about 0.315 in^2 and outer aluminum is about 0.5226 in^2. The fiber to resin ratio in the inner carbon strength member is 70/30 by weight and the outer glass layer fiber to resin ratio is 75/25 by weight.

The specifications are summarized in the following table:

Glass Vetrotex roving R099-686 (900 Yield)	
Tensile Strength, psi	298,103
Elongation at Failure, %	3.0
Tensile Modulus, $\times 10^6$ psi	11.2
Glass Content, %	57.2

Carbon (graphite) Carbon: Torayca T700S (Yield 24 K)	
Tensile strength, Ksi	711
Tensile Modulus, Msi	33.4
Strain	2.1%
Density lbs/ft^3	0.065
Filament Diameter, in	2.8E−04

Epoxy Matrix System	
Araldite MY 721	
Epoxy value, equ./kg	8.6–9.1
Epoxy Equivalent, g/equ.	109-
Viscosity @ 50 C, cPs	3000–6000
Density @ 25 C lb/gal.	1.150–1.18
Hardener 99-023	
Viscosity @ 25 C, cPs	75–300
Density @ 25 C, lb/gal	1.19–1/22
Accelerator DY 070	
Viscosity @ 25 C, cPs	<50
Density @ 25 C, lb/gal	0.95–1.05

An ACCC reinforced cable having the above specifications is manufactured according to the following. The process used to form the composite cable in the present example is illustrated in FIG. **1**. First, 126 spools of glass fiber tows **12** and **8** spools of carbon are set up in the rack system **14** and the ends of the individual fiber tows **12**, leading from spools **11**, are threaded through a fiber tow guide **18**. The fibers undergo tangential pulling to prevent twisted fibers. A puller **16** at the end of the apparatus pulls the fibers through the apparatus. Each dispensing rack **14** has a small brake to individually adjust the tension for each spool. The tows **12** are pulled through the guide **18** and into a preheating oven **20** at 150° F. to evacuate moisture.

The tows **12** are pulled into wet out tank **22**. Wet out tank **22** is filled with Araldite MY 721/Hardener 99-023/Accelerator DY070 to impregnate the fiber tows **12**. Excess resin is removed from the fiber tows **12** during wet out tank **22** exit. The fiber tows **12** are pulled from the wet out tank **22** to a B-stage oven **24** and are heated to −200° F. Fiber tows **12** are kept separated by the guide **18** and are pulled into a second B-stage oven **26** also at 200° F. comprising a plurality of consecutive bushings to compact and configure the tows **12**. In the second B-stage oven **26**, the fiber tows **12** are directed through a plurality of passageways provided by the bushings. The consecutive passageways continually compact and configure the fiber tows **12** into the final uniform composite core member.

The first bushing has two rows of 32 passageways, two inner rows of 31 passageways each and two inner most rows of 4 passageways each. The 126 glass fiber tows are pulled through the outer two rows of 32 and 31 passageways, respectively. The carbon fiber tows are pulled through the inner two rows of 4 passageways each. The next bushing splits the top two rows in half and the left portion is pulled through the left upper and outer corner passageway in the second bushing. The right portion is pulled through the right upper and outer corner passageway in the second bushing. The bottom two rows are split in half and the right portion is pulled through the lower right outer corner of the second bushing and the left portion is pulled through the lower left outer corner of the second bushing. Similarly, the two inner rows of carbon are split in half and the fibers of the two right upper passageways are pulled through the inner upper right corner of the second bushing. The fibers of the left upper passageways are pulled through the inner upper left corner of the second bushing. The fibers of the right lower passageways are pulled through the inner lower right corner of the second bushing and the fibers of the left lower passageways are pulled through the inner lower left corner of the second bushing.

The fiber bundles are pulled through a series of seven bushings continually compacting and configuring the bundles into one hybridized uniform concentric core member.

The composite core member is pulled from the second B-stage oven **26** to a next oven processing system **28** at 330° F. to 370° F. wherein the composite core member is cured and pulled to a next cooling system **30** at 30° F. to 100° F. for cooling. After cooling, the composite core is pulled to a next oven processing system **32** at 330° F. to 370° F. for post curing. The pulling mechanism pulls the product through a 10 foot air cooling area at about 180° F.

Nine trapezoidal shaped aluminum strands each having an area of about 0.0350 sq. in. or about 0.315 sq. in. total area on the core are wrapped around the composite core after cooling. Next, thirteen trapezoidal shaped aluminum strands each strand having an area of about 0.0402 sq. in. or about 0.5226 sq. in. total area on the core are wrapped around the inner aluminum layer.

It is to be understood that the invention is not limited to the exact details of the construction, operation, exact materials, or embodiments shown and described, as modifications and equivalents will be apparent to one skilled in the art without departing from the scope of the invention.

We claim:

1. A composite core for an electricity transmission cable comprising:

a. an inner core comprising a plurality of substantially continuous reinforcing fibers of at least a first type, the fiber type having a modulus of elasticity that exceeds the modulus of elasticity of glass fibers;

b. an outer core surrounding the inner core comprising a plurality of substantially continuous reforcing fibers of at least a second type, the fibers having a modulus of elasticity of or similar to glass fibers; and

c. a cured resin matrix, wherein the fibers of the inner and the outer cores are embedded in said resin matrix;

wherein, the fibers of the outer core are different from the fibers of the inner core and wherein, the fibers of theinner and the outer cores are oriented substantially parallel to the longitudinal axis.

2. A composite core according to claim **1**, the composite core having at least 50% fiber to resin volume fraction to produce a composite core having a predetermined set of mechanical properties.

3. A composite core according to claim **1**, wherein the fibers of the inner core are carbon fibers.

4. A composite core according to claim **1**, comprising an inner core comprising carbon fibers and an outer core comprising glass fibers.

5. A composite core according to claim **1**, wherein the fibers of the inner core comprise a modulus of elasticity that exceeds the modulus of elasticity of glass fibers and the fibers in the outer core comprise glass fibers.

6. A composite core according to claim **1**, wherein the inner core comprises carbon fibers; and the outer core comprises fibers having a modulus of elasticity of or similar to glass fibers.

7. A composite core according to claim **1**, wherein said composite core comprises a resin having a tensile strength, a flexural strength and an elongation value that is compatible with the mechanical properties of the fibers.

8. A composite core according to claim **1**, wherein the resin is formed with one of a ceramic, a thermosetting resin, or a thermoplastic resin.

9. A composite core according to claim **8**, wherein the resin is adjustable to achieve a predetermined set of mechanical properties.

10. A composite core according to claim **1**, wherein the fibers of the inner core are high-strength fibers.

11. A composite core according to claim **1**, wherein the fibers of the outer core are low-stiffness fibers.

12. A composite core according to claim **1**, the composite core further comprising an inner core comprising carbon fibers and an outer core comprising glass fibers the core having a carbon to glass fiber ratio; wherein the ratio of carbon to glass fibers may be changed to vary at least one mechanical property of the composite core.

13. A composite core for an electrical cable comprising:

a. a first section comprising a plurality of substantially continuous reinforcing fibers of at least a first type, the fiber type comprising a modulus of elasticity that exceeds the modulus of elasticity of glass fibers;

b. one or more other sections that surround the first section comprising a plurality of substantially continuous reinforcing fibers of at least a second type, the fibers comprising a modulus of elasticity of or similar to glass fibers; and

c. a cured resin matrix, wherein the fibers of the first second and the one or more other sections are embedded within the resin matrix;

wherein, the fibers of the inner and the outer cores are oriented substantially parallel to the longitudinal axis and wherein, the fibers of the first section are different from the fibers of the one or more other sections.

14. A composite core according to claim **13**, wherein the first section is formed from a plurality of carbon fibers embedded in the matrx.

15. A composite core according to claim **13**, wherein the fibers comprising the one or more other sections are glass fibers.

16. A composite core according to claim **13**, wherein the matrix material is one of a ceramic, thermosetting resin, or a thermoplastic resin.

17. A composite core according to claim **13**, wherein the first section comprises a plurality of carbon fibers and at least one other fiber having a tensile strength that exceeds glass embedded in the resin.

18. A composite core according to claim **17**, wherein the plurality of fibers comprising the one or more other sections are glass.

19. A composite core according to claim **13**, wherein the core comprises a fiber to resin ratio of at least 50% by volume fraction.

20. A composite core according to claim **13**, the core further comprising a first section comprising a plurality of carbon fibers surrounded by a second section comprising a plurality of glass fibers embedded in the resin matrix, wherein, the fiber and resin matrix comprises a carbon/glass ratio.

21. A composite core according to claim **20**, wherein the carbon/glass ratio may be changed.

22. A composite core according to claim **13**, wherein the resin comprises mechanical properties that can be adjusted resulting to changes to at least one mechanical property of the core.

23. A composite core for an electrical cable comprising:

a. an inner core comprising a plurality of substantially continuous reinforcing carbon fibers;

b. an outer core surrounding the inner core comprising a plurality of substantially continuous reinfocing glass fibers; and

c. a cured resin matrix wherein, the fibers of the inner and the outer cores are embedded in said resin matrix;

wherein the fibers of the inner and the outer cores are oriented substantially parallel to the longitudinal axis, and wherein the composite core comprises a set of mechanical properties.

24. A composite core according to claim **23**, wherein the composite core has at least 50% fiber to resin volume fraction, and further comprises a ratio of carbon to glass fibers.

25. A composite core according to claim **24**, wherein the fiber to resin volume fraction may be changed to vary the mechanical properties of the composite core.

26. A composite core according to claim **24**, wherein the ratio of carbon fibers to glass fibers may be adjusted to vary the mechanical properties of the core.

27. A composite core for an electrical cable comprising:

a. a first section comprising a plurality of substantially continuous reinforcing carbon fibers; and

b. at least one other section surrounding the first section comprising a plurality of substantially continuous reinforcing glass fibers; and

c. a cured resin matrix, wherein the fibers of the first section and the at least one other section are embedded within the resin matrix;

wherein the fibers of the first section and the at least one other section are oriented substantially parallel to the longitudinal axis and wherein, the core comprises a set of mechanical properties.

28. A composite core according to claim **27**, wherein the core has at least 50% fiber to resin volume fraction, and further comprises a ratio of carbon to glass fibers.

29. A composite core according to claim **28**, wherein the carbon to glass fiber ratio may be adjustable to change the mechanical properties of the core.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 7,211,319 B2 Page 1 of 1
APPLICATION NO. : 10/691447
DATED : May 1, 2007
INVENTOR(S) : Clement Hiel and George Korzeniowski

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the claims:

Col. 31 claim 1, line 45, delete "reforcing" and insert --reinforcing--
Col. 31 claim 1, line 52, delete "theinner" and insert --the inner--
Col. 32 claim 14, line 44, delete "matrx" and insert --matrix--
Col. 33 claim 23, line 11, delete "reinfocing" and insert --reinforcing--

Signed and Sealed this

Fourth Day of March, 2008

Jon W. Dudas

JON W. DUDAS
Director of the United States Patent and Trademark Office

EXHIBIT E

US 7,211,319 C1 (7549th)

ALUMINUM CONDUCTOR COMPOSITE CORE REINFORCED CABLE AND METHOD OF MANUFACTURE

Clement Hiel, Rancho Palos Verdes, Calif., and George Korzenlowski, Woodland Hills, Calif., assignors to CTC Cable Corporation, Irvine, Calif.

Reexamination Request No. 90/009,491, Jul. 18, 2009.

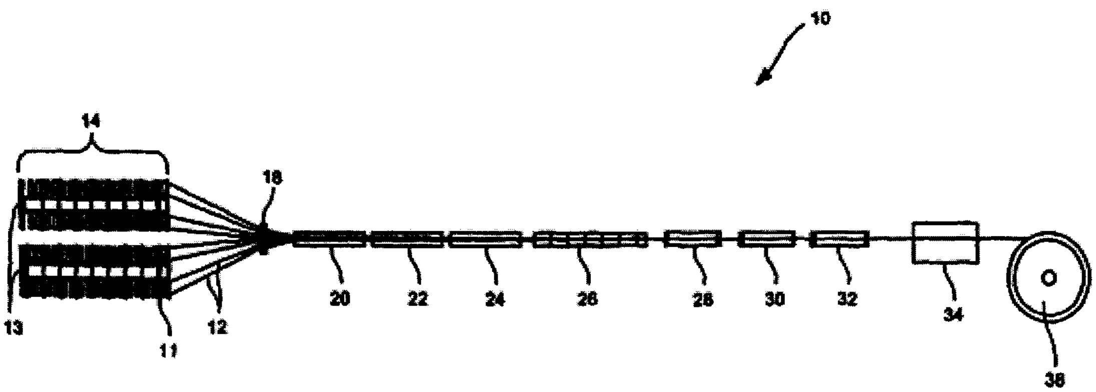
Reexamination Certificate for Patent 7,211,319, issued May 1, 2007, Appl. No. 691,447, Oct. 22, 2003.

Continuation-in-part of application No. P/US03/12520, filed on Apr. 23, 2003, Provisional application No. 60/374,879, filed on Apr. 23, 2002.

This patent is subject to a terminal disclaimer.

Int. Cl. B32B *27/04;27/12* (2006.01)

U.S. Cl. 428—300.7



AS A RESULT OF REEXAMINATION, IT HAS BEEN DETERMINED THAT:

Claims **1, 13, 23** and **27** are determined to be patentable as amended.

Claims **2-12, 14-22, 24-26, 28** and **29**, dependent on an amended claim, are determined to be patentable.

New claims **30-72** are added and determined to be patentable.

1. A composite core for an electricity transmission cable comprising:
   a. an inner core comprising a plurality of substantially continuous reinforcing fibers of at least a first type, the fiber type having a modulus of elasticity that exceeds the modulus of elasticity of glass fibers;
   b. an outer core surrounding the inner core comprising a plurality of substantially continuous reinforcing fibers of at least a second type, the fibers having a modulus of elasticity of or similar to glass fibers; and
   c. a cured resin matrix, wherein the fibers of the inner and the outer cores are embedded in said resin matrix;

   wherein[,]the fibers of the outer core are different from the fibers of the inner core and wherein[,]the fibers of the inner and the outer cores are oriented substantially parallel to the longitudinal axis *and wherein the composite core is adapted for use as a load member in an electricity transmission cable.*

EXHIBIT F

US007211319C2

(12) EX PARTE REEXAMINATION CERTIFICATE (9059th)
United States Patent (10) Number: **US 7,211,319 C2**
Hiel et al. (45) Certificate Issued: ***Jun. 5, 2012**

(54) **ALUMINUM CONDUCTOR COMPOSITE CORE REINFORCED CABLE AND METHOD OF MANUFACTURE**

(75) Inventors: **Clement Hiel**, Rancho Palos Verdes, CA (US); **George Korzenlowski**, Woodland Hills, CA (US)

(73) Assignee: **Partners for Growth II, L.P.**, San Francisco, CA (US)

Reexamination Request:
No. 90/011,690, Jun. 6, 2011

Reexamination Certificate for:

Patent No.:	**7,211,319**
Issued:	**May 1, 2007**
Appl. No.:	**10/691,447**
Filed:	**Oct. 22, 2003**

Reexamination Certificate C1 7,211,319 issued Jun. 1, 2010

(*) Notice: This patent is subject to a terminal disclaimer.

Certificate of Correction issued Mar. 4, 2008.

Certificate of Correction issued Sep. 2, 2008.

Related U.S. Application Data

(63) Continuation-in-part of application No. PCT/US03/12520, filed on Apr. 23, 2003.
(60) Provisional application No. 60/374,879, filed on Apr. 23, 2002.

(51) **Int. Cl.**
B32B 27/04 (2006.01)
B32B 27/12 (2006.01)

(52) **U.S. Cl.** **428/300.7**; 428/297.4; 428/298.1; 428/299.1; 428/299.4; 428/300.4; 428/378

(58) **Field of Classification Search** .... None
See application file for complete search history.

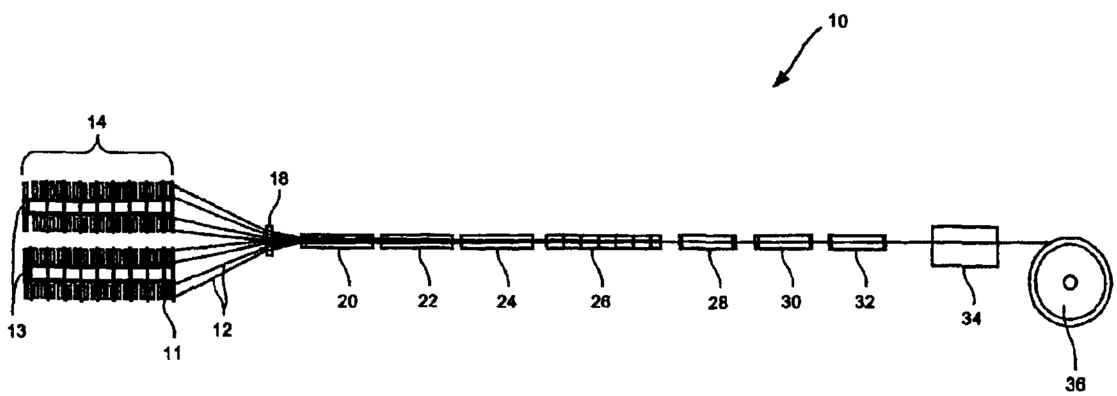
(56) **References Cited**

To view the complete listing of prior art documents cited during the proceeding for Reexamination Control Number 90/011,690, please refer to the USPTO's public Patent Application Information Retrieval (PAIR) system under the Display References tab.

Primary Examiner—Norca L Torres Velazquez

(57) **ABSTRACT**

This invention relates to an aluminum conductor composite core reinforced cable (ACCC) and method of manufacture. An ACCC cable has a composite core surrounded by at least one layer of aluminum conductor. The composite core comprises a plurality of fibers from at least one fiber type in one or more matrix materials. The composite core can have a maximum operating temperature capability above 100° C. or within the range of about 45° C. to about 230° C., at least 50% fiber to resin volume fraction, a tensile strength in the range of about 160 Ksi to about 370 Ksi, a modulus of elasticity in the range of about 7 Msi to about 37 Msi and a coefficient of thermal expansion in the range of about -0.7×10^{-6} m/m/° C. to about 6×10^{-6} m/m/° C. According to the invention, a B-stage forming process may be used to form the composite core at improved speeds over pultrusion processes wherein the speeds ranges from about 9 ft/min to about 60 ft/min.



EX PARTE REEXAMINATION CERTIFICATE ISSUED UNDER 35 U.S.C. 307

THE PATENT IS HEREBY AMENDED AS INDICATED BELOW.

Matter enclosed in heavy brackets [ ] appeared in the patent, but has been deleted and is no longer a part of the patent; matter printed in italics indicates additions made to the patent.

AS A RESULT OF REEXAMINATION, IT HAS BEEN DETERMINED THAT:

Claims **1**, **13**, **23**, **27**, **60**, **69** and **71** are determined to be patentable as amended.

Claims **2-12**, **14-22**, **24-26**, **28-59**, **61-68**, **70** and **72**, dependent on an amended claim, are determined to be patentable.

1. A composite core for an *overhead* electricity transmission cable comprising:

a. an inner core comprising a plurality of substantially continuous reinforcing fibers of at least a first type, the fiber type having a modulus of elasticity that exceeds the modulus of elasticity of glass fibers;

b. an outer core surrounding the inner core comprising a plurality of substantially continuous reinforcing fibers of at least a second type, the fibers having a modulus of elasticity of or similar to glass fibers; and

c. a cured resin matrix, wherein the fibers of the inner and the outer cores are embedded in said resin matrix;

wherein the fibers of the outer core are different from the fibers of the inner core and wherein the fibers of the inner and the outer cores are oriented substantially parallel to the longitudinal axis and wherein the composite core is adapted for use as a load member in an *overhead* electricity transmission cable.

13. A composite core for an *overhead* electrical cable, comprising:

a first section comprising a plurality of substantially continuous reinforcing fibers of at least a first type, the fiber type comprising a modulus of elasticity that exceeds the modulus of elasticity of glass fibers;

b. one or more other sections that surround the first section comprising a plurality of substantially continuous reinforcing fibers of at least a second type, the fibers comprising a modulus of elasticity of or similar to glass fibers; and

c. a cured resin matrix, wherein the fibers of the first section and the one or more other sections are embedded within the resin matrix;

wherein, the fibers of the first section and the one or more other sections are oriented substantially parallel to the longitudinal axis and wherein, the fibers of the first section are different from the fibers of the one or more other sections, and wherein the composite core is adapted for use as a load member in an *overhead* electrical cable.

23. A composite core for an *overhead* electrical cable, comprising:

a. an inner core comprising a plurality of substantially continuous reinforcing carbon fibers;

b. an outer core surrounding the inner core comprising a plurality of substantially continuous reinforcing glass fibers; and

c. a cured resin matrix wherein, the fibers of the inner and the outer cores are embedded in said resin matrix;

wherein the fibers of the inner and the outer cores are oriented substantially parallel to the longitudinal axis, and wherein the composite core comprises a set of mechanical properties, and wherein the composite core is adapted for use as a load member in an *overhead* electrical cable.

27. A composite core for an *overhead* electrical cable comprising:

a. a first section comprising a plurality of substantially continuous reinforcing carbon fibers; and

b. at least one other section surrounding the first section comprising a plurality of substantially continuous reinforcing glass fibers; and

c. a cured resin matrix, wherein the fibers of the first section and the at least one other section are embedded within the resin matrix;

wherein the fibers of the first section and the at least one other section are oriented substantially parallel to the longitudinal axis and wherein the core comprises a set of mechanical properties, and wherein the composite core is adapted for use as a load member in an *overhead* electrical cable.

60. An *overhead* electrical cable, comprising:

a composite core load member including:

a first section comprising a plurality of substantially continuous reinforcing fibers of a first type having a modulus of elasticity that exceeds the modulus of elasticity of glass fibers; <a second section surrounding the first section and comprising a plurality of substantially continuous reinforcing fibers of a second type having a modulus of elasticity that is the same or similar to glass fibers; and

a cured resin matrix, wherein the fibers of the first and second sections are embedded within the resin matrix;

wherein the fibers of the first section and second section are oriented substantially parallel to the longitudinal axis of the composite core, and wherein the fibers of the first section are different from the fibers of the second section, and

a conductive layer that surrounds the composite core load member *to form an overhead electrical cable*.

69. An *overhead* electrical conductor having increased ampacity over **[**a**]** *an overhead* steel-cored electrical conductor having the same outside conductor diameter, comprising:

a composite core load member including:

a first section comprising a plurality of substantially continuous reinforcing fibers of a first type having a modulus of elasticity that exceeds the modulus of elasticity of glass fibers;

a second section surrounding the first section and comprising a plurality of substantially continuous reinforcing fibers of a second type having a modulus of elasticity that is the same or similar to glass fibers; and

a cured resin matrix, wherein the fibers of the first and second sections are embedded within the resin matrix to form the composite core load member having an outside composite core diameter and a tensile strength;

wherein the fibers of the first section and the second section are oriented substantially parallel to the longitudinal axis of the composite core and wherein the fibers of the first section are different from the fibers of the second section; and

wherein the outside composite core diameter is smaller than that of a steel core having the same tensile strength, and

a conductive layer that surrounds the composite core load member, wherein the conductive layer has a larger volume of conductive material than the steel-cored *overhead* electrical conductor having the same outside conductor diameter, thereby providing increased ampacity thereover.

71. A composite core for an *overhead* electrical cable, comprising:

a first section comprising a plurality of substantially continuous reinforcing fibers of a first type having a modulus of elasticity that exceeds the modulus of elasticity of glass fibers;

a second section surrounding the first section and comprising a plurality of substantially continuous reinforc-

ing fibers of a second type having a modulus of elasticity that is the same or similar to glass fibers; and

a cured resin matrix, wherein the fibers of the first and second sections are embedded within the resin matrix to form the composite core having an outside diameter and a tensile strength;

wherein the fibers of the first and second sections are oriented substantially parallel to the longitudinal axis of the core, wherein the composite core is adapted for use as a load member in an *overhead* electrical cable, and wherein the outside diameter of the composite core is smaller than that of a steel core having the same tensile strength as the composite core thereby allowing the composite core to be wound with an increased volume of conductive material without changing the conductor outside diameter.

* * * * *

UNITED STATES DISTRICT COURT
CENTRAL DISTRICT OF CALIFORNIA

NOTICE OF ASSIGNMENT TO UNITED STATES MAGISTRATE JUDGE FOR DISCOVERY

This case has been assigned to District Judge James V. Selna and the assigned discovery Magistrate Judge is Arthur Nakazato.

The case number on all documents filed with the Court should read as follows:

SACV13- 753 JVS (ANx)

Pursuant to General Order 05-07 of the United States District Court for the Central District of California, the Magistrate Judge has been designated to hear discovery related motions.

All discovery related motions should be noticed on the calendar of the Magistrate Judge

---

NOTICE TO COUNSEL

A copy of this notice must be served with the summons and complaint on all defendants (if a removal action is filed, a copy of this notice must be served on all plaintiffs).

Subsequent documents must be filed at the following location:

[ ] **Western Division**
312 N. Spring St., Rm. G-8
Los Angeles, CA 90012

[ ] **Southern Division**
411 West Fourth St., Rm. 1-053
Santa Ana, CA 92701-4516

[ ] **Eastern Division**
3470 Twelfth St., Rm. 134
Riverside, CA 92501

Failure to file at the proper location will result in your documents being returned to you.

Name & Address:
Matthew S. Rork (State Bar No. 194884)
Fairfield and Woods, P.C.
1700 Lincoln Street, Suite 2400, Denver, CO 80203
Telephone: 303-830-2400; Fax: 303-830-1033
Email: mrork@fwlaw.com

UNITED STATES DISTRICT COURT
CENTRAL DISTRICT OF CALIFORNIA

CTC GLOBAL CORPORATION, a Delaware corporation PLAINTIFF(S) v. MERCURY CABLE & ENERGY, INC., d/b/a Mercury Cable & Energy, LLC, a Nevada corporation, (see attachment) DEFENDANT(S).	CASE NUMBER **SACV13 - 00753 JVS (ANx)** **SUMMONS**

TO: DEFENDANT(S):

A lawsuit has been filed against you.

Within 21 days after service of this summons on you (not counting the day you received it), you must serve on the plaintiff an answer to the attached ☑ complaint ☐ ______________ amended complaint ☐ counterclaim ☐ cross-claim or a motion under Rule 12 of the Federal Rules of Civil Procedure. The answer or motion must be served on the plaintiff's attorney, Matthew S. Rork, whose address is 1700 Lincoln Street, Suite 2400, Denver, Colorado 80203. If you fail to do so, judgment by default will be entered against you for the relief demanded in the complaint. You also must file your answer or motion with the court.

Clark, U.S. District Court

Dated: MAY 10

By: DODJIE LAGMAN
Deputy Clerk

(Seal of the Court)

[Use 60 days if the defendant is the United States or a United States agency, or is an officer or employee of the United States. Allowed 60 days by Rule 12(a)(3)].

ATTACHMENT TO SUMMONS

ENERGY TECHNOLOGIES INTERNATIONAL COMPANY, a Cook Island company, ADVANCED TECHNOLOGIES HOLDINGS, LTD., a Belize international business company, RONALD MORRIS, an individual, TODD HARRIS, an Individual, and DOES 1-10.

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UNITED STATES DISTRICT COURT
CENTRAL DISTRICT OF CALIFORNIA

CTC GLOBAL CORPORATION, a Delaware corporation PLAINTIFF(S) v.	CASE NUMBER **SACV13 - 00753 JVS (ANx)**
MERCURY CABLE & ENERGY, INC., d/b/a Mercury Cable & Energy, LLC, a Nevada corporation, (see attachment) DEFENDANT(S).	**SUMMONS**

TO: DEFENDANT(S):

A lawsuit has been filed against you.

Within 21 days after service of this summons on you (not counting the day you received it), you must serve on the plaintiff an answer to the attached ☑ complaint ☐ ____________ amended complaint ☐ counterclaim ☐ cross-claim or a motion under Rule 12 of the Federal Rules of Civil Procedure. The answer or motion must be served on the plaintiff's attorney, Matthew S. Rork, whose address is 1700 Lincoln Street, Suite 2400, Denver, Colorado 80203. If you fail to do so, judgment by default will be entered against you for the relief demanded in the complaint. You also must file your answer or motion with the court.

Clerk, U.S. District Court

Dated: MAY 10

By: DODJIE LAGMAN
Deputy Clerk

SEAL OF THE U.S. DISTRICT COURT CENTRAL DIST. OF CALIFORNIA
1225

(Seal of the Court)

[Use 60 days if the defendant is the United States or a United States agency, or is an officer or employee of the United States. Allowed 60 days by Rule 12(a)(3)].

UNITED STATES DISTRICT COURT, CENTRAL DISTRICT OF CALIFORNIA
CIVIL COVER SHEET

I. (a) PLAINTIFFS (Check box if you are representing yourself ☐)

CTC Global Corporation

DEFENDANTS (Check box if you are representing yourself ☐)

Mercury Cable & Energy, Inc., Energy Technologies International Company, Advanced Technology Holdings, Ltd., Ronald Morris, Todd Harris and Does 1-10

(b) Attorneys (Firm Name, Address and Telephone Number. If you are representing yourself, provide same.)
Matthew S. Rork
Fairfield and Woods, P.C.
1700 Lincoln Street, Suite 2400, Denver, Colorado 80203
(303) 830-2400

(b) Attorneys (Firm Name, Address and Telephone Number. If you are representing yourself, provide same.)

II. BASIS OF JURISDICTION (Place an X in one box only.)

☐ 1. U.S. Government Plaintiff
☒ 3. Federal Question (U.S. Government Not a Party)
☐ 2. U.S. Government Defendant
☐ 4. Diversity (Indicate Citizenship of Parties in Item III)

III. CITIZENSHIP OF PRINCIPAL PARTIES-For Diversity Cases Only
(Place an X in one box for plaintiff and one for defendant)

	PTF	DEF		PTF	DEF
Citizen of This State	☐ 1	☐ 1	Incorporated or Principal Place of Business in this State	☐ 4	☐ 4
Citizen of Another State	☐ 2	☐ 2	Incorporated and Principal Place of Business in Another State	☐ 5	☐ 5
Citizen or Subject of a Foreign Country	☐ 3	☐ 3	Foreign Nation	☐ 6	☐ 6

IV. ORIGIN (Place an X in one box only.)

☒ 1. Original Proceeding ☐ 2. Removed from State Court ☐ 3. Remanded from Appellate Court ☐ 4. Reinstated or Reopened ☐ 5. Transferred from Another District (Specify) ☐ 6. Multi-District Litigation

V. REQUESTED IN COMPLAINT: JURY DEMAND: ☒ Yes ☐ No (Check "Yes" only if demanded in complaint.)

CLASS ACTION under F.R.Cv.P. 23: ☐ Yes ☒ No ☐ **MONEY DEMANDED IN COMPLAINT: $** ______

VI. CAUSE OF ACTION (Cite the U.S. Civil Statute under which you are filing and write a brief statement of cause. Do not cite jurisdictional statutes unless diversity.)
This action is brought in part due to violation of Section 43(a) of the Lanham Act as set for in 15 U.S.C. Section 1051 et seq.

VII. NATURE OF SUIT (Place an X in one box only).

OTHER STATUTES
- ☐ 375 False Claims Act
- ☐ 400 State Reapportionment
- ☐ 410 Antitrust
- ☐ 430 Banks and Banking
- ☐ 450 Commerce/ICC Rates/Etc.
- ☐ 460 Deportation
- ☐ 470 Racketeer Influ-enced & Corrupt Org.
- ☐ 480 Consumer Credit
- ☐ 490 Cable/Sat TV
- ☐ 850 Securities/Com-modities/Exchange
- ☐ 890 Other Statutory Actions
- ☐ 891 Agricultural Acts
- ☐ 893 Environmental Matters
- ☐ 895 Freedom of Info. Act
- ☐ 896 Arbitration
- ☐ 899 Admin. Procedures Act/Review of Appeal of Agency Decision
- ☐ 950 Constitutionality of State Statutes

CONTRACT
- ☐ 110 Insurance
- ☐ 120 Marine
- ☐ 130 Miller Act
- ☐ 140 Negotiable Instrument
- ☐ 150 Recovery of Overpayment & Enforcement of Judgment
- ☐ 151 Medicare Act
- ☐ 152 Recovery of Defaulted Student Loan (Excl. Vet.)
- ☐ 153 Recovery of Overpayment of Vet. Benefits
- ☐ 160 Stockholders' Suits
- ☐ 190 Other Contract
- ☐ 195 Contract Product Liability
- ☐ 196 Franchise

REAL PROPERTY
- ☐ 210 Land Condemnation
- ☐ 220 Foreclosure
- ☐ 230 Rent Lease & Ejectment

REAL PROPERTY CONT.
- ☐ 240 Torts to Land
- ☐ 245 Tort Product Liability
- ☐ 290 All Other Real Property

TORTS
PERSONAL INJURY
- ☐ 310 Airplane
- ☐ 315 Airplane Product Liability
- ☐ 320 Assault, Libel & Slander
- ☐ 330 Fed. Employers' Liability
- ☐ 340 Marine
- ☐ 345 Marine Product Liability
- ☐ 350 Motor Vehicle
- ☐ 355 Motor Vehicle Product Liability
- ☐ 360 Other Personal Injury
- ☐ 362 Personal Injury-Med Malpratice
- ☐ 365 Personal Injury-Product Liability
- ☐ 367 Health Care/ Pharmaceutical Personal Injury Product Liability
- ☐ 368 Asbestos Personal Injury Product Liability

IMMIGRATION
- ☐ 462 Naturalization Application
- ☐ 465 Other Immigration Actions

TORTS
PERSONAL PROPERTY
- ☐ 370 Other Fraud
- ☐ 371 Truth in Lending
- ☐ 380 Other Personal Property Damage
- ☐ 385 Property Damage Product Liability

BANKRUPTCY
- ☐ 422 Appeal 28 USC 158
- ☐ 423 Withdrawal 28 USC 157

CIVIL RIGHTS
- ☐ 440 Other Civil Rights
- ☐ 441 Voting
- ☐ 442 Employment
- ☐ 443 Housing/ Accomodations
- ☐ 445 American with Disabilities-Employment
- ☐ 446 American with Disabilities-Other
- ☐ 448 Education

PRISONER PETITIONS
Habeas Corpus:
- ☐ 463 Alien Detainee
- ☐ 510 Motions to Vacate Sentence
- ☐ 530 General
- ☐ 535 Death Penalty

Other:
- ☐ 540 Mandamus/Other
- ☐ 550 Civil Rights
- ☐ 555 Prison Condition
- ☐ 560 Civil Detainee Conditions of Confinement

FORFEITURE/PENALTY
- ☐ 625 Drug Related Seizure of Property 21 USC 881
- ☐ 690 Other

LABOR
- ☐ 710 Fair Labor Standards Act
- ☐ 720 Labor/Mgmt. Relations
- ☐ 740 Railway Labor Act
- ☐ 751 Family and Medical Leave Act
- ☐ 790 Other Labor Litigation
- ☐ 791 Employee Ret. Inc. Security Act

PROPERTY RIGHTS
- ☐ 820 Copyrights
- ☒ 830 Patent
- ☐ 840 Trademark

SOCIAL SECURITY
- ☐ 861 HIA (1395ff)
- ☐ 862 Black Lung (923)
- ☐ 863 DIWC/DIWW (405 (g))
- ☐ 864 SSID Title XVI
- ☐ 865 RSI (405 (g))

FEDERAL TAX SUITS
- ☐ 870 Taxes (U.S. Plaintiff or Defendant)
- ☐ 871 IRS-Third Party 26 USC 7609

FOR OFFICE USE ONLY: Case Number: **SACV13 - 00753 JVS (ANx)**

AFTER COMPLETING PAGE 1 OF FORM CV-71, COMPLETE THE INFORMATION REQUESTED ON PAGE 2.

UNITED STATES DISTRICT COURT, CENTRAL DISTRICT OF CALIFORNIA
CIVIL COVER SHEET

VIII(a). IDENTICAL CASES: Has this action been previously filed in this court and dismissed, remanded or closed? ☒ NO ☐ YES

If yes, list case number(s):

VIII(b). RELATED CASES: Have any cases been previously filed in this court that are related to the present case? ☐ NO ☒ YES

If yes, list case number(s): CTC Cable Corp v. Mercury Cable, Case No. SA CV 09-0261; Mercury Cable v. Chen et al, Case No. SA CV 12-1857

Civil cases are deemed related if a previously filed case and the present case:

(Check all boxes that apply)
☐ A. Arise from the same or closely related transactions, happenings, or events; or
☐ B. Call for determination of the same or substantially related or similar questions of law and fact; or
☒ C. For other reasons would entail substantial duplication of labor if heard by different judges; or
☒ D. Involve the same patent, trademark or copyright, and one of the factors identified above in a, b or c also is present.

IX. VENUE: (When completing the following information, use an additional sheet if necessary.)

(a) List the County in this District; California County outside of this District; State if other than California; or Foreign Country, in which **EACH** named plaintiff resides.

☐ Check here if the government, its agencies or employees is a named plaintiff. If this box is checked, go to item (b).

County in this District:*	California County outside of this District; State, if other than California; or Foreign Country
Orange	Mercury Cable and Energy, Inc. - Orange

(b) List the County in this District; California County outside of this District; State if other than California; or Foreign Country, in which **EACH** named defendant resides.

☐ Check here if the government, its agencies or employees is a named defendant. If this box is checked, go to item (c).

County in this District:*	California County outside of this District; State, if other than California; or Foreign Country
Orange	Energy Technologies International Company - Cook Islands

(c) List the County in this District; California County outside of this District; State if other than California; or Foreign Country, in which **EACH** claim arose.
NOTE: In land condemnation cases, use the location of the tract of land involved.

County in this District:*	California County outside of this District; State, if other than California; or Foreign Country
Orange	Advanced Technology Holdings, Ltd. - Belize

***Los Angeles, Orange, San Bernardino, Riverside, Ventura, Santa Barbara, or San Luis Obispo Counties**
Note: In land condemnation cases, use the location of the tract of land involved

X. SIGNATURE OF ATTORNEY (OR SELF-REPRESENTED LITIGANT): [signature] DATE:

Notice to Counsel/Parties: The CV-71 (JS-44) Civil Cover Sheet and the information contained herein neither replace nor supplement the filing and service of pleadings or other papers as required by law. This form, approved by the Judicial Conference of the United States in September 1974, is required pursuant to Local Rule 3-1 is not filed but is used by the Clerk of the Court for the purpose of statistics, venue and initiating the civil docket sheet. (For more detailed instructions, see separate instructions sheet).

Key to Statistical codes relating to Social Security Cases:

Nature of Suit Code	**Abbreviation**	**Substantive Statement of Cause of Action**
861	HIA	All claims for health insurance benefits (Medicare) under Title 18, Part A, of the Social Security Act, as amended. Also, include claims by hospitals, skilled nursing facilities, etc., for certification as providers of services under the program. (42 U.S.C. 1935FF(b))
862	BL	All claims for "Black Lung" benefits under Title 4, Part B, of the Federal Coal Mine Health and Safety Act of 1969. (30 U.S.C. 923)
863	DIWC	All claims filed by insured workers for disability insurance benefits under Title 2 of the Social Security Act, as amended; plus all claims filed for child's insurance benefits based on disability. (42 U.S.C. 405 (g))
863	DIWW	All claims filed for widows or widowers insurance benefits based on disability under Title 2 of the Social Security Act, as amended. (42 U.S.C. 405 (g))
864	SSID	All claims for supplemental security income payments based upon disability filed under Title 16 of the Social Security Act, as amended.
865	RSI	All claims for retirement (old age) and survivors benefits under Title 2 of the Social Security Act, as amended. (42 U.S.C. 405 (g))

UNITED STATES DISTRICT COURT, CENTRAL DISTRICT OF CALIFORNIA
CIVIL CASE COVER SHEET

IX. VENUE (continued)

County in this District	California County outside of this District; State, if other than California; or Foreign Country
Orange	Ronald Morris - Orange

County in this District	California County outside of this District; State, if other than California; or Foreign Country
Orange	Todd Harris - Orange