UNITED STATES PATENT AND TRADEMARK OFFICE (USPTO)
OFFICE ACTION (OFFICIAL LETTER) ABOUT APPLICANT'S TRADEMARK APPLICATION

U.S. APPLICATION SERIAL NO. 85281225

MARK:

85281225

CORRESPONDENT ADDRESS:
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APPLICANT: Heatcon, Inc.

CORRESPONDENT'S REFERENCE/DOCKET NO :
18.421
CORRESPONDENT E-MAIL ADDRESS:

OFFICE ACTION

STRICT DEADLINE TO RESPOND TO THIS LETTER

TO AVOID ABANDONMENT OF APPLICANT'S TRADEMARK APPLICATION, THE USPTO MUST RECEIVE APPLICANT'S COMPLETE RESPONSE TO THIS LETTER **WITHIN 6 MONTHS** OF THE ISSUE/MAILING DATE BELOW.

ISSUE/MAILING DATE:

THIS IS A FINAL ACTION.

This Office action is in response to applicant's communication filed on June 3, 2014.

The refusal under Trademark Act Section 2(e)(5) is now made FINAL for the reasons set forth below. *See* 15 U.S.C. §1052(e)(5); 37 C.F.R. §2.64(a). In addition, the following requirement is now made FINAL: drawing requirement. *See* 37 C.F.R. §2.64(a).

Registration was refused on the Supplemental Register because the applied-for mark, which consists of a three-dimensional configuration of the goods, is a functional design for such goods and is unregistrable. Trademark Act Section 23(c), 15 U.S.C. §1091(c); *see* TMEP §1202.02(a)-(a)(ii). A feature is functional if it is "'essential to the use or purpose of the [product]'" or "'it affects the cost or quality of the [product].'" *TrafFix Devices, Inc. v. Mktg. Displays, Inc.*, 532 U.S. 23, 33, 58 USPQ2d 1001, 1006 (2001) (quoting *Qualitex Co. v. Jacobson Prods. Co.*, 514 U.S. 159, 165, 34 USPQ2d 1161, 1163-64 (1995)); *Inwood Labs., Inc., v. Ives Labs., Inc.*, 456 U.S. 844, 850 n.10, 214 USPQ 1, 4 n.10 (1982); TMEP §1202.02(a)(iii)(A).

Applicant's arguments have been considered and found unpersuasive for the reason(s) set forth below.

Please note that functional matter may not be registered on either the Principal or Supplemental Registers, regardless of evidence of acquired distinctiveness. Trademark Act Sections 2(e)(5) and 23(c), 15 U.S.C. §§1052(e)(5), 1091(c); *see TrafFix Devices, Inc.*, 532 U.S. at 29, 58 USPQ2d at 1006; *In re Controls Corp. of Am.*, 46 USPQ2d 1308, 1311 (TTAB 1998); TMEP §1202.02(a)(iii)(A).

In general terms, trade dress is functional, and cannot serve as a trademark, if a feature of that trade dress is "essential to the use or purpose of the article or if it affects the cost or quality of the article." *Qualitex Co. v. Jacobson Prods. Co.*, 514 U.S. 159, 165, 34 USPQ2d 1161, 1163-64 (1995) (quoting *Inwood Labs., Inc. v. Ives Labs., Inc.*, 456 U.S. 844, 850, n.10, 214 USPQ 1, 4, n.10 (1982)). 1202.02(a).

While some courts had developed a definition of functionality that focused solely on “competitive need” – thus finding a particular product feature functional only if competitors needed to copy that design in order to compete effectively – the Supreme Court held that this “was incorrect as a comprehensive definition” of functionality. *TrafFix,* 532 U.S. at 33, 58 USPQ2d at 1006. The Court emphasized that where a product feature meets the traditional functionality definition – that is, it is essential to the use or purpose of the product or affects its cost or quality – then the feature is functional, regardless of the availability to competitors of other alternatives. *Id.*; *see also Valu Eng'g, Inc. v. Rexnord Corp.*, 278 F.3d 1268, 1276, 61 USPQ2d 1422, 1427 (Fed. Cir. 2002) (“Rather, we conclude that the [*TrafFix*] Court merely noted that once a product feature is found functional based on other considerations there is no need to consider the availability of alternative designs, because the feature cannot be given trade dress protection merely because there are alternative designs available” (footnote omitted).) TEMP §1202.02(a)(iii)(A).

The functionality doctrine, which prohibits registration of functional product features, is intended to encourage legitimate competition by maintaining a proper balance between trademark law and patent law. As the Supreme Court explained, in *Qualitex Co. v. Jacobson Prods. Co.,* 514 U.S. 159, 164-165, 34 USPQ2d 1161, 1163 (1995):

The functionality doctrine prevents trademark law, which seeks to promote competition by protecting a firm’s reputation, from instead inhibiting legitimate competition by allowing a producer to control a useful product feature. It is the province of patent law, not trademark law, to encourage invention by granting inventors a monopoly over new product designs or functions for a limited time, 35 U.S.C. Sections 154, 173, after which competitors are free to use the innovation. If a product’s functional features could be used as trademarks, however, a monopoly over such features could be obtained without regard to whether they qualify as patents and could be extended forever (because trademarks may be renewed in perpetuity).

In other words, the functionality doctrine ensures that protection for utilitarian product features be properly sought through a limited-duration utility patent, and not through the potentially unlimited protection of a trademark registration. Upon expiration of a utility patent, the invention covered by the patent enters the public domain, and the functional features disclosed in the patent may then be copied by others – thus encouraging advances in product design and manufacture. In *TrafFix Devices, Inc. v. Mktg. Displays, Inc.,* 532 U.S. 23, 34-35, 58 USPQ2d 1001, 1007 (2001), the Supreme Court reiterated this rationale, also noting that the functionality doctrine is not affected by evidence of acquired distinctiveness. TEMP §1202.02(a)(iii).

The applicant argues that the mark is non-functional. However, the trade dress-- the arrangement of the components on the applicant’s device--is essential to the use or purpose of the product.

Consumers will not recognize that the layout as a source identifier because it is comprised of all functional items. The mark is the combination of functional elements which makes the mark functional overall.

Determining functionality normally involves consideration of one or more of the following factors, commonly known as the "*Morton-Norwich* factors":

> (1) The existence of a utility patent that discloses the utilitarian advantages of the product or packaging design sought to be registered.
>
> (2) Advertising by the applicant that touts the utilitarian advantages of the design.
>
> (3) Facts pertaining to the availability of alternative designs.
>
> (4) Facts pertaining to whether the design results from a comparatively simple or inexpensive method of manufacture.

In re Becton, Dickinson & Co., 675 F.3d 1368, 1374-75, 102 USPQ2d 1372, 1377 (Fed. Cir. 2012); *In re Morton-Norwich Prods., Inc.*, 671 F.2d 1332, 1340-41, 213 USPQ 9, 15-16 (C.C.P.A. 1982); TMEP §1202.02(a)(v).

In this case, please see attached copies of U.S. Patent Nos. 6,976,519 and 7,789,643 for similar devices. The patents encompass bonding or curing devices that incorporate the same elements as the applicant's equipment. The system in U.S. Patent No. 6,976,519 "includes a carrying case, a controller located within the carrying case and having a microprocessor, a vacuum pump located within the case and having at least two vacuum ports for connection of vacuum lines, at least two vacuum sensor connectors for receiving leads of vacuum sensors, at least two heater connectors for receiving leads of electrical heaters, and at least two temperature sensor connectors for receiving leads of thermocouples. The controller is operably connected to the vacuum pump, the vacuum sensor connectors, the heater connectors, and the temperature sensor connectors. A touch-screen video display is mounted within the carrying case and operably connected to the controller to display information from the controller and input information to the controller." Like the applicant's device, the patent registrant's goods incorporate vacuum ports, thermocouple connectors, vacuum pumps, sensors and a video display.

A third-party utility patent is relevant evidence of functionality when the patent discloses the utilitarian advantages of the applied-for product or product packaging configuration sought to be registered. *See, e.g.*, *Kistner Concrete Prods. Inc. v. Contech Arch Techs., Inc.*, 97 USPQ2d 1912, 1921 n.7 (TTAB 2011); *In re Dietrich*, 91 USPQ2d 1622, 1627 (TTAB 2009); TMEP §1202.02(a)(v)(A). A utility patent claiming the design features at issue is strong evidence that those features are functional. *TrafFix Devices, Inc. v. Mktg. Displays, Inc.*, 532 U.S. 23, 29-30, 58 USPQ2d 1001, 1005 (2001); *In re Becton, Dickinson & Co.*, 675 F.3d 1368, 1375, 102 USPQ2d 1372, 1377 (Fed. Cir. 2012); *see* TMEP §1202.02(a)(iv), (a)(v)(A). However, a patent need not claim the exact configuration for which trademark protection is sought to prove functionality. *See In re Becton, Dickinson & Co.*, 675 F.3d at 1375, 102 USPQ2d at 1377 (citing *TrafFix Devices, Inc. v. Mktg. Displays, Inc.*, 532 U.S. at 32-33, 34-35, 58 USPQ2d at 1005). "[S]tatements in a patent's specification illuminating the purpose served by a design may constitute equally strong evidence of functionality." *Id.*

The applicant argues that "the configuration of the arrangement provides no real utilitarian advantages to the user, and is one of many equally feasible, efficient and competitive designs for a hot bonder's user interface." According to Composites Manufacturing Magazine, the industry spends "a lot of time focusing on building a tool that technicians can use day-to-day and not something that is overly complex to operate." See http://compositesmanufacturingmagazine.com/2012/03/turning-heat-composite-repair/. According to the applicant's website at http://www.heatcon.com/products/equipment/hot-bonders/details/774/234/equipment/hot-bonders/dual-zone/hcs9200b---dual-zone, the standard features of one of applicant's hot bonders include the following:

· Operate by easy to follow menus on Hi-Resolution, Hi-Contrast, Sunlight readable LCD Screen

· Easy change of any cure parameter while program is running

· In progress graphic and numeric displays are easy to interpret

· Store 30 programs, enter or revise from key pad

· Temperature control by TC 1 or 2, hottest/coolest (automatically locates) or average of all thermocouples, mode selected by operator

· 10 thermocouple inputs per zone per aerospace manufacturers recommendations

· Temperature adjustments made in increments of 1°F or C.

· Exceptional integration of alarm and control systems:

  - Scans all thermocouples for alarm and Control
  - High/low temperature deviation alarms for both ramp and dwell
  - Select low vacuum alarm level
  - Alarm system advises specific problem
  - Any alarm causes hold condition, not shut down
  - Alarm hold is automatically released when problem is corrected
  - Easy to silence audible alarm
  - Adjustable loudness

· Precise PID control, plus Auto-Tune for unusual situations

· Automatic management of thermocouple break or malfunction

· Intelligent, automatic restart function after power loss

· Dot matrix printer offers the following:

  - Standard paper tape and ribbon
  - Time, date, and full program/cure description
  - Record of Tag Number, P/N, Employee ID
  - Graph of actual cure showing time and temperature
  - Setpoint, actual temperatures and vacuum are printed at selected intervals
  - Print - Temperature Summary or all Thermocouples
  - Record of alarm conditions and alarm clear
  - Prints any program changes or adjustments made during cure

· Quiet internal vacuum system runs off plant air

· Vacuum system capable of up to 28 in Hg

· Monitor vacuum by separate line from repair

· External filter/trap cleans plant air

· Adjustable vacuum level, readable before starting cure

· Shock mounted components

· Operates on 90 - 270V, 47 - 63Hz

· 30 amps per zone allows bigger blankets and more heat

· Both zones on HCS9200B can be independently powered/operated

· HCS9200B "Slave" function runs two zones or blankets as one

· Temperature display in Celsius or Fahrenheit, user selectable

· Vacuum display in Millibars, in, Hg or Kpa, user selectable

· Easy to upgrade hardware, software, and other features

· Multiple blanket per zone capability

· All aluminum, scratch resistant, anodized faceplate

· **Ergonomic design, convenient hookup of all accessories**

· Removable lid, lightweight, portable and rugged

· Circuit breakers are on front panel, no fuses to replace

· Handles on three sides for convenient handling

Options:

· Built in Electric Vacuum Pump - Max. flow is 0.75cubic ft/min (354 cm3/sec) and Max. level is 28+ in Hg (0.967kgs/cm2)

· Software Security Lock with password access

· Foreign language menu systems

· Software modifications for special applications

· Customized silicone rubber heat blankets

· Accessory Kits and tool packages

· Type "K" Thermocouples

· Special Hot Bonder/cure process training

The applicant's composite repair system "has a built-in vacuum system to allow easier mobility to the repair site and without the need for an alternative air source." See http://www.heatcon.com/products/equipment/hot-bonders/details/679/234/equipment/hot-bonders/dual-zone/hcs9200b-ev-dual-zone. " The new bonders feature Rapid Startup and a New USB Interface for data export, with the data capture analysis software and USB drive included. Also featured are Enhanced Menu and Text Entry Systems for easier navigation and Automatic Graph Scaling for high temperature cures above 500 degrees Fahrenheit. Additional features of the bonders include capabilities for up to 30 customizable, user-named profiles, a lightweight size for easy portability, and a hi-resolution, sunlight

readable LCD screen." See
http://webcache.googleusercontent.com/search?q=cache:FVh6RFfMr10J:www.hypercoat.co.in/Images/New
Here, the applicant's combination of thermocouples, switches, knobs, warning lights, display screen and numeric keypad is essential to the device fulfilling the desired function of the device. The internal vacuum system makes the unit portable and usable in various environments for ease of repair. The inclusion of the display enables the unit to be all inclusive as opposed to having to use an external monitor or laptop. The thermocouples allow auxiliary hoses and cables to be attached. The unit's "ergonomic design" allows for "convenient hookup of all accessories."

Further, according to http://www.compositesworld.com/articles/in-situ-composite-repair-builds-on-basics, "Wichitech Industries (Baltimore, Md.) and HEATCON Composite Systems (Seattle, Wash.) offer hot bonders designed specifically for use on fueled aircraft. HEATCON's design purges and pressurizes its bonders and uses arc-suppressing power connectors…" The applicant's products are touted at https://depts.washington.edu/amtas/events/amtas_04jan/Heatcon.pdf, as being easy to operate and upgrade, with plain paper printout, built-in vacuum port and ten thermocouples per zone with dual voltage.

The applicant's units for flightline/hazardous environment operation encompass the following:

- The case has controlled pressurization and purging to eliminate any possibility of internal explosive vapors. An external air source is required for this function. The same air source is also used for the hot bonder's vacuum system.
- The purge cycle is started by turning on the power switch, while plant air is connected. Once the case is pressurized and purged, the unit is ready for operation. Lighted indicators on the faceplate show case pressure status, purge cycle initiation, and when the system is ready.
- Input and output power connectors are manufactured specifically for use in hazardous environments. The connector requires two separate motions to disconnect. The first turn of the locking ring allows the electrical connections to separate, while retaining the connector body captive. At this point, any arc that occurs is contained, not allowing any external vapor ignition. The second turn of the locking ring frees the connector from the receptacle.
- A Ground Fault Interrupter (GFI) minimizes chance of electrical shock. Leakage of more than 4 milliamps of current to ground trips the GFI, cutting off all power.
- An independent high limit controller is used with special "supervisory" heat blankets. The high limit controller connects to a temperature sensing circuit embedded in the heat blanket. If the blanket sensor detects any hot area exceeding 80% of the flash point of aviation jet fuel, the controller will disable power output to the blanket. The circuit is self-resetting when the temperature falls below the critical level. An indicator and alarm will alert the operator to the condition.

See http://www.aerospaceonline.com/doc/hcs9000-fl-and-hcs9200-fl-flightline-hot-bond-0001.

The applicant argued in the January 5, 2012 response, that there are equally efficient and/or competitive, alternative designs for the arrangement of the hot bonder's user interface components. However, the various devices by competitors also encompass the same functional elements in similar arrangements for ease of use. See also attached websites of third party companies with devices that incorporate the same elements in their composite repair and hot bonding equipment to achieve the same results including wichitechindustries.com/ and www.atacs.com/. For example, the hot bonder by Wichitech Industries contains couplers and ports along the top of the device with a numeric keypad in the center. The controls for each zone are oriented on the left and rights sides of the panel for the dual control units with the power switches in the center above the keypad.

Further, when functionality is found based on other considerations, there is “no need to consider the [third *Morton-Norwich* factor regarding] availability of alternative designs, because the feature cannot be given trade dress protection merely because there are alternative designs available.” *In re Becton, Dickinson & Co.*, 675 F.3d 1368, 1376, 102 USPQ2d 1372, 1378 (Fed. Cir. 2012) (quoting *Valu Eng’g Inc. v. Rexnord Corp.*, 278 F.3d 1268, 1276, 61 USPQ2d 1422, 1427 (Fed. Cir. 2002)); TMEP §1202.02(a)(v)(C).

Accordingly, the refusal is made final.

DRAWING OF THE MARK REQUIREMENT MADE FINAL

The applicant was required to submit a drawing of the mark with the non-claimed functional elements in broken or dotted lines. The functional elements on the face of the control panel are depicted in solid lines. The applicant argues that the three-dimensional configuration of the whole user interface contains all of the interface’s components shown in solid lines as the location of each of the components is relative to location of each of the interface’s other components. However, applicant must depict the mark in the drawing to include broken or dotted lines to show the position of the mark on the goods or container. 37 C.F.R. §2.52(b)(4); TMEP §§807.08, 1202.02(c)(i). Applicant must only show the mark itself using solid lines. *See* 37 C.F.R. §§2.52(c), 2.54(e); TMEP §§807.05(c), 807.06(a).

A special form drawing must show the mark (1) in black on a white background, if color is not a feature of the mark, or (2) in color on a white background, if color is a feature of the mark. 37 C.F.R. §2.52(b); *see* TMEP §807.04. In addition, the mark must be shown clearly so as to produce a high quality image when copied; all lines in the drawing must be clean, sharp, solid, and not fine or crowded. *See* 37 C.F.R. §§2.52, 2.53(c), 2.54(e); TMEP §807.04(a).

To submit a new drawing via the Trademark Electronic Application System (TEAS), applicant must use the response form and follow the instructions regarding submission of a drawing. TMEP §807.05(b); *see* 37 C.F.R. §2.53(b). An applicant must submit a drawing via TEAS in jpg format, and the USPTO recommends a digitized image with a length and width no smaller than 250 pixels and no larger than 944 pixels. 37 C.F.R. §2.53(c); TMEP §807.05(c).

For drawings submitted on paper, the paper should be approximately 8.5 inches wide by 11 inches long, white, non-shiny, and include the caption “DRAWING PAGE” at the top. 37 C.F.R. §2.54(a)-(c) ; TMEP §807.06(a). The mark in the drawing must appear no larger than 3.15 inches (8 cm) high by 3.15 inches (8 cm) wide. 37 C.F.R. §2.54(b); TMEP §807.06(a). Further, the drawing must be made with ink or by a process that will provide a high definition when scanned. 37 C.F.R. §2.54(e); TMEP §807.06(a). A photolithographic, printer’s proof copy, or other high-quality reproduction of the mark may be used. 37 C.F.R. §2.54(e); TMEP §807.06(a).

Accordingly, the drawing requirement is made final.

Applicant must respond within six months of the date of issuance of this final Office action or the application will be abandoned. 15 U.S.C. §1062(b); 37 C.F.R. §2.65(a). Applicant may respond by providing one or both of the following:

(1) A response that fully satisfies all outstanding requirements and/or resolves all outstanding refusals.

(2) An appeal to the Trademark Trial and Appeal Board, with the appeal fee of $100 per class.

37 C.F.R. §2.64(a); TMEP §714.04; *see* 37 C.F.R. §2.6(a)(18); TBMP ch. 1200.

In certain rare circumstances, an applicant may respond by filing a petition to the Director pursuant to 37 C.F.R. §2.63(b)(2) to review procedural issues. 37 C.F.R. §2.64(a); TMEP §714.04; *see* 37 C.F.R. §2.146(b); TBMP §1201.05; TMEP §1704 (explaining petitionable matters). The petition fee is $100. 37 C.F.R. §2.6(a)(15).

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All informal e-mail communications relevant to this application will be placed in the official application record.

WHO MUST SIGN THE RESPONSE: It must be personally signed by an individual applicant or someone with legal authority to bind an applicant (i.e., a corporate officer, a general partner, all joint applicants). If an applicant is represented by an attorney, the attorney must sign the response.

PERIODICALLY CHECK THE STATUS OF THE APPLICATION: To ensure that applicant does not miss crucial deadlines or official notices, check the status of the application every three to four months using the Trademark Status and Document Retrieval (TSDR) system at http://tsdr.uspto.gov/. Please keep a copy of the TSDR status screen. If the status shows no change for more than six months, contact the Trademark Assistance Center by e-mail at TrademarkAssistanceCenter@uspto.gov or call 1-800-786-9199. For more information on checking status, see http://www.uspto.gov/trademarks/process/status/.

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HCS9200B - Dual Zone

Description | Features and Options | Specifications | Additional Information

Standard Features:

- Operate by easy to follow menus on Hi-Resolution, Hi-Contrast, Sunlight readable LCD Screen
- Easy change of any cure parameter while program is running
- In progress graphic and numeric displays are easy to interpret
- Store 30 programs, enter or revise from key pad
- Temperature control by TC 1 or 2, hottest/coolest (automatically locates) or average of all thermocouples, mode selected by operator
- 10 thermocouple inputs per zone per aerospace manufacturers recommendations
- Temperature adjustments made in increments of 1°F or C.
- Exceptional integration of alarm and control systems:
  - Scans all thermocouples for alarm and Control
  - High/low temperature deviation alarms for both ramp and dwell
  - Select low vacuum alarm level
  - Alarm system advises specific problem
  - Any alarm causes hold condition, not shut down
  - Alarm hold is automatically released when problem is corrected
  - Easy to silence audible alarm
  - Adjustable loudness
- Precise PID control, plus Auto-Tune for unusual situations
- Automatic management of thermocouple break or malfunction
- Intelligent, automatic restart function after power loss

USA - AS9100 / ISO 9001:2008

UK - AS9120 / ISO 9001:2008

- Intelligent, automatic restart function after power loss
- Dot matrix printer offers the following:
  - Standard paper tape and ribbon
  - Time, date, and full program/cure description
  - Record of Tag Number, P/N, Employee ID
  - Graph of actual cure showing time and temperature
  - Setpoint, actual temperatures and vacuum are printed at selected intervals
  - Print - Temperature Summary or all Thermocouples
  - Record of alarm conditions and alarm clear
  - Prints any program changes or adjustments made during cure
- Quiet internal vacuum system runs off plant air
- Vacuum system capable of up to 28 in Hg
- Monitor vacuum by separate line from repair
- External fi lter/trap cleans plant air
- Adjustable vacuum level, readable before starting cure
- Shock mounted components
- Operates on 90 - 270V, 47 - 63Hz
- 30 amps per zone allows bigger blankets and more heat
- Both zones on HCS9200B can be independently powered/operated
- HCS9200B "Slave" function runs two zones or blankets as one
- Temperature display in Celsius or Fahrenheit, user selectable
- Vacuum display in Millibars, in, Hg or Kpa, user selectable
- Easy to upgrade hardware, software, and other features
- Multiple blanket per zone capability
- All aluminum, scratch resistant, anodized faceplate
- Ergonomic design, convenient hookup of all accessories
- Removable lid, lightweight, portable and rugged
- Circuit breakers are on front panel, no fuses to replace
- Handles on three sides for convenient handling

Options:

- Built in Electric Vacuum Pump - Max. flow is 0.75cubic ft/min (354 cm3/sec) and Max. level is 28+ in Hg (0.967kgs/cm2)
- Software Security Lock with password access
- Foreign language menu systems
- Software modifications for special applications
- Customized silicone rubber heat blankets
- Accessory Kits and tool packages
- Type "K" Thermocouples
- Special Hot Bonder/cure process training

Support Program: HCS9200 - ESP1

Quantity: 1

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CUSTOMER TESTIMONIALS

"We wanted to thank you for taking the time in preparing training for our employees on the Heatcon Hot Bonder & Heat Blanket Tester."

Francis N - GA Telesis

"I wanted to extend a note of appreciation to HEATCON Composite Systems for a recent expedited order for 4 36" blankets to The Boeing Company. Your team's hard work and dedication to exceeding expectations and delivery dates has provided our team additional opportunities to be successful in our project scope. Your company has provided a tremendous service to us!"

Timothy K - Boeing

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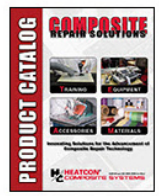

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HCS9200FL - Dual Zone Flightline

Description | Features and Options | Specifications | Additional Information

Distinctive Specifications:

- These Units are Purged and Pressurized for Use in Hazardous Environments.
- Dynamic Alarm/Control Integration with Indicators for Pressure Status, Purge Cycle Initiation and System Ready
- Arc Suppressing Power Connectors are Specifically Designed for Hazardous Environments
- A Ground Fault Interrupter (GFI) to Maximize Equipment Safety.
- Independent High Limit Controller Disables Power in the Event of Over-Temperature Conditions.

Standard Specifications:

- Weight - Only 37lbs (16.9kg)
- Dimensions - 29in x 19in x 9.5in (73.66cm x 48.26cm x 24.13cm)
- Hi-Resolution, Sunlight readable LCD Screen (5.25in x 6.75in) (13.33cm x 17.14cm)
- Improved Text Entry System with Alphanumeric Keypad
- USB Interface for Data Export to USB Storage Device
- Rapid Start-up (in as little as 5 seconds)
- Up to 48 hours of Cure Information (12 Cure Records) Stored for Data Export
- Up to Eight (8) Ramps and Dwells per Program
- Automatic Graph Scaling for High Temperature Cures above 500°F (260°C)
- Dynamic Alarm / Control Integration
- Select by Hottest, Coldest, Average of All or No. 1 / No. 2 Thermocouple (10 Thermocouple Inputs)
- Selectable Metric or English Units
- 90-264VAC (45-65Hz)
- 30A Power Output per Zone
- Power Failure Auto Recovery

USA - AS9100 / ISO 9001:2008

UK - AS9120 / ISO 9001:2008

- Up to 30 Customizable User Named Cure Profiles
- Control / Monitor Toggle for Individual Thermocouples
- Enhanced Menu Interface for Easier Navigation

Support Program: HCS9200-ESP1 Quantity: 1 **Add to Quote Cart**

CUSTOMER TESTIMONIALS

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Timothy K - Boeing

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HIGH-PERFORMANCE Composites

November 2008

In-situ composite repair builds on basics

For on-aircraft repair, demand is on the rise for specialized composites training and expertise.

Author: Karen Wood

Posted on: 10/20/2008
High-Performance Composites

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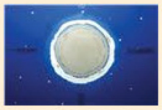
The cost to airlines of an unscheduled aircraft on the ground is, on average, $100,000 per day. Aircraft OEMs, airlines and MROs are

The goal of any commercial aircraft maintenance and repair crew is the fastest safe return of the aircraft to service — especially in view of the fact that the cost in lost revenue of an unscheduled AOG (aircraft on the ground) is, on average, $100,000 per day. No wonder, then, that in the run-up to the launches of the Airbus A380 and Boeing 787, much has been made of airline and maintenance and repair organization (MRO) concern about how aircraft composites would be repaired. Considering that the average permanent composite repair, as permitted in Structural Repair Manuals (SRMs), takes roughly 15 hours, according to SAE's Commercial Airline Composite Repair Committee (CACRC), in-situ composite repairs performed at the flight line can cause flight delays

OEMs, airlines and MROs are crafting damage repair strategies designed to keep ground time for new composite-airframed passenger jets to a minimum. Source: The Boeing Co.

Close-up view shows scarfing in progress. Source: The Boeing Co.



During the development phase of the 787 program, repairs were performed on a composite test barrel to prove repair technology. The 787 SRM specifies three types of composites repair: traditional vacuum debulked bonded scarfed repair (shown below); the company's patented quick composite repair technique; and conventional bolted repair. Source: The Boeing Co.

composite repairs performed at the flight line can cause flight delays and cancellations. It's a dilemma made more challenging by fast gate turnarounds — between 30 and 60 minutes for domestic flights — and an overwhelming lack of line mechanics with specialized composites training. But aircraft OEMs, airlines and MROs are crafting strategies to minimize ground time, simplify repair regimes and make composite materials and processes accessible to technicians who are more accustomed to working with metals.

Repair readiness

According to Mark Loyd, lead engineer of composites, plastics and transparencies at American Airlines' Composite Repair Center in Tulsa, Okla., one of the chief obstacles is logistics. "Our in-situ problems are like real estate," he muses. "Everything is location, location, *location* — location of the airplane, location of the people and equipment, location of the repair material and location of the damage. We have to weigh flying a crew, materials and equipment to a station to do a repair or obtaining a spare part and replacing it, or ferry flying the airplane to a maintenance base for part replacement."

Access, equipment and the ability to handle the part are critical, explains Loyd. "Obviously, the shop environment is much better equipped, with better vacuum systems, grind booths, constant air supply and shop supplies like bagging film, sealant tapes, etc.," he adds. On the flight line, however, equipment and processes are strictly controlled to guard against potential fire hazards created by the presence of fueled aircraft (for more on flight line curing options, see the sidebar, below). "The properly executed in-situ repair requires far more advanced planning," says Loyd. "Once deployed for the repair, you can't afford wasted time for resupply."

Long-range tactics for dealing with un-scheduled composite repair include measures designed to identify potential defects *before* they require in-situ repair, during scheduled inspection stops. A variety of advanced nondestructive inspection (NDI) technologies and onboard structural health monitoring techniques are or soon will be available. These will permit airline MROs to move away from a find-and-fix mentality to one of a predict-and-manage mindset (see "Learn More," at right). These technologies certainly will play a large future role in minimizing the need for in-situ repair. But today, the necessary art of in-situ repair relies heavily on a foundation of traditional composites and metal repair techniques and the experience and training of a handful of composites specialists — most of whom are stationed at major repair depots.

Unscheduled repairs

The most disruptive repair situation, in terms of downtime, is the unscheduled repair. Impact damage, hail damage, and moisture ingress/intrusion are the most common types of damage to composite structures that cause an aircraft to be taken abruptly out of service. "Operators all face the same aircraft to be taken abruptly out of service. "Operators all face the same issues regarding repair materials, spare part inventory and equipment location," says Loyd. Most repair materials have a finite shelf life, and MROs perform a balancing act to keep adequate repair materials on hand without having extremely high material waste. Each operator must forecast material use well in advance because "currently, lead times of more than 20 weeks are not uncommon," says Loyd. "Operators with multiple fleet types often face the challenge of stocking multiple types of the same material, such as three different types of 350°F/177°C carbon fabric prepreg."

Currently, the predominant in-service composite aircraft components are sandwich-structure control surfaces cored with honeycomb or foam. In general, the repair techniques used on them have been around since composites were first used in aircraft. "We've not experienced any 'game-changing' repair materials or techniques in quite a while," says Loyd. "The OEMs are allowing increased use of elevated-temperature wet layup repairs, but the repair methodologies used today are very close to what they were a decade ago."

The vast majority of repairs to composite structures carried out by aircraft line maintenance technicians are low-temperature (room temperature to 150°F/66°C) wet layups, which are typically temporary or time-limited repairs. These technicians, who are typically generalists with minimal training in composites repair, must diagnose and correct both minor and major aircraft damage at the gate. A room-temperature wet layup repair requires no disassembly and no external heat sources, such as hot-bonding equipment, which would require more extensive training to properly operate and can be hazardous when used on a fueled aircraft.

For permanent repairs, wet layup bonded repairs must be cured at 180°F/82°C to 200°F/93°C. Prepreg repairs, which can be used to repair thinner sandwich panels as well as the thick solid laminates common to the load-bearing structures on both the Boeing 787 and Airbus A380, cure at temperatures ranging from 250°F/121°C to 350°F/177°C and are generally left to composite specialists at major repair stations (see "Learn More").

Repair options for thicker laminates

Boeing has spent considerable effort attempting to make the 787's solid laminates less susceptible to the dents and dings associated with hail damage, tool drops and jetway impacts that plague thinner composite structures. The company has performed extensive research in damage probability, calculating energies associated with everything from the corner of a toolbox striking an upward facing structure to the impact of a jetway on a cargo or passenger entry door. "We've tried to correlate the damage that we see today and the repairs that are required and translate that into impact energy," explains Justin Hale, Boeing's chief mechanic for the 787 program. "The result has been new sizing for upward facing structures and structures around doors to make the airplane more resistant to damage."

Damage will occur, however, and when it does, the first step is to assess if and how much internal damage there is within the laminate, which will require ultrasonic inspection, says Hale. Yet, when a small dent is noticed during visual inspection at the gate, performing ultrasonic testing can be time consuming, and will require a technician with specialized training. "When you have a small impact consuming, and will require a technician with specialized training. "When you have a small impact damage, the SRM will provide allowable damage limits, based on the dent size," explains Hale. "But if you can characterize what's going on inside that structure by assessing delamination, these limits are more generous in allowing you to dispatch the airplane." To aid in this process, Boeing developed the Ramp Damage Checker — a simple "go/no go" handheld device (similar to a stud finder) that identifies the presence of delamination. "It's not intended to provide detailed information, such as depth, but it can confirm the presence of delamination," says Hale. "We en-vision it being used in the field by a maintenance lead or inspector — not necessarily an ultrasonic specialist." The first commercial Ramp Damage Checker is now available from Olympus NDT (Waltham, Mass.). Other brands will follow.

For damage repair, Boeing has specified a variety of options in the 787 SRM: traditional bonded repairs; the company's patented quick composite repair technique; and conventional bolted repair.

Bonded repair of a solid laminate panel is similar to that for a sandwich structure. "These are very traditional vacuum-debulked bonded repairs," stresses Hale, which include 250°F/121°C to 350°F/177°C prepreg repairs as well as 200°F/93°C wet layup repairs. Repair times may increase when multiple cure cycles are needed for thicker structures or if extensive repair is necessary. The general rule of thumb for scarfing is to remove 0.5 inch/13 mm per ply. "Ply thickness varies depending on the materials used in the original structure, but for carbon fiber unidirectional tape, it can be as thin as 0.13 mm/0.005 inch," says Michael Hoke, president of Abaris Training Resources Inc. (Reno, Nev.). "A 0.375-inch/9.525-mm thick structure could be approximately 75 plies thick." By the standard rule of thumb, this would translate to a scarf of ~37.5 inches/~952.5 mm.

"Scarf distance is measured not from the center of the damage but from the edge of the cleaned-up damaged area," explains Hoke. "So if the damaged structure has a 6-inch/152-mm dia-meter hole in it after the damage is removed, then the outer diameter of the scarfed area would be 37.5 inches/952.5 mm plus 6 inches/152 mm plus 37.5 inches/952.5 mm, for a total diameter of 81 inches/2m."

"Such a large scarf would be very time consuming," says Hoke. "On a structure this thick, a bolted doubler repair, if allowed, would be much quicker and generally easier to perform. However, there may be aerodynamic reasons, concerns about damaging the underlying structure during drilling, or radar signature reasons in military aircraft, which would require a scarfed repair," he adds.

"Of course, the 0.5-inch-per-ply scarf ratio is not cast in concrete," adds Hoke. "Engineering analysis might support a different scarf ratio, such as 0.25 inch/6.35 mm per ply. If so, then the total diameter of the repair would be 43.5 inches/1.1m, which is still large but an easier repair to perform."

With a smaller scarf, less undamaged material is removed but the area of the adhesive bond, which transfers load through the repair plies, also is reduced. "There are many tradeoffs in repair design," says Hoke. "The scarf angle is only one of many such tradeoffs that need to be carefully evaluated by a qualified repair design engineer."

Boeing has developed new debulking techniques designed to reduce cycle times for thicker repairs. Also, in an effort to save time and money, Boeing has qualified common repair materials throughout the 787. "Because we had multiple partners designing different parts of the airplane, the potential for a variety of repair materials was great," explains Hale. "We wanted this variety to be transparent to the mechanic, technician and airline engineers working a repair. So even in areas where we used a different carbon fiber/epoxy specification, we qualified a common repair material."

The quick composite repair is not permanent, but rather a "Band-Aid" designed to get a damaged airplane back into service quickly. "The precured composite patch is epoxy bonded onto the outside of the airplane over the damaged area," explains Hale. "It restores enough residual strength into the damaged area to provide revenue service on a temporary basis." The process allows small-area damage to be repaired in less than an hour. The adhesive is cured by relatively low temperatures provided by a chemical heat pack, which eliminates the need to dry the part, and is designed to be applied at the gate if necessary. "This is very important if you don't have widespread repair capability throughout your system," adds Hale.

Bolted repair. The same types of mechanically fastened repairs — doublers, scab patch, flush, etc. — that are performed on metal airplanes have been included in the SRM for the 787. In a bolted repair, a cover plate is mechanically fastened around the damaged area. Although fasteners create stress concentrations that can degrade the performance of the parent structure, bolted repair of composites has been service proven on Boeing's 777.

"These are damage-tolerant, permanent repairs," explains Hale. Typically these repairs would be carried out using a titanium sheet, although Boeing has also successfully tested carbon fiber patch materials and is specifying aluminum as an additional option. "If you are not using titanium or carbon fiber, you must take additional steps to protect the galvanic coupling between an aluminum patch and the carbon fiber skin," cautions Hale. Because an aluminum patch also would require periodic inspection for corrosion, its use would most likely be temporary, in which case, paint scheme and fay surface sealant protection on the aluminum part would be adequate to protect against galvanic corrosion, adds Hale. Titanium fasteners, however, are required in all cases.

"At the highest level, the bolted repair for a composite aircraft is the same as that on a metal aircraft," says Hale. "It's the same process, same skills, and, in general, the same tools." In the details, however, there are some differences. "For instance, when you drill into a composite structure, you use the same drill motor but a different drill bit, and you have to adjust speed and pressure," explains Hale. "You also have to be aware of things like fiber breakout on the backside."

"There is certainly a need for training to understand a few minor differences, but, in general, a line technician or mechanic who performs bolted repairs on a metal aircraft today will very easily transition into bolted repairs on a composite structure," stresses Hale.

"Generally, the thickest laminates would be in areas of heavier loads, such as cargo door surround structure," explains Loyd. "When these areas are damaged on a metal aircraft, it generally requires a stacked doubler repair and significant teardown and re-assembly. The composite repair to the same areas will have a different work scope, but we don't anticipate the downtime to be significantly different," he adds.

Bonded vs. bolted

"The choice between a bonded and a bolted repair may come down to how much time you have available to do the repair," posits Hoke. "The huge much time you have available to do the repair," posits Hoke. "The huge advantage of the bolted repair is there is no heat required," he adds. Although a bolted repair can impact the aerodynamics and radar signature of the aircraft, in Boeing's view, *flush* bolted repairs are nearly equivalent to bonded repairs in terms of aerodynamics and cosmetics. Further, when a metal/composite stack-up is drilled, residual metal chips can damage composite holes. Also, dull bits or incorrect drill speeds can burn composites, and proper steps must be followed to avoid hole misalignment.

Generally, bonded patches provide more efficient load transfer than bolted repairs and are more attractive from an aerodynamic and cosmetic standpoint. And, as with bolted repairs, the quality of a bonded repair depends on many variables: age and quality of materials, surface preparation, and successful adhesion. In essence, the success of either a bonded or bolted repair relies heavily on the skill of the technician.

"With ... all-composite aircraft, the biggest need will be transitioning the workforce from the metal aircraft repair philosophies to the composite repair philosophy," says Loyd. "This will be a paradigm shift akin to switching from propeller-driven aircraft to jet power." Without doubt, composites repair technicians also will need some form of certification or license. Industry steering groups, such as the CACRC, already are pushing for a Composite Materials License to establish an experience baseline for maintenance technicians, says Loyd. Additionally, the Professional Aviation Maintenance Assn. (PAMA) and the SAE Institute are currently developing technical certifications for the repair of aerospace composite materials.

On-aircraft curing options

In-situ composite repairs that require high-temperature cures can be problematic. Obtaining uniform cure temperatures is difficult due to heat sinks created by the airframe structures. In addition, when performing high-temperature in-situ repairs on the flight line with a fueled aircraft, many restrictions apply in terms of acceptable equipment and tools, and standard hot-bonding equipment is not allowed at the gate because of the risk of fire. Wichitech Industries (Baltimore, Md.) and HEATCON Composite Systems (Seattle, Wash.) offer hot bonders designed specifically for use on fueled aircraft. HEATCON's design purges and pressurizes its bonders and uses arc-suppressing power connectors, while Wichitech hermetically seals the elements of its bonders and includes an internal vacuum pump to speed setup time.

For wet-layup, glass-reinforced repair processes, a rapid-cure resin system patented by TRI/Austin (Austin, Texas) and developed for the U.S. Air Force Research Laboratory (Wright Patterson AFB, Dayton, Ohio) reportedly cures in as little as 20 minutes, using UV light at low temperature. During the process, alternating layers of the acrylate-based resin system and woven fiberglass fabric are applied to fill the hole and form a UV-curable composition. Traditional vacuum bagging is then applied, and the patch is irradiated with UV light. The temperature peaks briefly at 60°C/140°F and then levels off at 30°C/86°F. In general, the width of the patch can be up to 2 ft/0.6m, and the depth can be as much as 200 mils/0.2 inch. Reportedly, glass-reinforced composites as thick as 120 mils/0.12 inch can be thoroughly cured. Although essentially a depot-level repair, the system can be deployed in the field when necessary to return an aircraft to service.

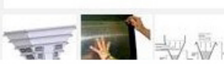
Another option for low-temperature curing of on- and off-aircraft composite repairs may be electron beam (EB) or X-ray curing, which is relatively fast and requires no heat input. Air Canada Maintenance Base (Winnipeg, Manitoba, Canada), with the help of Lockheed Martin Skunk Works (Palmdale, Calif.) and Atomic Energy of Canada Ltd. (Pinawa, Manitoba, Canada), studied the feasibility and economics of EB curing for repair by testing a variety of composite components, including the fairing from an Airbus A320 aircraft. Subsequently, Transport Canada issued a Repair Design Certificate for EB repair of fiberglass wing to box fairing panels. Acsion Industries (Pinawa, Manitoba, Canada) supplies EB-curable products and related services.

A deep-core curing method developed by Cornerstone Research Group Inc. (CRG, Dayton, Ohio) uses a photo-delivery system to cure certified aircraft repair adhesives without surface heating. Developed for military aircraft, CRG's prototype photo-delivery system integrates a high-power optical energy source with an optical scrim embedded into the film adhesive. The technology reportedly provides uniform heat distribution within the bond line and achieves full cure at 250° F/121°C without backside heating.

— Karen Wood

Hot plate

max. 538 °C | MCH



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Drum heater (heating belt)
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Drum heater (heating belt)
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Drum heater (heating belt)
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Drum heater (heating belt)
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Drum heater (heating jacket)
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Drum insulating jacket
max. 260 °C

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Heating mat for IBC containers
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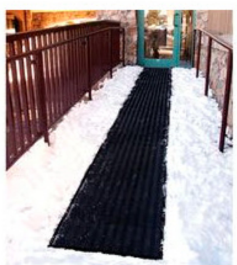
Snow melting

Snow melting system for ramps
40 W | Cozy Ice



Snow melting system for ramps
37 - 40 W | HeatTrak

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max. 482 °C | HM

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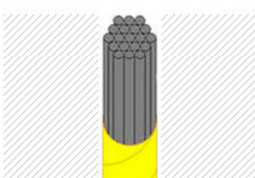

Heating cable
max. 593 °C | RW series

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Ambient thermostat
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Hot bonder for composite repair
ACR3

Hot bonder for composite repair
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max. 204 °C | TT

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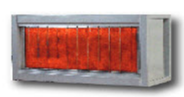
Our exclusively patented Rapid Curing technology, using 28Vdc Thermoreactor emitters, provide quick curing of sealants, paints and adhesives. Thanks to the wide spectrum far infra-red low temperature beam, the energy transfer to the material to be cured is optimized, and cure times can be reduced by a factor of 10 up to 20! Our process works at low temperatures, and is certified for safe operation inside fuel tanks or other hazardous areas (ATEX certified).

Our process does not change the physical properties of the material and hence, mechanical characteristics are not affected.

The RCD (P/N: RC-D-1001) includes a control panel with touch-sensitive screen for set-up and display of information. The operators control in real-time the curing operation in progress.

Polymerization report can be downloaded/printed at the end of the process. 28Vdc Thermoreactor emitters are integrated into transportable packaging (Rapid Curing Device) for repair on operational aircraft and in industrial systems for aeronautical production and maintenance workshops.

A choice of emitters of various sizes are approved for use inside fuel tanks; larger units are also available for external use, to cure any joints (wing, canopy etc...). All units are compatible with the same RCD control panel.



Windshield replacement

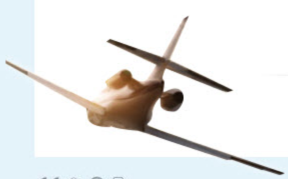
The Windshield Rapid Curing System (WRCS) is composed of a control panel and a set of light weight emitters, affixed close to the front windshield.

The specific low temperature infra-red beam of the emitters enables to cure sealant in less than 1 hour, independantly of environmental conditions, allowing windshield replacement in shortest possible time.

The WRCS unit is portable, easy to set-up and can be used for production, maintenance or AOG situations (delivered in shockproof container). Various frames are available to fit with windhield geometry (Airbus, Boeing, ATR etc...).

Composite repair

Spot repairs, sealant & paint jobs, adhesives, resins for composites surface repairs.
The Multi Function Rapid Curing system (MFRC) is composed of a compact control panel enabling to connect up to 4 wide-spectrum infra-red emitters.



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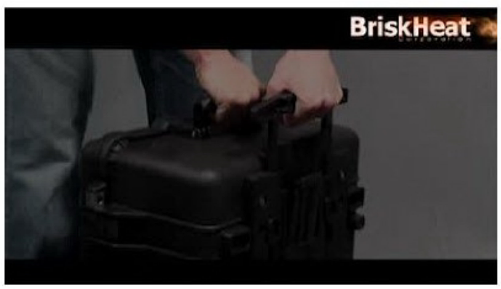
Resistance Wire
Hazardous-Area

Products → Composite Curing Solutions → ACR 3 Hot Bonder

Products

BriskHeat®

ACR 3 Hot Bonder



EASIER • BETTER

- Easy-to-Use Full-Color HD Touch-Screen
- NEW Fast Dual Vacuum System: Both a Built-in Electric Pump and Vacuum Venturi
- NEW Rugged Carrying Case and Improved Design
- NEW Handles and Wheels for Easy Transport
- EASY Data Transfer with USB Flash Drive

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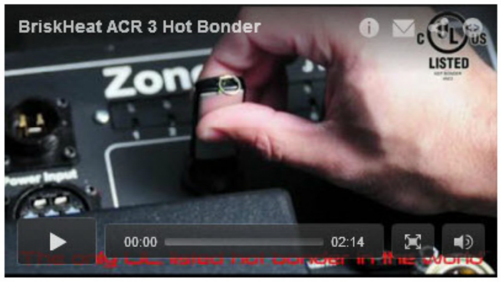
Hot Bonders and Composite Blankets

Aircraft Infrared NDT Kits

Vacuum Curing / Debulking Tables



UPDATED 1.6 Software with Improved Interface and More Languages

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Product Highlights

✔ Easier and Better Composite Curing

- Single or dual zone
- 8.4" (213mm) touch-screen
- Dual vacuum system: Built-in electric vacuum pump and vacuum venturi for each zone
- Universal voltage: 100-130VAC, 200-240VAC
- 30 amps output per heat zone
- 10 thermocouple sensors per zone
- Accepts J-type thermocouples
- Includes everything you need

✔ Easy-To-Use Interface on a Full-Color HD Touch-Screen

- Quick 3-step programming: Stores up to 30 programs on hot bonder
- Easy-to-follow menu choices
- Quick and easy data entry: Uses simple drop-down menus and a familiar QWERTY keyboard interface
- Secure: Multiple levels of password protection
- Upgradeable
- Multi-task: Perform several operations at once
- Retains history of last 12 cures
- Customized post cure analysis: Data logging intervals 1 to 99 minutes
- Multiple language support: English, German, Russian, Chinese (Mandarin)

✔ Fast and Simple Data Transfer with USB Drive (USB Flash Disk Included)

- Transfer and archive post cure data history to your PC.
- Instantaneously analyze your data on your spreadsheet and word processor programs including Microsoft ® Excel ® and Word ®
- Transfer your programs quickly from one bonder to another
- Update your hot bonder easily with the latest software version for FREE.

ACR ®-3 Hot Bonder Brochure

Specifications

General

- Single or dual zone
- 8.4" (213mm) touch-screen with easy-to-use interface
- USB port for data transfer (USB flash disk included)
- Input ground fault interrupter breaker protected
- Audible and visual alarms for high and low temperature / vacuum limits
- Data logs digitally or through built-in printer : prints and records real-time status of cure including program parameters
- c UL us LISTED

Power

- Input Voltage: 100-130VAC, 200-240VAC
- MAINS supply voltage fluctuations up to ±10% of the nominal voltage
- Transient over voltages typically found on a Category II power source: i.e. a lighting circuit
- Frequency: 50-60Hz
- 30 amps maximum per zone
- Output cord receptacle: NEMA L15-30R

Vacuum

- Dual vacuum system: Built-in electric vacuum pump and vacuum venturi for each zone
- Pressure: 28in Hg (13.8PSI)
- Ability to manually adjust pressure for each zone

Temperature Control

- Cure up to 1400 ^{0} F (760 ^{0} C)
- 10 thermocouple sensor inputs per zone
- Accepts J-type thermocouple connectors
- Accuracy: ±3°F (1.67°C)
- Monitors all thermocouples for alarms

Environment

- Intended for use in dry environments. Do not expose to spray.
- Altitude up to 6562ft (2000m)
- Storage temperature range: -4 to 140 °F (-20 to 60 °C)
- Operating temperature range: 41 to 104 °F (5 to 40 °C)
- Maximum relative humidity: 80% for temperatures up to 88 °F (31 °C) decreasing linearly to 50% relative to humidity at 104 °F (40 °C)
- Pollution degree 2 (normally only non-conductive pollution occurs, however a temporary conductivity caused by condensation must be expected)

Support

- ACR ® 3 Hot Bonder Demonstration and Training Video
- FREE Software Update
- Informational Brochure
- Technical Data Sheet
- Operating Instruction Manual (PN: 41039-03)

Ordering Information

The ACR ® 3 Hot Bonder can be purchased either with or without heaters.

ACR ® 3 Hot Bonder Kit

Number of Zones	Voltage	NEMA	Part Number
1	120VAC	L5-30P	ACR-3-S1
1	120VAC	L5-30P	ACR-3-D1
2	240VAC	L6-30P	ACR-3-S2
2	240VAC	L6-30P	ACR-3-D2

ACR ® 3 Hot Bonder Kit includes

- ACR ® 3 hot bonder unit

- ACR ® 3 hot bonder unit
- 10ft (3m) vacuum hoses (2 per zone)
- 10ft (3m) input power cord (1 per zone)
- 5ft (1.5m) heater output power cord (1 per zone)
- USB flash disk
- J-type thermocouples (10 per zone)
- Standard connector adapters for thermocouple receptacles (10 per zone)
- Vacuum bag feed-throughs (2 per zone)
- Extra printer ribbon and paper (1 per zone)
- DVD Training Video

ACR ® 3 Hot Bonder Kit with Heaters

Number of Zones	Voltage	Part Number	NSN*
1	120VAC	ACR-3-S120KIT	4920-01-538-9296
1	240VAC	ACR-3-S240KIT	4920-01-538-9296
2	120VAC	ACR-3-D120KIT	4920-01-545-5200
2	240VAC	ACR-3-D240KIT	4920-01-545-5200

*Please indicate voltage when ordering with NSN.

ACR ® 3 Hot Bonder Kit with Heaters includes

- ACR ® 3 hot bonder unit
- One 10" x 10" (254 x 254mm) SR composite heat curing blanket per zone
- One 12" x 12" (305 x 305mm) SR composite heat curing blanket per zone
- One 16" x 16" (406 x 406mm) SR composite heat curing blanket per zone
- 10ft (3m) vacuum hoses (2 per zone)
- 10ft (3m) input power cord (1 per zone)
- 5ft (1.5m) heater output power cord (1 per zone)
- USB flash disk
- J-type thermocouples (10 per zone)
- Standard connector adapters for thermocouple receptacles (10 per zone)
- Vacuum bag feed-throughs (2 per zone)
- Extra printer ribbon and paper (1 per zone)
- DVD Training Video

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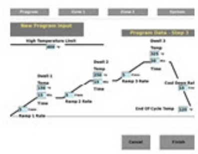

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NEW ACR MiniPRO Hot Bonder

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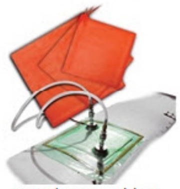

SR Silicone Rubber Composite Curing Heating Blankets

Radome Composite Curing Heating Blankets

VT Vacuum Curing and Debulking Table

TT Table Top Composite Curing Controller

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Apparatus for monitoring bonding

US 6026881 A

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Fee status	Lapsed
Inventors	Scott R. Durso
Original Assignee	Lord Corporation
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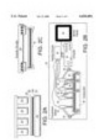
Patent Citations (11), Non-Patent Citations (2), Referenced by (9), Classifications (6), Legal Events (6)

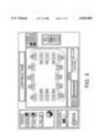
External Links: USPTO, USPTO Assignment, Espacenet

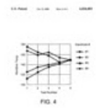
ABSTRACT

An apparatus for monitoring parts bonded by a bonder such as an RF bonder having tunable electrodes for delivering respective variable amounts of RF energy to respective portions of the bonded part includes a plurality of thermometers, at least one thermometer for each electrode, for measuring respective surface temperatures of the bonded part. The apparatus also includes an electronic digital computer that records and displays effects of tuning the electrodes and circuitry for interfacing the computer to the thermometers. The computer receives and processes temperature measurements generated by the thermometers and information on a dwell time of the bonded part in a nest with no power, the electrodes' temperatures, an ambient temperature, and a geometry of the bonded part, and the computer uses this information to determine the effects of tuning the electrodes.

IMAGES (4)







CLAIMS (7)

What is claimed is:

1. An apparatus for monitoring a part bonded by a bonder that has delivered a variable amount of energy to respective portions of the bonded part, comprising:

a plurality of thermometers to be used at the respective portions of the bonded part, at least one thermometer for each portion, for measuring respective temperatures of the bonded part;

an electronic computer, wherein the computer records and displays effects of varying the amount of energy delivered; and

circuitry for interfacing the computer to the thermometers;

wherein the computer receives and processes temperature measurements generated by the thermometers and information on a dwell time of the bonded part in a cooling nest with no power, the bonder's temperature, an ambient temperature, and a geometry of the bonded part; and the computer uses the temperature measurements and information for monitoring the effects of varying the amount of energy delivered by the bonder and processes information on the bonder's operating and environmental conditions.

2. The apparatus of claim 1, wherein the computer numerically and graphically displays current temperature measurements of a current bonded part and compares a current temperature measurement to a stored temperature measurement of a previous bonded part for monitoring adjustments of the bonder.

3. The apparatus of claim 1, wherein the computer actuates an alarm based on a comparison of a current temperature measurement of a current bonded part and

a stored temperature measurement of a previous bonded part.

4. An apparatus for monitoring a part bonded by a bonder having a plurality of tunable electrodes for delivering variable amounts or RF energy to respective portions of the bonded part, comprising:

a plurality of thermometers to be used at the respective portions of the bonded part, at least one thermometer for each electrode, for measuring respective surface temperatures of the bonded part;

an electronic computer, wherein the computer records and displays effects of tuning the electrodes; and

circuitry for interfacing the computer to the thermometers;

wherein the computer receives and processes temperature measurements generated by the thermometers and information on a dwell time of the bonded part in a cooling nest with no power, the electrodes' temperatures, an ambient temperature, and a geometry of the bonded part; and the computer uses the temperature measurements and information for monitoring the effects of tuning the electrodes and processes information on the bonder's operating and environmental conditions.

5. The apparatus of claim 4, wherein each thermometer is attached by a ball-and-socket joint, a mounting bracket, and a tubular extension arm to at least one of a robotic shuttle that removes the bonded part from the RF bonder and places the bonded part on the cooling nest.

6. The apparatus of claim 4, wherein the computer numerically and graphically displays current temperature measurements of a current bonded part and compares a current temperature measurement to a stored temperature measurement of a previous bonded part for tracking the effects of tuning the electrodes.

7. The apparatus of claim 4, wherein the computer actuates an alarm based on a comparison of a current surface temperature measurement of a current bonded

part and a stored surface temperature measurement of a previous bonded part.

DESCRIPTION

BACKGROUND

Bonding machines are commonly used for curing adhesives that have been deposited between opposing surfaces of two objects, such as two sheets that are to be glued together. These machines have many applications, including the production of automotive body panels and components. This description is written in terms of bonding two sheets together, but it will be appreciated that Applicant's invention is not limited to such use.

Many kinds of bonding machine are currently in use, including heated platen presses, microwave and radio frequency (RF) bonders, hot-air-impingement bonders, ovens, and infrared and other radiative bonders. For example, a heated platen press forces the two sheets and interposed adhesive together between two opposing appropriately shaped platens, and the adhesive is cured by heat conducted from the platens, which may be heated by steam, electricity, hot oil, or hot water. An RF bonder heats the sheets and adhesive, which are disposed between opposing electrodes, usually by some combination of electric current and atomic-scale motion induced by RF energy applied to the electrodes. Such heating by induced motion is analogous to the heating that occurs in a conventional microwave oven. Heating devices are described in many publications, including U.S. Pat. No. 5,223,684 and No. 5,277,737, both to Li et al. and U.S. Pat. No. 5,554,252 to Foran.

The problem with both heated presses and RF bonders is that today's highly engineered adhesives often can be properly cured only by carefully controlling their temperature. Over-heating some adhesives causes degradation and reduced bond strength. Under-heating leaves some adhesives uncured and can preclude the bonded part's compliance with required bond strength and dimensional tolerances. In addition, economical mass production requires each bonded component to be heated quickly for the minimal amount of time. RF bonders are currently more able than are heated presses to meet these requirements. For example, an RF bonder using a frequency of twenty-seven megahertz (27 MHz) at a power on the order of 1-100 kilowatts can need only thirty seconds for curing a large component at 280° F. (138° C.) while a press heated to the same temperature can require several times as long. It will be appreciated that these parameters vary greatly depending on the bonding method and materials used.

Despite their heating speed, current RF bonders have problems in controlling the spatial temperature distribution of large components, such as automotive body panels. The sources of these problems are many. The amount of heat generated is strongly dependent on many process parameters, such as the gap between the electrodes and bonded part as described in U.S. Pat. No. 4,941,937 to Iseler et al. for example. Also, an RF bonder large enough to handle large components includes as many as 16-24 electrodes, each of which may require tuning by adjustment of a respective capacitor. Further, it is desirable to minimize the time needed to complete the production cycle for each component, i.e., the steps of moving the component into the bonder, heating the component, and moving the component out of the bonder in preparation for the next component, but doing so reduces one's control over the bonding process.

One known approach to monitoring an RF bonder involves the use of a thermal imaging system. A thermographic camera captures a continuously updated "picture" of each bonded part after it is shuttled out of the bonder. Different colors in the "picture" indicate different surface temperatures on the bonded part, and these surface temperatures are used as rough indications of the temperature at the actual bondline, which is usually at some depth beneath the surface. One problem with this system is the camera's view of the part is almost always partially obstructed, preventing measurement of all of the important portions of the part. Another problem with this system is that the indicated temperatures become more and more inaccurate, both absolutely and relatively, as one moves toward the edges of the part. Since adhesives are applied near the edges of many kinds of parts, this kind of thermal imager is most inaccurate in the areas of most interest.

Another known system employs a number of individual infrared thermometers, one aimed at each corner of the bonded part, to determine surface temperatures of parts that have been shuttled out of the bonder. The several surface temperatures determined for each part are displayed on a computer process control screen. This system has problems that are similar to the problems of the system described above. The system gives information on the heating ability of only a few out of many (e.g., four out of sixteen) bonder electrodes.

Besides their other problems, neither of these known systems is accurate enough or suitable for tuning an RF bonder. In this application, the word "tuning" means adjusting so that a desired amount of energy is deposited into an adhesive layer. As mentioned above, an RF bonder large enough to handle large components includes as many as 16-24 electrodes, each of which is tuned by adjusting a respective capacitor. This is depicted in FIG. 1, which shows one view of bonder having sixteen electrodes 1-16 disposed around the edges of a part to be bonded. In a typical bonder, the electrodes receive RF energy distributed through a grid 18 from a single RF source, and an adjustment of one electrode unpredictably changes the tuning of all of the other electrodes. As a result, tuning is currently a tedious process of trial and error, which produces a large number of scrapped parts and long bonder down times, and results are qualitative, requiring interpretation based on experience.

SUMMARY

Applicant's invention improves the current methods and apparatus for monitoring bonders such as multi-electrode RF bonders, reducing the number of scrapped parts and the time needed for tuning. With Applicant's invention, results are quantitative and proper adhesive curing conditions can be ensured. Applicant's apparatus facilitates rapid adjustment, e.g., RF tuning ,of bonders used for ensured. Applicant's apparatus facilitates rapid adjustment, e.g., RF tuning ,of bonders used for bonding SMC exterior automotive body panels, allows an operator to quantify the effect of efforts to adjust or tune a bonder, and greatly reduces the dependence on user-interpreted observational destructive testing techniques. Furthermore, Applicant's monitoring apparatus can be used for temperature mapping, tuning, and to assist quality assurance for any thermal bonding technique, such as hot-air-impingement and heated-platen-press bonding.

In one aspect of Applicant's invention, an apparatus for monitoring a part bonded by a bonder that has delivered a variable amount of energy to respective portions of the bonded part includes a plurality of thermometers, at least one thermometer for each portion, for measuring respective temperatures of the bonded part. The apparatus further includes an electronic computer that records and displays effects of varying the amount of energy delivered and circuitry for interfacing the computer to the thermometers. The computer receives and processes temperature measurements generated by the thermometers and information on a dwell time of the bonded part in a cooling nest with no power, the bonder's temperature, an ambient temperature, and a geometry of the bonded part; and the computer uses the temperature measurements and information for monitoring the effects of varying the amount of energy delivered by the bonder.

The computer may numerically and graphically display current temperature measurements of a current bonded part and compare a current temperature measurement to a stored temperature measurement of a previous bonded part for monitoring adjustments of the bonder. The computer also may actuate an alarm based on a comparison of a current temperature measurement of a current bonded part and a stored temperature measurement of a previous bonded part.

In another aspect of Applicant's invention, an apparatus for monitoring an RF bonder having a plurality of tunable electrodes for delivering respective variable amounts of RF energy to respective portions of a part to be bonded comprises a plurality of thermometers, at least one thermometer for each electrode, for measuring respective surface temperatures of the bonded part. The apparatus further comprises an electronic digital computer that records and displays effects of tuning the electrodes and circuitry for interfacing the computer to the thermometers.

The computer receives and processes temperature measurements generated by the thermometers, as well as information on a dwell time of the bonded part in a cooling nest with no power, the electrodes' temperatures, an ambient temperature, and a geometry of the bonded part, and the computer uses these measurements and information to determine the effects of tuning the electrodes.

In other aspects of the invention, each thermometer may be attached by a ball-and-socket joint, a mounting bracket, and a tubular extension arm to a robotic shuttle that removes the bonded part from the RF bonder or to a cooling nest into which the shuttle deposits the removed part. The computer may numerically and graphically display current surface temperatures of the bonded part and compare these surface temperatures to surface temperatures of parts previously bonded for tracking the effects of tuning the electrodes.

tracking the effects of tuning the electrodes.

BRIEF DESCRIPTION OF THE DRAWINGS

The features and objects of Applicant's invention will be understood by reading this description in conjunction with the drawings, in which like elements are identified by like reference numerals and in which:

FIG. 1 illustrates an RF bonder having sixteen electrodes disposed around the edges of a bonded part;

FIGS. 2A, 2B, and 2C illustrate one embodiment of a tuning kit in accordance with Applicant's invention and a portion of an RF bonder;

FIG. 3 illustrates the information and format of a display generated by a tuning kit in accordance with Applicant's invention;

FIG. 4 illustrates a display showing bondline temperatures determined at each of a plurality of electrodes for each of a plurality of test runs;

FIG. 5A depicts an idealized cross-section of an RF bonder electrode and a bonded part; and

FIG. 5B illustrates geometries of bonded components.

DETAILED DESCRIPTION

Applicant has recognized that a bonder monitoring and tuning apparatus should perform several main functions. First, the apparatus should measure the temperature at several locations on a bonded part, e.g., at the location of each RF bonder electrode, so that the effects of tuning attempts can be tracked and controlled. Second, the apparatus should include a system for recording and displaying the effects of bonder adjustments, such as RF bonder tuning. Third, the apparatus should include flexible, fast-executing, and user-friendly computer software that processes information on the bonder's operating and environmental conditions. It will be appreciated that although this description is written in terms of RF bonders, the principles of the invention can be applied to the other types of bonders described above.

FIGS. 2A, 2B, and 2C illustrate one embodiment of a monitoring and tuning apparatus 30 in accordance with Applicant's invention and a portion of an RF bonder. As illustrated in FIG. 2A, the portion of the RF bonder comprises a set of electrodes, each of which comprises two opposed electrode elements 22, 24, and a portion of a bonded component 20 that is disposed between the electrode elements. In one application of Applicant's invention, the bonded component 20 may comprise two sheets 25, 27 of SMC polymer that are separated by an adhesive layer 29.

As illustrated in FIG. 2B, the apparatus 30 comprises a group of non-contacting thermometers or temperature sensors 32, one thermometer for each bonder electrode, for measuring the surface temperature of the bonded component 20. Only four thermometers 32 are illustrated in FIG. 2B for clarity. The thermometers are mounted in a convenient fashion with respect to the bonded component. For example, each thermometer may be a model OS65-MV-R7-4-RS4-CC-BB-X7 infrared thermometer made by Omega that may be attached by a ball-and-socket joint, a mounting bracket, and a tubular extension arm (collectively indicated by reference numeral 33) to a robotic shuttle 26 (schematically illustrated in FIG. 2C) that removes the component from the bonder or more preferably to the cooling nest 28 into which the shuttle 26 deposits the removed part. Such attachment hardware 33 facilitates thermometer positioning and portability. The particulars of the robotic shuttle 26 and the cooling nest 28, which is suitably shaped to support uniformly the bonded part, are well known to those of ordinary skill in this art, as indicated for example by the description of nests and bonders in the above-cited U.S. patent to Iseler et al.

The illustrated monitoring and tuning apparatus 30 further comprises an electronic digital computer 34 and suitable circuitry 36 for interfacing the computer 34 to the thermometers 32. The interface circuitry 36 preferably provides signal amplification close to the signal source for increased accuracy, and advantageously is modular for easy expansion and portability. Suitable interface circuitry, including signal multiplexer amplifiers, distributed signal conditioning I/O modules, and computer interface cards, is commercially available from National Instruments, Austin, Tex. The computer 34 receives and processes the temperature measurements generated by the thermometers 32, presenting either the raw or processed information on a suitable control panel and display 38 as described in more detail below. The computer 34 may also receives information on the component's dwell time in the cooling nest with no power, the electrodes' temperatures, the ambient temperature, and the component geometry.

The computer executes software for enabling and coordinating data acquisition and display of the raw and processed information. Such software may be custom-designed, but commercially available software applications may be used instead. For example, the LabVIEW™ 3.1.1 application that is commercially available from National Instruments is suitable. It will be appreciated that it should also be possible for the computer to control the operation of the bonder using this information, provided the hardware and software interfaces between the computer 34 and bonder are appropriately constructed.

The computer 34 numerically and graphically displays the current SMC surface temperature under each electrode at RF power shut off. FIG. 3 is an example of the information and format of such a display. Blocks #1 through #16 show numerical values of the bondline temperatures at respective electrodes 1-16. (The 0.00 values shown in FIG. 3 are simply illustrations.) Advantageously, each block may be colored according to whether the respective temperature is acceptable (e.g., green), too hot (e.g., red), or too cold (e.g., blue). The particular colors and their temperatures may be identified by a suitable key that is also shown on the control panel and display 38.

Since a single conventional desktop-class computer would typically be able to process temperature measurements from a plurality of bonders, it is currently believed to be preferable to switch the display 38 between or among those bonders, thereby maximizing the display area devoted to each. Accordingly, FIG. 3 depicts a bonder display selection switch and indicators for identifying the bonder displayed. Other areas of the display 38 may be devoted to a variety of other status, control, and other information as desired, such as alarms for identifying bonded parts that fail to conform to predetermined specifications. This information is determined by the computer 34 based on the appropriate current and historical temperature measurements. The computer may actuate an alarm based on a comparison of a current temperature measurement of a current bonded part and a stored temperature measurement of a previous bonded part.

The current temperature data may also be graphically compared with temperature data obtained from components that have previously been run through the bonder so that the effects of tuning efforts on each electrode can be tracked. The computer 34 can easily be programmed so that it stores such information. An example of such a graphical comparison is shown in FIG. 4, which depicts a snapshot of the computer's display showing bondline temperatures determined at each of four electrodes #1, #2, #3, #4 for five test runs 1, 2, 3, 4, 5. Such a tracking display might be initiated by actuation of a suitable selector device, such as the plot thermal history button illustrated in FIG. 3.

As described above, currently available RF bonders have problems in controlling the spatial temperature distribution of large components because, among other reasons, the amount of heat generated is strongly dependent on many process parameters. This is illustrated by FIG. 5A, which depicts an idealized cross-section of an RF bonder electrode and a bonded part. As described above, the bonded part typically comprises two portions 25, 27 and an interposed adhesive layer 29, and the part is disposed between the elements 22, 24 of the bonder electrode. The bondline temperature is determined not only by the amount of RF energy emitted by the electrode but also by parameters such as the temperatures and thermal conductivities of the electrode elements, the temperatures and thermal conductivities of the polymer portions, and the thickness and volume of the adhesive layer. These latter dimensions of the adhesive relate to the geometry of the bonded component in that, as depicted in FIG. 5B, even nominally identical components 25', 27', 29'; 25", 27", 29" can have different geometries at the same electrode depending on SMC geometry. The electromagnetic absorptions of each of the layers 29 and the exothermic behavior during curing of different adhesives are yet other important parameters.

A bonder monitoring apparatus in accordance with Applicant's invention has several advantages over previous systems. Applicant's determination of the actual bondline temperature under each electrode at the time RF power is shut off is the most valuable information needed for efficiently tuning an RF bonder. The knowledge of bondline temperatures can also be used for optimizing the cure cycle for the adhesive. Furthermore, Applicant's graphical display and tracking of the temperatures makes the effect of tuning efforts immediately and quantitatively apparent.

It will be understood that Applicant's invention is not limited to the particular embodiments described above and that modifications may be made by persons skilled in the art. The scope of Applicant's invention is determined by the following claims, and any and all modifications that fall within that scope are intended to be included therein.

PATENT CITATIONS

Cited Patent	Filing date	Publication date	Applicant	Title
US3573658 *	Mar 12, 1969	Apr 6, 1971	Bondit Corp	Tank cavity resonator for use in high frequency oscillator
US3888715 *	Aug 27, 1973	Jun 10, 1975	Weyerhaeuser Co	Method of inducing high frequency electric current into a thermosetting adhesive joint
US4352707 *	Apr 23, 1981	Oct 5, 1982	Grumman Aerospace Corporation	Composite repair apparatus
US4389438 *	Jul 10, 1981	Jun 21, 1983	Toyo Ink Manufacturing Co., Ltd.	Process for preparing laminates
US4713523 *	Sep 2, 1986	Dec 15, 1987	Gte Government Systems Corporation	For heat curing
US4941936 *	Apr 28, 1988	Jul 17, 1990	The Budd Company	Method for bonding FRP members via dielectric heating
US4941937 *	Apr 28, 1988	Jul 17, 1990	The Budd Company	Method for bonding reinforcement members to FRP panels
US5064494 *	Jun 10, 1988	Nov 12, 1991	Teroson G.M.B.H.	Process for the at least partial curing of sealants and adhesives using pulsed microwave energy
US5223684 *	May 6, 1991	Jun 29, 1993	Ford Motor Company	Method and apparatus for dielectrically heating an adhesive
US5277737 *	Dec 28, 1992	Jan 11, 1994	Ford Motor Company	Applying a high frequency electric field to cure
US5554252 *	Jan 27, 1995	Sep 10, 1996	The Budd Company	Hot and cool air bonding apparatus

* Cited by examiner

NON-PATENT CITATIONS

Reference		
1		"Instrumentation Reference and Catalogue, Test and Measurement Industrial Automation 1996", pp. 2-1-246; 3-154-3-172; 3-224-3228; 6-9-6-10, National Instruments Corp. 1995.
2	*	Instrumentation Reference and Catalogue, Test and Measurement Industrial Automation 1996 , pp. 2 1 246; 3 154 3 172; 3 224 3228; 6 9 6 10, National Instruments Corp. 1995.

* Cited by examiner

REFERENCED BY

Citing Patent	Filing date	Publication date	Applicant	Title
US7066642 *	Oct 4, 2004	Jun 27, 2006	Illinois Tool Works Inc.	Hot melt adhesive detection methods
US7150559 *	Feb 1, 2003	Dec 19, 2006	Illinois Tool Works Inc.	Hot melt adhesive detection methods and systems
US7213968 *	Sep 25, 2002	May 8, 2007	Illinois Tool Works Inc.	Hot melt adhesive detection methods and systems

			Inc.	systems
US8147135 *	Mar 12, 2008	Apr 3, 2012	Alliant Techsystems Inc.	Methods and systems for verifying sensor bond integrity
US8708555	Dec 4, 2009	Apr 29, 2014	Alliant Techsystems Inc.	Methods and systems for verifying sensor bond integrity and structures employing such systems
US20090229372 *	Mar 12, 2008	Sep 17, 2009	Alliant Techsystems Inc.	Methods and systems for verifying sensor bond integrity
US20110146879 *	Oct 14, 2010	Jun 23, 2011	Marie Marguerite Dugand	Method and apparatus for joining panels constituting components of motor-vehicle bodies, with quality control
US20130218534 *	Feb 16, 2012	Aug 22, 2013	Ford Global Technologies, Llc	Adhesive cure monitor
EP1145837A2 *	Mar 14, 2001	Oct 17, 2001	Dieter Schmidt	Apparatus for joining of at least two construction elements

* Cited by examiner

CLASSIFICATIONS

U.S. Classification	156/359, 156/64, 156/382
International Classification	G05G15/00
Cooperative Classification	G05G15/00
European Classification	G05G15/00

LEGAL EVENTS

Date	Code	Event	Description
Apr 20, 2004	FP	Expired due to failure to pay maintenance fee	**Effective date:** 20040222
Feb 23, 2004	LAPS	Lapse for failure to pay maintenance fees	
Sep 10, 2003	REMI	Maintenance fee reminder mailed	
Jan 2, 2001	CC	Certificate of correction	
Dec 20, 1999	AS	Assignment	**Owner name:** LORD CORPORATION, NORTH CAROLINA **Free format text:** NUNC PRO TUNC ASSIGNMENT;ASSIGNOR:DURSO, SCOTT R.;REEL/FRAME:010480/0521 **Effective date:** 19991208 **Owner name:** LORD CORPORATION 110 CORNING ROAD, SUITE 100 CARY
Aug 13, 1997	AS	Assignment	**Owner name:** LORD CORPORATION, NORTH CAROLINA **Free format text:** ASSIGNMENT OF ASSIGNORS INTEREST;ASSIGNOR:DURSO, SCOTT R.;REEL/FRAME:008666/0475 **Effective date:** 19970715

Proceedings of the INCCOM-7

Advanced Hot Bonding System For Repair Of Aerospace Structures

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[1] Scientist; [2] Head Of The Division (Retd.); [3] Project Assistant; [4] Senior Technical Assistant

Advanced Composites Division, National Aerospace Laboratories

Abstract

Repair techniques play an important role in increasing the useful life of the aerospace structures. They increase the confidence level of the user and promote the application of composites. Among the various repair techniques, hot bonding is widely acclaimed for its ability to restore the strength close to the original values. It is used for the repair of metal or composites structures. Hot bonding performed using flexible heater blanket and vacuum bag is the most suitable method for in-situ repair.

Hot bonding is performed through elevated temperature cured adhesive system, which increases the glass transition temperature and hence the service temperature of the final product. These adhesive systems are sensitive to temperature gradient. If the gradient exceeds ±5°C, the cross-linking process and the quality of repair is adversely affected. In the hot bonding process, only the repair area is heated and the rest of the part is left in atmospheric condition. Due to partial heating, the region below the centre of the heater gets hotter than the surrounding. This problem worsens if the job has skin and spar construction or has non-uniform cross-section as in the case of aircraft control surfaces or windmill blades. The hot bonding equipment currently being imported (none manufactured within India) does not ensure temperature uniformity.

This paper discusses the design and development aspects of multi-zone, portable hot bonding equipment, which overcome the above problems. Multiple numbers of appropriately placed heater blankets, sensors and a data acquisition device coupled with a novel control algorithm and multi-threaded software has resulted in the portable and reliable hot bonder. The equipment was tested on typical aircraft parts, such as an aluminium rudder and a composites fin tip. The conventional single heater blanket method has resulted in a temperature gradient of over 12₀C, while this product has limited the temperature gradient to within ±1.5₀C.

1.0 INTRODUCTION

Aircraft structures whether made of alloy or composites do get damaged during service due to many unavoidable reasons. Damages can be repaired either in situ or in a lab depending on their severity, size and location. In situ repairs are advantageous as they can be performed quickly and without dismantling the defective part.

Hot bonding is an in situ repair technique that closely restores the original structural characteristics by the use of high temperature cured adhesive and vacuum bag. It can be used to bond a pre-cured composites laminate or a metal sheet on the damaged area or simultaneously cure and bond a wet patch. In this process, only the repair area is heated by direct conduction from a flexible heater blanket enclosed in a vacuum bag. By evacuating the air from the vacuum bag, atmospheric pressure is made to act on the heater and repair area thereby ensuring good heat conduction, compaction and removal of gases emanated during polymerisation.

Hot bonding process creates temperature gradient due to number of reasons that include partial heating, (structure surrounding the repair area is at atmospheric temperature), non-uniform cross-section, varying skin thickness, skin and spar construction or sand-which construction etc. If the temperature gradient exceeds about 8₀C the cross-linking process and therefore the repair quality is affected drastically.

2.0 EXISTING METHODS TO MINIMISE TEMPERATURE GRADIENT

2.1 Selection Of Control Sensor

The hot bonding equipment currently being imported (none produced within India) control the temperature based on one of the following methods, which are operator selectable.

- Lagging or leading temperature sensor
- Any of the selected temperature sensor
- Average of a group of temperature sensors

All of the above methods, including the „average value control" fail to correct the temperature gradient.

2.2 Patterned Heaters With Non-Uniform Heat Dissipation

Specially patterned heaters whose watt-density is not uniform, but matched to the thermal characteristics of the part under repair can control the temperature gradient. However, such heaters are very expensive to fabricate and this method requires complete knowledge about the defective part and its thermal characteristics. Hence, this method is impracticable.

2.3 Thermal Insulation And External Infra Red Heating

In this method a thermal survey is conducted before the actual repair. After analysing temperature gradient, heat insulators in the form of thin, flexible sheets are placed between the heater and the hotter region to reduce the heat flow and Infra red lamps are shined over the colder regions to increase the heat flow. Essentially, these are manual methods that require constant attention and yet result in poor control and inconsistent cure.

3.0 ADVANCED HOT BONDING WITH MULTI ZONE HEATERS

In the advanced hot bonding method the damaged area is heated with number of small heaters, which are controlled independently through a closed loop control system. Electrical power to each heater is varied based on the real time temperature data acquired at multiple locations across the damaged area. This technique provides completely automatic and job-independent temperature gradient control without demanding a thermal survey or prior knowledge about the job.

3.1 Heater Arrangement

Heating the structure with more number of smaller heaters can minimize temperature gradient. However, for closed loop control each heater requires at least one sensor and one SSR. This would increase the number of analog inputs and digital outputs to be interfaced with the controller. Placing large quantity of sensors and heaters and connecting them carefully for every repair is a tedious work. With lesser number of heaters the major constrain is that the temperature gradient within one heater area cannot be controlled. Considering the temperature gradient present in typical aircraft structures, as an engineering compromise between complexity and application demands, a five-zone heater control was chosen. For a typical repair area of 80mm X 80mm a 100mm x 100mm heater was used for the inner region surrounded by 50mm x 150mm heater on all sides. Fig.1 shows the prevailing single heater arrangement and the new five-zone heater arrangement to limit the temperature gradient.

1
5
HEATERS(5 Nos.)
HTR1: 100mm X 100mm
HTR2 TO 5(4 Nos.)
50mm X 150mm
4
2
1
PART
REPAIR AREA
3
PART
SINGLE HEATER
size 200mm X 200mm
REPAIR AREA

Fig. 1: Single Heater And Five-Zone Heater Arrangement

3.2 Design Goals

The goal of Design and Configuration is to solve the following major problems arising in cure control of bonded repairs.

- Rate of heating/cooling, dwelling time and temperature gradient control
- Measurement and control of vacuum
- Hardware minimization to achieve portability and reliability

- Cure cycle programming, execution and documentation.

3.3 Construction

The major hardware was realized using a Notebook computer and an USB based Temperature / data logger card having 14 analog channels and 8 digital channels. The other hardware include signal conditioners for thermocouples with built-in-Cold Junction Compensation (CJC) and Auto Zero channels and an array of eight optically isolated Solid State Relays (SSR) that controls the AC supply to the heater blankets and the vacuum control valves. The simplified block schematic is shown in fig.2. Silicon insulated flexible heater blankets of size 100mm x 100mm (1 no.) and 75mm x 150mm (4 nos.) were used to heat the repair area of 200mm x 200mm.

Notebook Computer with Multi-zone Hot-bonder Software
Temperature and Vacuum data Logger
Digital Outputs
Signal conditioner with CJC and Auto zero
Digital Buffers
Thermocouples 1 to 12 channels
Vacuum sensor
SSR
Supply to heaters (Zone-1 to 5)

(Zone-1 to 5)
Bank
Suction and Vent Valves
USB cable
Flat Ribbon Cable

Fig. 2: Block Schematic Of Advanced Hot Bonding System

The software was developed using the Microsoft Visual C++ compiler on Windows platform. In addition to performing the unique control functions explained above, the software provides for complete SCADA (Supervisory Control and Data Acquisition) features including numerical/graphical data display or print out either on-line or off-line. Fig.3 shows the photograph of the hot bonding equipment with heater blankets.

3.4 MIMO (Multi Input Multi Output) Temperature Gradient Control Algorithm:

The Multi-zone temperature control algorithm accepts up to twelve thermocouples configured as two per zone and two standbys. It controls five heaters simultaneously and can affect their status once in every 0.5 second.

The user‟s cure program consists of heat up ramp, soak time, cool down ramp etc, which essentially defines the required uniform temperature in the repair area as a function of time. Accordingly, set-points (SP) are generated once in a fixed time interval known as scan interval. Scan interval was determined according to the maximum rate of heating, display resolution and the time required by data logger card for digitising all the analog channels etc., and it was fixed as five seconds. During every scan interval all the temperature channel data are acquired. Control sensor for each zone can be selected as any one of the two sensors, the leading sensor, the lagging sensor or the average of both the sensors. This value forms the Process Variable (PV) of the given zone.

The SP and the working PV of each zone are passed on to individual PID loops. Five PID loops are run simultaneously. Every PID loop determines the control output for that particular zone, based on the pre-programmed PID constants. The normalized control output is computed in percentage, that is 0-100% with 0 indicating no heating power and 100% indicating full heating power demand. To feed the PID control output (0 to 100%) and to vary the heater power between 0 to 100% a DAC (Digital to

Analog Converter) card and a phase-angle fired SCR module are required respectively. These devices have been eliminated through a cycle time control program. It converts the linear control output into a pulse width modulated digital signal. This approach requires only a digital output device and a Solid-State Relay (SSR) for every heater. Based on the demand heaters are switched in steps of 0.5second interval. For example, if the heat demand is 50% then for half of the scan interval heaters will be ON. The ON and OFF pulses are properly interleaved to achieve smooth change in temperature. The software repeats set point calculation, PV calculation, PID algorithm and cycle time control loop for every five seconds.

Thermo-
couples

AC input
Supply

Heater
Blankets

Fig. 3: Photograph Of The Multi-Zone Hot Bonding System

4.0 TESTS AND RESULTS

4.1 Thermal Survey On A Composites Fin Tip

An aircraft fin tip was considered as a typical composites specimen for thermal survey. This part is made of glass fibre reinforced plastics. The repair area chosen is partly on a rib. A defect of size 80 mm diameter and a heater size of 200mm x 200mm was considered. One thermocouple was placed in the centre for controlling and four were placed on the edges for monitoring. All the sensors were located well within the heater area of 200mm x200mm. Vacuum bagging and air evacuation was carried out with out prepreg. The cure cycle chosen consists of heating at a rate of 8°C/min. from ambient temperature to 120°C, holding at 120°C for 24 minutes, heating at a rate of 8°C/min from 120°C to 176°C, holding at 176°C for 24 minutes, cooling at a rate of 8°C/min from 176°C to 100°C and finally holding it at 100°C for 24 minutes. Throughout the cure a constant vacuum of less than 40 torr was maintained. The temperature data plot of the control sensor, leading and lagging sensors are shown in Fig.4. It is found that a temperature gradient of about 12°C exists between the leading sensor

and the lagging sensor. The same experiment was repeated using the five zone hot bonder with five heaters arranged as shown in fig.1 and the data are plotted in fig.4. It is found that the temperature gradient has been brought down to about 1.5°C throughout the cure.

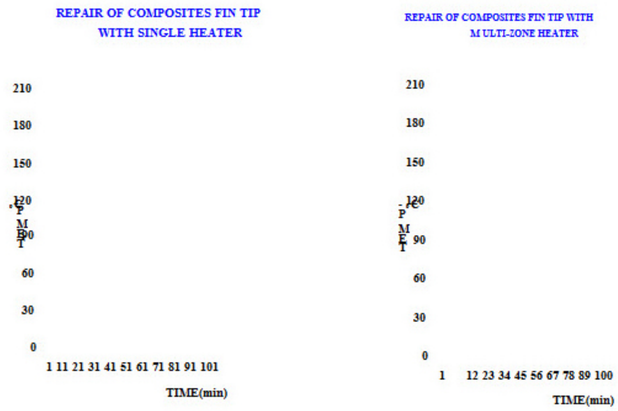

Fig. 4: Temperature Gradient In A Composites Fin Tip With Single And Multi Zone Heaters

A thermal survey using multi zone hot bonder with five heaters was carried out on a typical aircraft rudder made of aluminium alloy. This part has two thin skins bonded to either side of a honeycomb structure and forms an aerofoil cross-section. Sensor placement and Cure cycle programming was carried out as indicated in the previous experiment. The PID constants obtained for composite part was retained. The temperature data acquired from the control sensor, leading and lagging sensor are plotted in Fig.5. The results indicate that a temperature gradient of less than 1.5 oC has been realized and the hot bonder works well with both metal and composite parts without changing the PID constants.

Typical screen shots of the cure cycle programming page and Programmed Cure Plot are shown in Fig.6

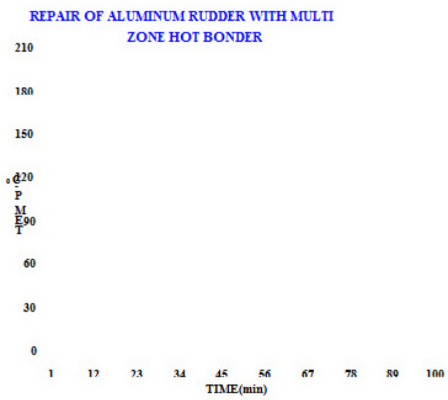

Fig. 5: Temperature gradient in a typical aluminium rudder with Multi-zone Heaters

Fig. 6: Cure cycle programming page and Programmed Cure Plot

News

HEATCON improves process control in composites repair

16 April 2012

To meet the demand from the increased use of composites in the commercial aerospace industry, HEATCON Composite Systems has launched a product designed to improve process control in the repair of composite materials.

The network controller is designed to maintain uniform temperatures as multiple hot bonders are used to repair large areas of composite parts.

"With large-area repairs, the difficulty in maintaining uniform temperature increases thermal characteristics of the part as well as the limitations of large heat blankets," explains HEATCON President Eric Casterline.

"This has created a unique need for the network controller in the composites market."

Hot bonders, heat blankets and other equipment from Seattle, USA, based HEATCON are used to repair composite aircraft components that require bonding processes. The network

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Heatcon supplies composite repair equipment to US army
Heatcon Composite Systems has won a US$2.6 million contract to provide the US army with equipment to repair composite aircraft in remote locations.

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Thicker laminate structure in new commercial passenger aircraft will affect maintainability. Vicki P.

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controller was designed to address advanced repair designs required for the newest airplanes and helicopters. The increased use of composites for commercial airlines has created a need for equipment to address the challenge of ensuring proper cure cycles over large repair areas, which supports processes from manufacturers and regulatory agencies as they become approved.

The geometrically complex shapes in the newest aircraft, which use increasing amounts of composite materials, will require more sophisticated repairs. Many of these advanced repair techniques can be better addressed using the network controller, HEATCON says.

"Substructure under a laminate surface can act as a heat sink, increasing the possibility of non-uniform temperature cures," Casterline reports.

affect maintainability. Vicki P. McConnell identifies possible changes in composite repair of these new designs.

Meeting the challenge of wind turbine blade repair

With a growing number of composite wind turbine blades now in service, rotor blade maintenance is becoming a major issue. George Marsh looks at the techniques used to inspect and repair blades and investigates a new system designed to speed up the repair process.

Members' Content

"The network controller has the capability of addressing advanced repair designs required for the latest aircraft. It allows coordination of a number of repair zones and has the ability to handle complex and demanding repair scenarios."

Using a single bonder to fix large areas of a composite part makes it difficult to control the temperature throughout the entire repair area. A typical bonder managing two repair zones may not provide sufficient coverage for controlling critical temperatures throughout the entire repair area.

Connecting several bonders to the new network controller lets technicians provide uniform temperatures, which improves the integrity of the part being repaired, HEATCON reports.

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HCS9000B-EV / HCS9200B-EV

EV Series Hot Bonders

RELIABLE
EASY TO USE
UPGRADEABLE
SUPERIOR CAPABILITIES
COMPACT SIZE/PORTABLE

Built in Electric Vacuum Pump Max. flow is 0.75 cubic ft/min (354 cm^3/sec) and Max. level is 28+ in/Hg (0.967kgs/cm^2)

HCS9000B-EV Specifications:
Weight - Only 29lbs (13.2kg)
Dimensions - 21.75in x 14.25in x 6.5in (552.5mm x 362mm x 165.1mm)

Applications:

This line of HEATCON® Composite Repair Systems has a built-in vacuum system to allow easier mobility to the repair site and without the need for a alternative air source.

The primary system application is composite and metal bond repairs, by heating and curing prepregs, resins or adhesives.

Manufacturing applications include secondary bonding processes normally accomplished with autoclaves or ovens. Hot bonders are also useful in R&D projects for materials and processes.

Accessories Included:

- Heat Blankets
- Power Cords
- Thermocouples
- Vacuum Hose
- Air Filter
- Extra Printer Ribbon and Printer Paper
- Accessory Storage in Removable Lid
- Data Capture Analysis Software
- USB drive

Specific accessories are described by quotation

HCS9200B-EV Specifications:
Weight - Only 38lbs (17.4kg) (Vacuum Pump located in Lid Assembly)
Dimensions - 21.75in x 14.25in x 6.5in (552.5mm x 362mm x 165.1mm)

Built in Vacuum System

See page 9 for Full Features and Options

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Figure 6-3:: HB-2 Operator Interface Parts

Find No	WichiTech P/N	Nomenclature	QTY Per Unit
1	P1ALM001	ALARM,SONIC	1
2	P0LEN001	LENS,DISPLAY.HB2	1
3	P0DOR005	DOOR,STORAGE,HB2	1
4	S0DOR001	ASSY,DOOR,PRINTER	1
5	P1CON014	CONNECTOR,PLG,17-3	2
6	P1CON20	CONNECTOR,SKT,17-3	2
7	A4TCB002	ASSY,TC BLOCK,ZONE 1	1
8	A4TCB003	ASSY,TC BLOCK,ZONE 2	1
9	P1BRE005	CIRCUIT BREAKER,20A	2
10	A4ZSS003	ASSY,SWITCH,ZONE SEL	1
11	P1VGA002	GAUGE,VACUUM,HB2	2
12	P1SWI012	SWITCH,TAP HAMMER	2
13	P0OVL001E	OVERLAY,DUALHD,HB2	1
14	A4PMR001	PWA,PWR MTR,ZONE 1	1
15	A4PMR002	PWA,PWR MTR,ZONE 2	1

Table 6-1:: HB-2 Operator Interface Parts

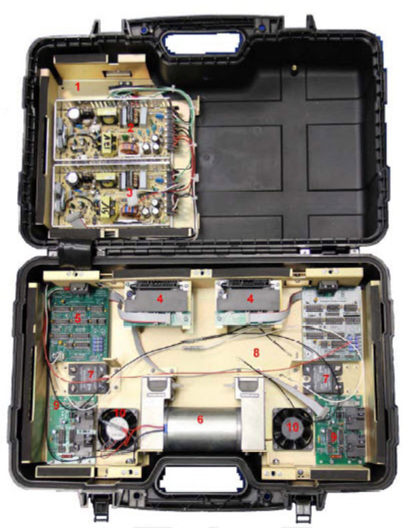

Figure 6-4:: HB2 Internal Assemblies

Find No	WichiTech P/N	Nomenclature	QTY Per Unit
1	A4BED006	ASSY,BEDPAN,UPPER	1
2	P1PWR009	POWER SUPPLY,12V	1
3	P1PWR008	POWER SUPPLY,5V	1
4	A4PRN002	ASSY,PRINTER,HB2	2
5	A4ZNC001 A4PDB002	PWA,ZONE CONTROL PWB,PRINTER DRIVER	1 1
6	A4VPA001	ASSY,VACUUM PUMP	1
7	P1REL004	ASSY,SSR	2
8	A4BED005	ASSY,BEDPAN,LOWER	1
9	A4TDR002	PWA,ACWD	2
10	A4FAN001	ASSY,FAN	2

Table 6-4:: HB2 Internal Assemblies

PRODUCTS OF THE MONTH

Scale calibrations

Jackson Aircraft Weighing Service conducts NIST traceable calibrations and repairs on all types of aircraft scale kits. Calibrations, digital upgrades to analog kits, replacement indicators for Revere kits, replacement load cells as well as used equipment are available. Calibration cost is priced right, quick turn times, and rental scales available if needed. For all your scale needs and repairs. ***For more information visit www.aircraftscales.com.***

Portable hot bonder

HEATCON Composite Systems offers the HCS8800, a portable hot bonder, with improved features. The lightweight portable HCS8800 retains the functionality of larger more traditional hot bonder units. The size and weight of the unit increases portability which can improve both technician response time and access to difficult repair environments. An enhanced operator interface includes a display with improved graphic representation and facilitates operator interpretation of cure process results. Another convenience of the HCS8800 is USB data export capability, allowing readout data to be transferred from the bonder and stored in other locations for historical record keeping. The internal library of the HCS8800 allows storage of up to eight multiple programs. Storage does not require the use of a personal computer. ***For more information call (206) 575.1333 or visit www.heatcon.com.***

Lighting

ProBuilt Professional Lighting manufactures durable, innovative lighting products for a wide range of job site and task lighting applications. Every product has been specifically designed with the specifications, features, and reliability demanded by the professional tradesman and the industrial environment. Its product lines include the patented, self-righting Wobblelight, Hang-A-Light temporary area work lights, Defender industrial lighting products, the new ProBuilt high intensity Torch, and the new SmithLight, battery-operated LED work lights. ProBuilt's products are designed to be safe, bright, and easy to use. All products are CSA, UL, or ETL listed. Many are energy efficient. ***For more information call (877) 707-0800 or visit www.probuiltlighting.com.***

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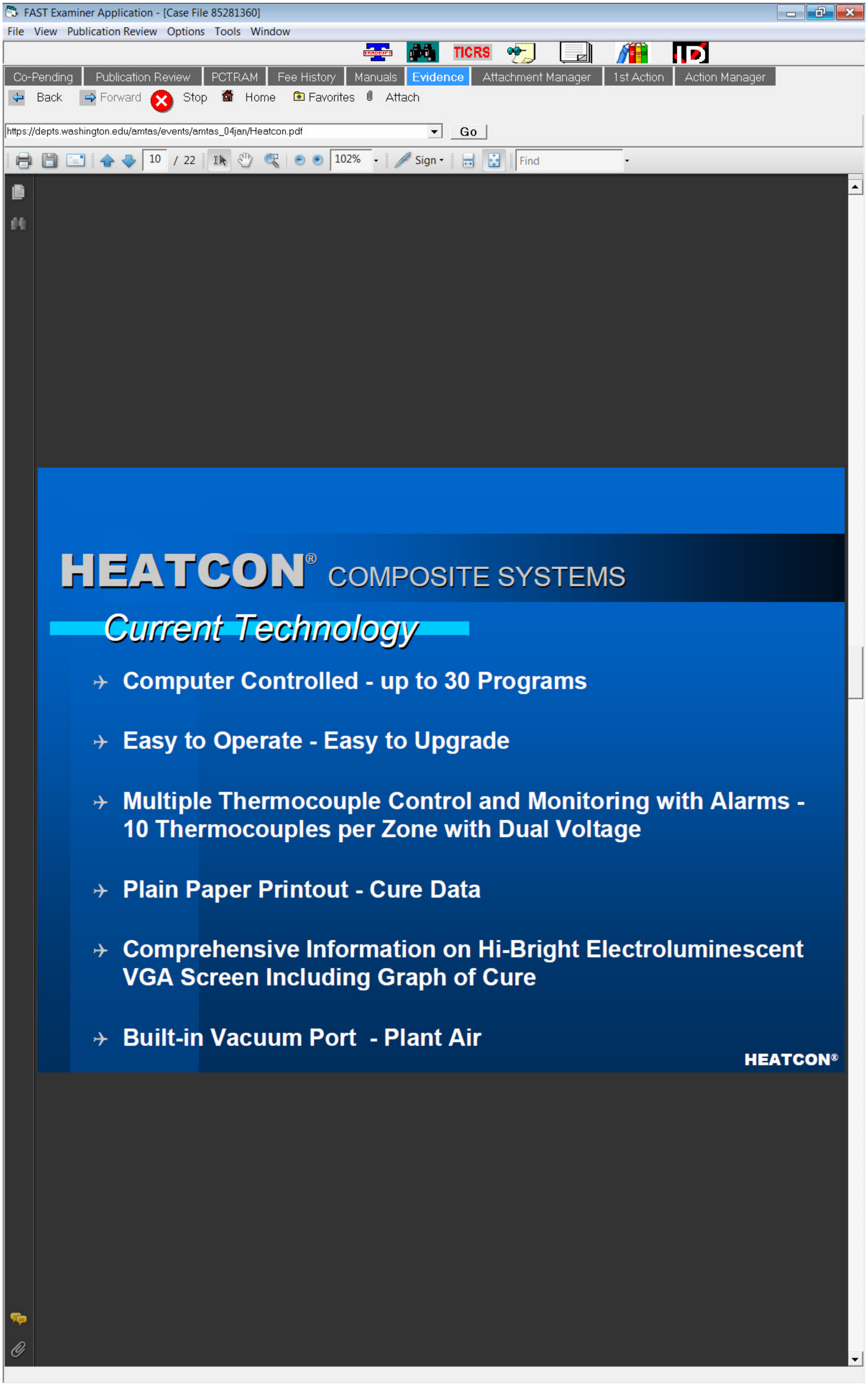
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Computer Controlled - up to 30 Programs
Easy to Operate - Easy to Upgrade
Multiple Thermocouple Control and Monitoring with Alarms - 10 Thermocouples per Zone with Dual Voltage
Plain Paper Printout - Cure Data
Comprehensive Information on Hi-Bright Electroluminescent VGA Screen Including Graph of Cure
Built-in Vacuum Port - Plant Air
HEATCON®

Product/Service

HCS9000-FL and HCS9200-FL Flightline Hot Bonders

Source: HEATCON Composite Systems

The HCS9000-FL and HCS9200-FL Flightline Hot Bonders (hazardous environment) are based on the standard HCS9OOOA Single Zone and HCS9200 Dual Zone units

The HCS9000-FL and HCS9200-FL Flightline Hot Bonders (hazardous environment) are based on the standard HCS9OOOA Single Zone and HCS9200 Dual Zone units. Basic features, operation and capability are identical. They are further designed to meet the requirements of Class I, Division II, hazardous environment operation per the U. S. National Electric Code, as promulgated by the National Fire Protection Association.

Added features for flightline/hazardous environment operation are as follows:

- The case has controlled pressurization and purging to eliminate any possibility of internal explosive vapors. An external air source is required for this function. The same air source is also used for the hot bonder's vacuum system.
- The purge cycle is started by turning on the power switch, while plant air is connected. Once the case is pressurized and purged, the unit is ready for operation. Lighted indicators on the faceplate show case pressure status, purge cycle initiation, and when the system is ready.
- Input and output power connectors are manufactured specifically for use in hazardous environments. The connector requires two separate motions to disconnect. The first turn of the locking ring allows the electrical connections to separate, while retaining the connector body captive. At this point, any arc that occurs is contained, not allowing any external vapor ignition. The second turn of the locking ring frees the connector from the receptacle.
- A Ground Fault Interrupter (GFI) minimizes chance of electrical shock. Leakage of more than 4 milliamps of current to ground trips the GFI, cutting off all power.

- An independent high limit controller is used with special "supervisory" heat blankets. The high limit controller connects to a temperature sensing circuit embedded in the heat blanket. If the blanket sensor detects any hot area exceeding 80% of the flash point of aviation jet fuel, the controller will disable power output to the blanket. The circuit is self-resetting when the temperature falls below the critical level. An indicator and alarm will alert the operator to the condition.

HEATCON Composite Systems, 600 Andover Park East, Seattle, WA 98188-7610. Tel: 206-575-1333; Fax: 206-575-0856.

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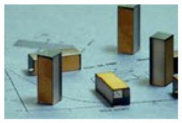
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Spectral Imaging For Bioscience Applications: Band-Sequential Techniques

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Product/Service

HB-2 Composite Repair System

Source: Wichitech Industries Inc.

The world's hottest hot bonder, the WichiTech HB-2 is a powerful, portable composite repair system that sets industry standards for ease of operation, safety, reliability and value

- Two operator programmable, independent heating zones
- Two individual, adjustable vacuum zones
- Menu driven functions with single keystroke execution
- Multiple thermocouples, audible alarms, circuit breakers, ground fault interrupter for safety/performance protection
- Dual custom size color-coded printers
- Tough, lightweight Xenoy transport case, small enough to fit in airplane overhead storage
- Self-storing unit with space for cables, heating blankets, thermocouples
- User-friendly warranty
- Fast, expert service; standard 72-hour turnaround time

The world's hottest hot bonder, the WichiTech HB-2 is a powerful, portable composite repair system that sets industry standards for ease of operation, safety, reliability and value. This durable system repairs metal, Kevlar, carbon, boron and fiberglass simply, safely and cost-effectively. HB-2 makes fast, flawless work of large or small repair jobs. The 35-pound USA-built unit is as simple to program as a microwave with its easy-to-read digital display and menu listed functions.

The custom made HB-2 is individually manufactured to your specifications. Select from a single zone unit programmed heating zones, twenty amps each, with two individual adjustable vacuum zones, or anywhere in between.

Recommended For You

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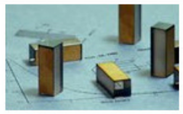

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Composites Manufacturing

Turning Up the Heat in Composite Repair

ACMA Staff

March 11, 2012

Eric Casterline is the president of Heatcon Composite Systems based in Seattle, Wash. Casterline has been working with Heatcon since 1994 and has been involved in various roles with the company including sales and development. He is currently working on projects to improve composite repair on large structures, such as the large panels on the Boeing 787 Dreamliner, and expects that composite repair will continue to influence the industry as more components are integrated.

How long has Heatcon been involved in composite repair solutions? Is that its main focus?

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Approximately 1,710 people can ride the new GateKeeper roller coaster at Cedar Point Amusement Park in Sandusky, Ohio, each hour. Learn how the roller coaster - and six other summer adventures - incorporate composites.

Is that its main focus?

Eric Casterline – President of Heatcon Composite Systems

Heatcon Composite Systems opened its doors in 1978 as a distributor of heating devises, basically a specialty distributor of heating and temperature sensors. In the early 80s we built a control panel system for Boeing. This became the first hot bonder, a control system for calculating the time and temperature of the heat area. After 1981, the heat bonder section of the business evolved and grew beyond distribution. That's when the company separated into the heat division and specifically composite repair. Now composite repair is the larger part of the company. Heatcon, Inc is the original company and there are three subsidiaries in the Heatcon Composite Systems branch; there is a subsidiary in the U.K., Heatcon Composite Systems in the U.S., and Heatcon Composite Training in the U.S.

What are challenges to repairing composite parts?

We like to think there are two distinct "challenging" areas. First, the aviation industry needs to learn more about composite repair in order to become more competitive with metals. The second challenge with repair materials, and the core of our business, is on equipment and how it can be adapted for easy use.

We spend a lot of time focusing on building a tool that technicians can use day-to-day and not something that is overly complex to operate. For example, the U.S. Army just ordered bonders that needed to be flexible to use in places without a power supply. We're frequently asked to create custom equipment for companies and we do that by adapting our current technology to fit to various industry applications.

How have recent market trends impacted your products?

Obviously, the big trend is that aerospace companies like Boeing and Airbus are building larger structures. The media is talking about the composite Boeing 787 Dreamliner. In one respect, this is nothing new to our industry (composites have been used in aerospace for many years) but the scale is completely new. Now they are using composites extensively in primary structures. The military had previously done something similar in the F-22 Raptor, but this is a game changer for commercial planes that will now need a larger customer base of technicians to handle repairs.

1 2

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Turning Up the Heat in Composite Repair

ACMA Staff

March 11, 2012

Manufactures have structural manuals for technicians to repair composite airplane parts. Previously, manufacturers limited the size of the repair on composites to ensure the structural security of the part. Now that there are more and

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larger composite parts for airplanes, the requirements have opened up for bigger repairs and that's an issue that we as an industry need to address. At Heatcon we're making larger heat blankets and products that can be used on newer aircraft structures.

What are some examples of common aerospace repairs?

Common repairable parts are secondary structures such as radomes, flaps and controlled surfaces for aircraft. On helicopters there are blade repairs and others from high heat or heat induced damage. Examples of damages we see in the field are from moisture damage when water gets through a crack in the surface. We'll find parts of the plane are frozen or have water damage in places. There are also failures due to contamination when you have oils or solvents like hydrolic oil can cause damage and cracking around fasteners. Then there's the wear and tear damage from hail, ground damage, luggage cart or service vehicle into the side. The problem with commercial aircrafts is dealing with the high usage parts for loading cargo and passengers.

How long does it take to repair parts?

It depends. Short repairs can take a few hours for small damage, using a resin sweep to repair a scratch on the surface. The Federal Aviation Administration has requirements for temporary repair. Extensive repair can take a week or a couple of weeks depending on the type of repair. I've actually never seen a study on average repair time. Part of the reason it's so difficult to define is that it's expensive to keep an airplane down for long periods of time. Technicians need to make a decision on whether or not to replace a part or do temporary repair. In the meantime, they typically replace the part to get it off the plane and bring the part in for repair. It ends up being another time concern for temporary fixes to ultimately take the time for a longer repair.

1 2

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United States Patent **6,976,519**
Bivens **December 20, 2005**

Portable curing system for use with vacuum bag repairs and the like

Abstract

A portable curing system includes a carrying case, a controller located within the carrying case and having a microprocessor, a vacuum pump located within the case and having at least two vacuum ports for connection of vacuum lines, at least two vacuum sensor connectors for receiving leads of vacuum sensors, at least two heater connectors for receiving leads of electrical heaters, and at least two temperature sensor connectors for receiving leads of thermocouples. The controller is operably connected to the vacuum pump, the vacuum sensor connectors, the heater connectors, and the temperature sensor connectors. A touch-screen video display is mounted within the carrying case and operably connected to the controller to display information from the controller and input information to the controller. The video display is pivotable between a stowed position and a viewing position.

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Assignee: **BH Thermal, Inc.** (Columbus, OH)
Family ID: **32965408**
Appl. No.: **10/733,870**
Filed: **December 11, 2003**

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Current International Class: B32B 031/26 (); B32B 035/00 ()
Field of Search: ;156/94,98,351,358,359,360,378,379,381 ;29/402.01,402.21 ;264/36.1,36.7 ;219/86.21,386,533 ;392/313

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U.S. Patent Documents

5837968	November 1998	Rohrberg et al.
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Primary Examiner: Koch; George
Attorney, Agent or Firm: Porter Wright Morris & Arthur, LLP

Parent Case Text

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the priority benefit of U.S. Provisional Patent Application No. 60/432,625, filed on Dec. 11, 2002, the disclosure of which is expressly incorporated herein in its entirety by reference.

Claims

What is claimed is:

1. A portable curing system comprising, in combination: a carrying case; a controller located within the carrying case and having a microprocessor; a vacuum pump located within the case and having at least one vacuum port for connection of a vacuum line; at least one heater connector for receiving a lead of an electrical heater; at least one temperature sensor connector for receiving of a lead of thermocouple; wherein the controller is operably connected to the vacuum pump, the heater connector and the temperature sensor connector; and a touch-screen video display mounted within the carrying case and operably connected to the controller to display information from the controller and to input information to the controller.

2. The portable curing system according to claim 1, wherein the video display is pivotable between a stowed position and a viewing position.

3. The portable curing system according to claim 2, wherein the video display is pivotable at least ninety degrees.

4. The portable curing system according to claim 2, wherein the video display is pivotable about a generally horizontal and pivot axis laterally extending between sides of the carrying case.

5. The portable curing system according to claim 1, wherein the carrying case has main body and a lid hingedly connected to the main body.

6. The portable curing system according to claim 1, wherein the vacuum pump is a venturi vacuum pump.

7. The portable curing system according to claim 1, wherein there are at least two of the heater connectors and at least two of the temperature sensor connectors.

8. The portable curing system according to claim 7, wherein there are at least ten of the temperature sensor connectors associated with each of the heater connectors.

9. The portable curing system according to claim 1, wherein the video display is a full color graphical video display.

10. The portable curing system according to claim 1, further comprising at least one vacuum sensor connector for receiving a lead of a vacuum sensor and operatively connected to the controller.

11. A portable curing system comprising, in combination: a carrying case; a controller located within the carrying case and having a microprocessor; a vacuum pump located within the case and having at least one vacuum port for connection of a vacuum line; at least one heater connector for receiving a lead of an electrical heater; at least one temperature sensor connector for receiving of a lead of thermocouple; wherein the controller is operably connected to the vacuum pump, the heater connector and the temperature sensor connector; a video display mounted within the carrying case and operably connected to the controller to display information from the controller; and wherein the video display is pivotable between a stowed position and a viewing position.

12. The portable curing system according to claim 11, wherein the video display is pivotable at least ninety degrees.

13. The portable curing system according to claim 11, wherein the video display is pivotable about a generally horizontal and pivot axis laterally extending between sides of the carrying case.

14. The portable curing system according to claim 11, wherein the carrying case has main body and a lid hingedly connected to the main body.

15. The portable curing system according to claim 11, wherein the vacuum pump is a venturi vacuum pump.

16. The portable curing system according to claim 11, wherein there are at least two of the heater connectors and at least two of the temperature sensor connectors.

17. The portable curing system according to claim 11, wherein there are at least ten of the temperature sensor connectors associated with each of the heater connectors.

18. The portable curing system according to claim 11, wherein the video display is a full color graphical video display.

19. The portable curing system according to claim 11, further comprising at least one vacuum sensor connector for receiving a lead of a vacuum sensor and operatively connected to the controller.

20. A portable curing system comprising, in combination: a carrying case; a controller located within the carrying case and having a microprocessor; a vacuum pump located within the case and having at least two vacuum ports for connection of vacuum lines; at least two vacuum sensor connectors located within the carrying case for receiving leads of vacuum sensors; at least two heater connectors located within the carrying case for receiving leads of electrical heaters; at least two temperature sensor connectors located within the carrying case for receiving leads of thermocouples; wherein the controller is operably connected to the vacuum pump, the vacuum sensor connectors, the heater connectors, and the temperature sensor connectors; a touch-screen video display mounted within the carrying case and operably connected to the controller to display information from the controller and input information to the controller; and wherein the video display is pivotable between a stowed position and a viewing position.

Description

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH

Not Applicable

REFERENCE TO MICROFICHE APPENDIX

Not Applicable

Not Applicable

FIELD OF THE INVENTION

The present invention generally relates to curing systems or hot bonders for use with vacuum bag or blanket repair systems and, more particularly, to portable curing systems which enable on-site repairs.

BACKGROUND OF THE INVENTION

In many industries, such as the aerospace industry, repairs are made to metal bonded and composite epoxy structures using vacuum bag or blanket repair systems. Curing systems or hot bonders provide and control a vacuum with the bag surrounding the repair site. It is also desired to provide and control a cure temperature at the repair site. See, for example, U.S. Pat. Nos. 6,468,372, 6,373,028, 6,270,603, 6,206,067, 6084,206 for examples of such blanket repair systems, the disclosures of which are expressly incorporated herein in their entireties by reference. When the system is portable, repairs can be made on location such as, for example, right on the vehicle to save manpower and reduce downtime.

While prior systems generally perform their intended purpose, they have difficulty processing new technology composite patches. Accordingly, there is a need in the art for an improved portable curing system or hot bonder.

SUMMARY OF THE INVENTION

In accordance with one aspect of the present invention a portable curing system includes, in combination, a carrying case, a controller located within the carrying case and having a microprocessor, a vacuum pump located within the case and having at least one vacuum port for connection of a vacuum line, at least one heater connector for receiving a lead of an electrical heater, and at least one temperature sensor connector for receiving of a lead of thermocouple. The controller is operably connected to the vacuum pump, the heater connector and the temperature sensor connector. The system also include a touch-screen video display mounted within the carrying case and operably connected to the controller to display information from the controller and to input information to the controller.

According to another aspect of the present invention, a portable curing system includes, in combination, a portable curing system comprises, in combination, a carrying case, a controller located within the carrying case and having a microprocessor, a vacuum pump located within the case and having at least one vacuum port for connection of a vacuum line, at least one heater connector for receiving a lead of an electrical heater, and at least one temperature sensor connector for receiving of a lead of thermocouple. The controller is operably connected to the vacuum pump, the heater connector and the temperature sensor connector. The system further includes a video display mounted within the carrying case and operably connected to the controller to display information from the controller. The video display is pivotable between a stowed position and a viewing position.

According to yet another aspect of the present invention, a portable curing system includes, in combination, a carrying case, a controller located within the carrying case and having a microprocessor, a vacuum pump located within the case and having at least two vacuum ports for connection of vacuum lines, at least two vacuum sensor connectors for receiving leads of vacuum sensors, at least two heater connectors for receiving leads of electrical heaters, and at least two temperature sensor connectors for receiving leads of thermocouples. The controller is operably connected to the vacuum pump, the vacuum sensor connectors, the heater connectors, and the temperature sensor connectors. The system further includes a touch-screen video display mounted within the carrying case and operably connected to the controller to display information from the controller and input information to the controller. The video display is pivotable between a stowed position and a viewing position.

From the foregoing disclosure and the following more detailed description of various preferred embodiments it will be apparent to those skilled in the art that the present invention provides a significant advance in the technology and art of portable curing systems. Particularly significant in this regard is the potential the invention affords for providing a high quality, reliable, low cost assembly. Additional features and advantages of various preferred embodiments will be better understood in view of the detailed description provided below.

BRIEF DESCRIPTION OF THE DRAWINGS

These and further features of the present invention will be apparent with reference to the following description and drawings, wherein:

FIG. 1 is a perspective view of a portable curing system according to the present invention;

FIG. 2 is a diagrammatic top plan view of an upper panel of the portable curing system of FIG. 1;

FIG. 3 is a diagrammatic top plan view of a lower panel of the portable curing system of FIGS. 1 and 2;

FIG. 4 is top plan view of a vacuum system of the portable curing system of FIGS. 1 to 3 wherein other components are removed for clarity;

FIG. 5 is a left side elevation view of the vacuum system of FIG. 4 but with the upper panel shown;

FIG. 6 is a front elevational view of the vacuum system of FIGS. 4 and 5 with the upper panel shown;

FIG. 7 is a fragmented, enlarged left side elevational view showing a pivotable display of the portable curing system of FIGS. 1 to 6; and

FIG. 8 Is a block diagram schematically showing the curing system of FIGS. 1 to 7.

It should be understood that the appended drawings are not necessarily to scale, presenting a somewhat simplified representation of various preferred features illustrative of the basic principles of the invention. The specific design features of a portable curing system as disclosed herein, including, for example, specific dimensions, orientations, and shapes of the portable curing system components will be determined in part by the particular intended application and use environment. Certain features of the illustrated embodiments have been enlarged or distorted relative to others to facilitate visualization and clear understanding. In particular, thin features may be thickened, for example, for clarity or illustration. All references to direction and position, unless otherwise indicated, refer to the orientation of the portable curing system illustrated in the drawings. In general, up or upward refers to an upward direction within the plane of the paper in FIG. 1, and down or downward refers to a downward direction within the plane of the paper in FIG. 1. Also in general, vertical refers to an upward/downward direction within the plane of the paper in FIG. 1 and horizontal refers to a left/right direction within the plane of the paper in FIG. 1. Further in general, right refers to a rightward direction in FIG. 1 and left refers to a leftward direction in FIG. 1. Moreover in general, front or forward refers a direction out of the plane of the paper in FIG. 1 and rear or rearward refers to a direction into the plane of the paper in FIG. 1.

DETAILED DESCRIPTION OF CERTAIN PREFERRED EMBODIMENTS

It will be apparent to those skilled in the art, that is, to those who have knowledge or experience in this area of technology, that many uses and design variations are possible for the improved portable curing system or hot bonder disclosed herein. The following detailed discussion of various alternative and preferred embodiments will illustrate the general principles of the invention with reference to a portable curing system for use with a composite patch repair. Other embodiments suitable for other applications will be apparent to those skilled in the art given the benefit of this disclosure.

Referring now to the drawings, FIG. 1 illustrate a portable, self contained curing system or hot bonder 10 according to the present invention for on-site repair of metal bonded and composite epoxy structures. The portable curing system 10 includes a portable carrying case 12 having a main body 14 and a lid 16 hinged to the main body 14. The main body 14 and lid 16 cooperate to form an internal cavity to house and selectively enclose the various components of the curing system 10. The cavity is sized and shaped to self-contain the other components of the curing system 10. The main body 14 is generally rectangular-shaped having a generally flat bottom wall and front, rear and side walls upwardly depending from the bottom wall to a top opening. The lid 16 is sized and shaped for closing the top opening and is secured to the rear wall by at least one hinge 18. The lid 16 hinges between a closed position wherein the lid 16 closes the top opening and seals the cavity and an open position wherein the

18. The lid 16 hinges between a closed position wherein the lid 16 closes the top opening and seals the cavity and an open position wherein the cavity is accessible through the top opening. A pair of latches 20 are provided on the front wall for releasably securing the lid 16 in its closed position. A handle 22 is also provided in the front wall for manually carrying the carrying case 12. The illustrated carrying case 12 is about 24 inches by about 16 inches by about 8 inches but other suitable shapes and sizes can be utilized. The illustrated carrying case 12 is formed of a metal such as aluminum but any suitable rigid material can alternatively be utilized such as, plastic, fiberglass, or the like.

As best shown in FIGS. 2 and 3, contained within the carrying case 12 are an upper panel 24 visible when the lid 16 is in its open position and a lower panel 26 located in the carrying case 12 below the upper panel 24 and above the bottom wall of the carrying case 12. The upper and lower panels 24, 26 are preferably mounted within the case by shock mounts 28 to reduce shock and/or vibrational loads applied to components secures to the upper and lower panels 24, 26. Also contained within the carrying case 12 is a vacuum system 30, a temperature control system 32, a power system 34, a microprocessor-based controller 36, and input/output devices 38 operably connected to the controller 36.

As best shown in FIGS. 4 to 6, the illustrated vacuum system 30 includes an internal venturi vacuum pump 40, an air-in or supply port 42, an air-out or exhaust port 44, first and second vacuum ports 46, 48, and a manually operated control valve 50. The illustrated vacuum pump 40 is driven by compressed air to pump fluids to pull a vacuum. It is noted that other suitable types of vacuum pumps can alternatively be utilized such as, for example, an electric vacuum pump. The illustrated vacuum pump 40 is secured to the upper panel 24 below the upper panel 24 and at the right side of the carrying case 12 (as viewed in FIG. 1). The air supply port 42 is connected to an air inlet of the vacuum pump 40 and is adapted for receiving an air input line to connect a source of compressed air to the vacuum pump 40. The illustrated air supply port 42 extends through the upper panel 24 so that an inlet end of the port 42 is located above the upper panel 24 and an outlet end of the port 42 is located below the upper panel 24 at a front end of the vacuum pump 40. Mounted in this manner, the air input line can be easily connected to the port 42 when the lid 16 of the carrying case 12 is in its open position. The air exhaust port 44 is connected to an outlet of the vacuum pump 40 for exhausting fluids from the vacuum pump 40. The illustrated air exhaust port 44 extends through the upper panel 24 so that an outlet end of the port 44 is located above the upper panel 24 and an inlet end of the port 44 is located below the upper panel 24 at a rear end of the vacuum pump 40. Mounted in this manner, air or other fluid can be easily discharged to the surrounding environment when the lid 16 of the carrying case 12 is in its open position. Preferably, the exhaust port 44 is provided with a deflector shield and/or muffler.

The first and second vacuum ports 46, 48 are provided for connection of first and second vacuum lines to connect a vacuum bag, blanket or other device in which a vacuum is to be pulled. The first and second vacuum ports 46, 48 are connected in series to a vacuum inlet of the vacuum pump 40 and are adapted for receiving the vacuum lines. The illustrated first and second vacuum ports 46, 48 extend through the upper panel 24 so that inlet ends of the ports 46, 48 are located above the upper panel 24 and outlet ends of the ports 46, 48 are located below the upper panel 24 at a right side of the vacuum pump 40. Mounted in this manner, the vacuum lines can be easily connected to the ports 46, 48 when the lid 16 of the carrying case 12 is in its open position. The control valve 50 is located between the first and second vacuum ports 46, 48 and the vacuum pump 40 to control the flow of fluids to the vacuum pump 40. The illustrated control valve 50 is provided with an adjustment knob 52 so that the operator can manually adjust the level of vacuum provided through the vacuum lines by the vacuum pump 40. The illustrated control valve 50 extends through the upper panel 24 so that the adjustment knob 52 is located above the upper panel 24 and the valve portion located below the upper panel 24 at a right side of the vacuum pump 40 in the line between the vacuum pump 40 and the vacuum ports 46, 48. Mounted in this manner, the adjustment knob 52 can be easily adjusted when the lid 16 of the carrying case 12 is in its open position. It is noted that the adjustment knob 52 can alternatively be any other suitable operator control device. It is also noted that the illustrated manually-operated control valve 50 can alternatively be a electric or pneumatic-operated control valve or the like.

A first and second vacuum sensor connectors 54, 56 are preferably provided for connecting leads of vacuum sensors which provide signals indicating the vacuum level in the two zones or locations to which the vacuum lines are connected. The illustrated first and second vacuum sensor connectors 54, 56 extend through the upper panel 24 so that plug or inlet ends of the connectors 54, 56 are located above the upper panel 24 and outlet ends of the connectors 54, 56 are located below the upper panel 24 generally to the left of the vacuum pump 40. Below the upper panel 24, the outlet ends of the connectors 54, 56 are suitably connected to the controller 36 as described in more detail hereinafter. Mounted in this manner, the vacuum sensor lines can be easily plugged into the connectors 54, 56 when the lid 16 of the carrying case 12 is in its open position. While the illustrated embodiment is configured with two vacuum ports 46, 48 and two vacuum sensor connectors 54, 56 to pull and control vacuum in two zones or locations, it is noted that the vacuum system 30 can alternatively be configured to pull a vacuum in only one zone or more than two zones

zones or locations, it is noted that the vacuum system 30 can alternatively be configured to pull a vacuum in only one zone or more than two zones by provide one or more than two of the vacuum ports 46, 48 and the vacuum sensor connectors 54, 56.

The temperature control system 32 includes first and second heater connectors 58, 60 and first and second sets of temperature sensor connectors 62, 64. The heater connectors 58, 60 are provided for connecting the leads of a pair of electrical heaters which supply heat to the two zones or locations. The heaters are preferably electrical resistance heaters but can be of any suitable type. The illustrated first and second heater connectors 58, 60 extend through the upper panel 24 so that plug or inlet ends of the connectors 58, 60 are located above the upper panel 24 and outlet ends of the connectors 58, 60 are located below the upper panel 24 generally to the left of vacuum sensor connectors 54, 56. Below the upper panel 24, the outlet ends of the connectors 58, 60 are suitably connected to the controller 36 as described in more detail hereinafter. Mounted in this manner, the heater leads can be easily plugged into the connectors 58, 60 when the lid 16 of the carrying case 12 is in its open position.

The sets of temperature sensor connectors 62, 64 are provided for connecting the leads of temperature sensors such as, for example, thermocouples or any other suitable type of temperature sensor which supply signals indicating temperature in the tow zones or locations being heated. The illustrated embodiment includes ten temperature sensor connectors 62, 64 for each of the temperature sensors in the two zones or locations being heated. It is noted that less than ten or more than ten temperature sensor connectors 62, 64 can be provided for each zone or location being heated. The illustrated temperature connectors 62, 64 are type J thermocouple inputs but any suitable type of input can be utilized. The illustrated sets of temperature sensor connectors 62, 64 extend through the upper panel 24 so that plug or inlet ends of the connectors 62, 64 are located above the upper panel 24 and outlet ends of the connectors 62, 64 are located below the upper panel 24. Below the upper panel 24, the outlet ends of the connectors 62, 64 are suitably connected to the controller 36 as described in more detail hereinafter. Mounted in this manner, the temperature sensor leads can be easily plugged into the connectors 62, 64 when the lid 16 of the carrying case 12 is in its open position. The illustrated temperature sensor connectors 62, 64 are located along the rear edge of the upper panel 24 to the rear of the heater connectors 58, 60. While the illustrated embodiment is configured to control heaters and temperature sensors in the two zones or locations, it is noted that the temperature control system 32 can alternatively be configured to control a single heater and/or temperature sensor in only one zone or more than two heaters and/or temperature sensors in more than two zones or locations.

The power system 34 includes a power-in connector 66, a main power switch 68, and a power supply 70. The power-in connector 66 is provided for receiving a power cord for connecting a suitable power source. The illustrated power-in connector 66 extends through the upper panel 24 so that a plug or inlet end of the connector 66 is located above the upper panel 24 and an outlet end of the connector 66 is located below the upper panel 24. Below the upper panel 24, the outlet end of the connector 66 is suitably connected to the controller 36 as described in more detail hereinafter. Mounted in this manner, the power cord can be easily plugged into the connector 66 when the lid 16 of the carrying case 12 is in its open position. The illustrated power-in connector 66 is located to the left edge of the first heater connector 58 and forward of the first set of temperature sensor connectors 62.

The main power switch 68 is provided so that the operator can manually switch power to the entire curing system 10 on and off as desired. The illustrated main power switch 68 extends through the upper panel 24 so that a throw lever 72 of the switch 68 is located above the upper panel 24 and an outlet end of the switch 68 is located below the upper panel 24. Below the upper panel 24, the outlet end of the switch is suitably connected to the controller 36 as described in more detail hereinafter. Mounted in this manner, the throw lever 72 can be easily operated by the user when the lid 16 of the carrying case 12 is in its open position. The illustrated main power switch 68 is located to the left of the power-in connector along the left edge of the upper panel 24. preferably, the power switch 68 is provided with a test button 74.

The power supply 70 is provided to supply desired power to various electrical components of the curing system 10. The illustrated power supply 70 is back mounted to the lower panel 26 is located at the right side of the lower panel 26. The power supply is operably connected to the controller 36 and the other components. The curing system 10 preferably has an operating voltage of 110/220 VAC, auto-switching, but any suitable operating voltage can be utilized.

The microprocessor-based controller 36 includes processing means and memory means and is operably connected to the vacuum pump 40, the vacuum sensors connectors 54, 56, the heater connectors 58, 60, and the temperature sensor connectors 62, 64 to perform desired function in vacuum sensors connectors 54, 56, the heater connectors 58, 60, and the temperature sensor connectors 62, 64 to perform desired function in controlling the vacuum and temperature at the two zones or locations. Preferably, temperatures can be controlled over the range of about 0 degrees Fahrenheit to about 1400 degrees Fahrenheit and temperature ramp rates can be controlled from about 1 degree Fahrenheit/minute to about 36 degrees Fahrenheit/minute. Soak times are preferably selectable from about 0 to about 99.9 hours. The controller 36 is preferably a PID based controller which provides automatic, precisely controlled temperature rise, temperature dwell, dwell intervals, and temperature ramp down. Preferably, there can be fixed point, single, double, or triple ramp operation. The operator can chose to control via highest, lowest, average or specified thermocouple. Preferably, advanced control tuning of PID parameters provides accurate control during soak/dwell. The controller 36 preferably digitally logs all data both during and after a cure cycle. Preferably, data can be logged as fast as once every four seconds. In the event of power failure, the controller 36 preferably retains all status in non-volatile memory. If power returns within a predetermined period of time such as two minutes, the programmed cure cycle resumes at the point where power failed. If power is returned after the predetermined period of time, the cure cycle is aborted. Programs of the controller 36 are preferably password protected.

The illustrated controller 36 includes a central processing unit (CPU) 76, a plurality of thermal couple processors 78, a video driver 80, an input/output (I/O) board 82, and a personal computer (PC) adapter 84. The CPU 76 includes processing and memory means which are programmed to provide the desired functions of the curing system 10. The thermal couple processors 78 are adapted to process the signals from the thermo couples to determine the temperatures in the two zones or locations. The video driver 80 interfaces with the video display to provide desired output on the video display. The illustrated video driver is a VGA driver but alternatively any other suitable video driver can be utilized. The I/O board 82 interfaces with the various input/output devices as described in more detail hereinafter. The PC adapter 84 enables the controller 36 to interface with a personal computer to import or export data or programs. Also provided is a floppy drive interface 86 for interfacing with an internal floppy drive. Each of the illustrated components of the controller 36 are located on the lower panel 26. It is noted that the controller 36 can include any other desired components.

The input/output devices include a video display 88, an internal floppy drive 90, a personal computer (PC) port, and a printer 94. The video display 88 is preferably a full color graphical display which displays any desired information, including programming selections while setting up a cure cycle and current status during operation of a cure cycle, from the controller 36. The video display 88 is also preferably a touch screen which enables the operator to input desired information to the controller 36 by touching appropriate locations on the screen of the video display 88. Preferably, the controller 36 permits the operator to program desired cure cycles and other features and functions via the touch screen video display 88. The illustrated video display 88 is located on the top of the upper panel 24 and forward of the vacuum sensor connectors 54, 56 and the heater connectors 58, 60. Mounted in this manner, the video display 88 can be easily viewed and touched by the user when the lid 16 of the carrying case 12 is in its open position. The video display is suitably connected to the video driver 80 and the controller.

As best shown in FIG. 7, the touch-screen video display 88 is preferably pivotably mounted to the upper panel 24 within the carrying case 12 so that the video display 88 is pivotable between a stored position generally parallel to the upper panel 24, with the screen facing upward, and an operational or viewing position generally perpendicular to the upper panel 24, with the screen facing forward. The illustrated video display 88 is pivotable about a generally horizontal and laterally extending pivot axis 96 which is generally parallel to the upper panel 24. The video display preferably pivots at least about ninety degrees. Mounted in this manner, the operator can manually adjust the viewing angle of the video display 88 to a wide variety of viewing angles. The user-adjustable video display 88 also enables a relatively large video display 88 to be utilized yet stored within the carrying case 12 without increasing the size of the carrying case 12.

The internal floppy drive 90 is provided for program and data transfer with the controller 36 by means of magnetically recordable floppy discs or the like. The illustrated internal floppy drive 90 is located on the upper panel 24 and forward of the display 88. Mounted in this manner, the floppy drive 90 can be easily utilized by the user when the lid 16 of the carrying case 12 is in its open position. The internal floppy drive is operably connected to the floppy drive interface 86 and the controller 36.

The PC port 92 is provided for direct connection of a PC or other suitable computer to upload or download programs to the controller 36 or to upload or download cure data from the controller 36. The PC port 92 is suitable connected to the PC adapter 84 and the controller 36. Therefore, information including programs, operation status and post cure information can be saved to or read from disk via the floppy drive 90 or exported to or imported from a PC via the direct PC port 92. It is noted that the curing system 10 can alternatively be provided with means for wirelessly communicating the information to remote locations. It should also be apparent from the above detailed description that the system permits both local and remote monitoring of the vacuum.

The printer 94 is provided for printing cure data output, or other information, for each of the two zones or locations in a single hard copy document. It is noted that any desired information can be printed by the printer 94. The illustrated printer 94 is located at the forward edge of the upper panel 24 and to the left of the video display 88 and the floppy drive 90. The printer 94 is operably connected to the I/O board 82 and the controller 36. Preferably the printer 94 includes a paper feed button 95 for advancing paper in the printer 94.

Preferably visual and/or audible alarms 98, 100 are provided which are triggered in the event of fixed and/or programmed events. Fixed events can be, for example, an open loop thermocouple, a loop break, and/or a power loss. Programmable events can be, for example, a high temperature limit alarm, a high temperature limit shutdown, a low temperature limit alarm, a low temperature limit shutdown, a low vacuum, or a high vacuum. The visual and audible alarms are operably connected to the controller 36.

As best shown in FIG. 8, during use the portable curing system 10 is moved to the site of the repair and is operably connected to the heater bag or blanket or the like or a pair of heater bags or blankets or the like which define a pair of zones or locations to be controlled. The carrying case 12 is positioned at the desired on-site operating location resting on the bottom wall of the carrying case 12. The lid 16 is unlatched and pivoted to its open position so that access to the upper panel 24 is fully provided. The video display 88 is upwardly pivoted to its desired viewing position. The first and second vacuum ports 46, 48 are connected to the two vacuum ports of the heater blanket using the pair of vacuum lines. The first and second vacuum sensor connectors 54, 56 are connected to the two vacuum sensors by the pair of leads. The first and second heater connectors 58, 60 are connected to the pair of heaters by the pair of leads. The first and second sets of temperature sensor connectors 62, 64 are connected to the thermal couples by the twenty leads. The air inlet port 42 is connected to a source of air by an air line. The power-in connector 66 is connected to a power source by a power cord. The operator powers the curing system by manually activating the power switch 68. The operator then activates desired control programs and inputs desired control parameter or information via the touch-screen video display 88, the PC port 92, or the floppy drive 90. The controller 36 then controls the vacuum and temperature in the two zones in the desired manner. The operator can monitor and/or download curing conditions via the video display 88, the floppy drive 90, the PC port 92, or the printer 94. Once completed, cure history data is stored in memory and can be viewed and/or downloaded via the video display 88, the floppy drive 90, the PC port 92, or the printer 94. Once all the connections are removed, the video display screen 88 is downwardly pivoted to its storage position and the lid 16 is downwardly pivoted to its closed position and latched to the main body 14 of the carrying case 12. The portable curing system 10 can then be moved as desired to a new site.

From the foregoing disclosure and detailed description of certain preferred embodiments, it is also apparent that various modifications, additions and other alternative embodiments are possible without departing from the true scope and spirit of the present invention. The embodiments discussed were chosen and described to provide the best illustration of the principles of the present invention and its practical application to thereby enable one of ordinary skill in the art to utilize the invention in various embodiments and with various modifications as are suited to the particular use contemplated. All such modifications and variations are within the scope of the present invention as determined by the appended claims when interpreted in accordance with the benefit to which they are fairly, legally, and equitably entitled.

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United States Patent **7,789,643**
Lepola , et al. **September 7, 2010**

In situ pipe repair controller and system

Abstract

A control apparatus used in conjunction with tools and devices such as electrical power supplies, fluid pumps and vacuums for in situ repair of pipes. A method for controlling in situ repair of pipe using electrical power sources, fluid and pressure sources and flexible heat and inflation bladder installing thermal responsive repair materials and applying the repair material to the interior wall surface. The apparatus controls the inflation of the repair tool inserted into a pipe and the amount and rate of fluid pressure and maintenance of a selected pressure. The apparatus may also control the evacuation of the fluid from the bladder of the repair tool. The device controls the heating of the tool used in the installation of the repair material. The invention also teaches a method for controlled inflation and expansion of the bladder carrying the repair material to the area of the pipe to be repaired and heating the material at a rate and to a temperature to facilitate optimum curing or installation of the thermally responsive repair material. The invention also teaches the detachment of the repair material and removal of the repair tool. The method further includes the procedures necessary to complete the installation of these materials.

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Parent Case Text

CROSS REFERENCE TO RELATED APPLICATION

This application claims the benefit of and priority to U.S. Provisional Application No. 60/642,566 entitled "V-Pac Controller" and filed Jan. 10, 2005.

Claims

What is claimed is:

1. A pipe repair device controller comprising a fluid control component, an electrical power control component and a motor control component wherein the controller controls fluid pressure and electrical power to an inflatable and resistively heatable bladder of the repair device and moves the repair device by a winch.

2. A controller attachable to a fluid source, an electrical power source, a motor powered winch, and a repair device wherein the controller comprises a fluid control component, an electrical power control component, and a motor control wherein the fluid control component extends a bladder from the repair device and inflates the bladder to press a repair material to an inside pipe wall the electrical power control heats the inflation bladder of the repair device and moves the repair device by fluid pressure or a motor powered winch.

3. The controller of claim 2 further comprising controls to a winding mechanism.

4. The controller of claim 2 further comprising an SCR.

5. The controller of claim 2 further comprising a fluid input, a fluid output, an electrical input and an electrical output.

6. The controller of claim 2 further comprising a CPU.

Description

BACKGROUND OF INVENTION

1. Field of Invention

The present invention generally relates to a control apparatus and method used in conjunction with pipe repair devices. More specifically, the invention pertains to a control apparatus and method permitting the installation of a repair material controlled from a remote location using fluid pressure and electrically resistive or impedance heating to deploy, form and cure the repair material to the inside surface of a pipe.

2. Description of Related Art

The invention pertains to the field of pipe or conduit repair. An example is installing a lining to the interior surface of a pipe. Heated water or steam is sometimes used as part of the lining installation process. Resistive heating may also be used.

BRIEF SUMMARY OF THE INVENTION

The invention pertains to an in situ pipe repair device controller that is attachable to a fluid source, an electrical power source and an in situ pipe repair device. The controller subject of the invention comprises a fluid controlling component and an electrical power controlling component wherein the controller controls fluid pressure and electrical power to an inflatable and resistively heatable bladder of the in situ pipe repair device.

The features and advantages of the present invention will be apparent from the following description taken in conjunction with the accompanying drawings, which illustrate, by way of example, the principles of the invention. The scope of the invention however, is not limited to this description. Other benefits of the invention will also become apparent to those skilled in the art and such advantages and benefits are included within the scope of this invention.

BRIEF SUMMARY OF DRAWINGS

FIG. 1 illustrates a perspective view of the control apparatus of the invention.

FIG. 2 illustrates a front view of the control apparatus showing individual controls comprising one embodiment of the invention.

FIG. 3 is an electrical and fluid schematic depiction of the components of the embodiment of the control apparatus shown in FIG. 2.

FIG. 4 is a cross sectional illustration of a repair device within the interior of a pipe and the device comprising multiple heating zones that can be controlled by the invention.

FIG. 5 illustrates another embodiment of the control panel subject of the invention.

FIG. 5A illustrates a detail of the control panel showing controls for electrically powered winding mechanisms that may be used to pull a repair device through a pipe.

FIG. 6 illustrates the steps of loading and installation of repair material using a bladder deployment canister device that can be used with and controlled by the subject invention.

FIG. 7 illustrates the arrangement of the apparatus with the repair device, fluid source and electrical power supply used in one embodiment of the invention.

FIG. 7A illustrates a detail of a device within a pipe that is controlled by the invention.

FIG. 8 illustrates the bladder device component and repair material used with the deployment canister and the invention.

FIG. 8A illustrates a detail of the attachment of the open bladder end to the canister.

FIG. 8B illustrates a cross sectional view of the canister and rotatable spool (shown in phantom) used to convey and deploy the bladder.

FIG. 8C illustrates a prior art canister repair device showing control components placed on the canister housing.

FIG. 9 illustrates a perspective view of a spot repair device used in conjunction with the invention.

FIG. 9A is a detailed illustrated of one end of the spot repair device and the connecting components to the controller.

FIGS. 10A through 10E illustrate the steps of a repair process controlled by the device of the invention.

The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate preferred embodiments of the invention. These drawings, together with the general description of the invention given above and the detailed description of the preferred embodiments given below, serve to explain the principles of the invention.

DETAILED DESCRIPTION OF INVENTION

While this invention is susceptible of embodiments in many different forms, there is shown in the drawings and will herein be described in detail preferred embodiments of the invention with the understanding that the present disclosure is to be considered as an exemplification of the principles of the invention and is not intended to limit the broad aspect of the invention to the embodiments illustrated. The above general description and the following detailed description are merely illustrative of the subject invention and additional modes, advantages and particulars of this invention will be readily suggested to those skilled in the art without departing from the spirit and scope of the invention.

The present invention generally relates to a control apparatus (hereinafter "controller") and method to be used in conjunction with pipe repair tools and devices and ancillary components such as electrical power supplies, fluid pumps, air compressors and vacuum pumps. The controller may be part of a system for in situ repair of a pipe or conduit (hereinafter "pipe") by using electrical power sources, fluid and pressure sources and one or more pipe repair devices having heatable and inflatable components. The pipe repair tools or devices (hereinafter "repair devices") may be used for installing thermal responsive repair materials to the interior pipe wall surface. The controller may control the movement of the repair device within the pipe. The controller may control the inflation of the repair device by controlling the amount and rate of fluid pressure and maintenance of a selected pressure within the inflatable component. The controller may also control the evacuation of the fluid from the inflatable component (hereinafter "bladder") of the repair tool. The controller can also control the heating of the repair device used in the installation of the repair material. The controller may also include the capability of controlling the deployment of a bladder and the ancillary components at the repair material. The controller may also include the capability of controlling the deployment of a bladder and the ancillary components at the interface or junction of two pipes.

The invention also teaches a method for controlled inflation and expansion of the bladder (a repair device or component of a repair device) carrying the repair material to the area of the pipe to be repaired. The method also teaches heating the material at a rate and to a temperature to facilitate optimum curing or installation of the thermally responsive repair material. The invention also teaches the detachment of the repair material and removal of the repair device. The method further includes the procedures necessary to complete the installation of these materials.

The invention teaches a controller used in conjunction with various repair devices to accomplish in situ repair of pipes, including but not limited to underground pipes such as storm water and waste water pipes. The pipes can have a horizontal or vertical orientation. For example, the controller can be used in the lining of roof drain pipes. The invention can also be used in the repair of pipe used in chemical or other product manufacture or refining. The pipes can be of various materials, including but not limited to metal, plastic and concrete. The controller can contain or be used in conjunction with a CPU, data recorder, data or signal input output components and displays or printer. It may also be used with television cameras and monitors to facilitate the operator being able to visually monitor the deployment, placement and installation of the repair material into the pipe. The operator can also inspect the completion of repair prior to removal of all tooling, thereby avoiding the necessity of redeploying inspection devices.

It will be appreciated that in many instances, the location for the pipe repair is of very limited accessibility. The pipes may be of less than 6 inch diameter. The location for pipe repair can be in hazardous, unhealthy or harsh environments. It is often difficult to maneuver the repair material through the pipe to the necessary location. It is desired to have the repair device placed at an access port closest the repair location. This access location is also often harsh, dangerous or otherwise unsuitable for the device operator. It is therefore desirable that the operator of the repair devices be able to control the repair operations from a remote and less hazardous location. The can be accomplished by a single unit controlling multiple devices, components and operations.

FIG. 1 illustrates one embodiment of the in situ pipe repair controller. The controller 600 is, in one embodiment, contained in a portable case or container which can be attached to varying components such as an electrical power supply (a power source), air compressor (a fluid source), as well as the repair material installation device (repair device), such as a spot repair bladder, a lateral interface device or a bladder deployment canister (also known as a portable pipe repair system with electrically heated positioning member). The controller case is constructed of a lightweight but resilient resin plastic. The case and control panel may also include multiple "o-rings" or similar structures for moisture protection.

With reference to FIG. 2, the controller subject of the invention may comprise fluid controlling components, illustrated as a male type air hose attachment fitting (fluid input) 601, and a counter part female air hose attachment outlet (fluid output) 602; a fluid pressure gauge 603 for measuring fluid, e.g., air in pounds per square inch or equivalent; a fluid pressure control 604 and pressure release valve 605. The fluid controlling components may be utilized in conjunction with an inflatable bladder or inflatable component of the in situ pipe repair device.

The controller may include electrical power controlling components for one or more electrically powered winders or winches that can be utilized in conjunction with tether components of the pipe repair device. The tether components, controllably powered by the controller, can be used to deploy or pull (by winding and unwinding) the repair device and as shown in FIGS. 10A through 10E.

The electrical power controls may also include components for controlling electrical current powering a resistive heating component within the pipe repair device. In one embodiment, the controller will include electrical control components that may comprise a 240 volt electrical input 611, a 480 volt electrical input 612, and an emergency power shut off switch 613. The controller may include one or more motorized cooling fans (not shown) and one or more vents 614, electrical power outlets 615, 616, circuit breakers 622, potentiometer 621, a timer 617 and electrical power meter 618 such as an amp meter. The controller also may also comprise a power on/off switch 619 and an electrical power controller 620. The controller may also contain power indicators (pilots) 623, 624 for each of the 240 volt and 480 volt circuits. The controller may contain a thyristor or silicon controlled rectifier (SCR). It may also include thermisters and temperature gauges responsive to one or more thermocouples. (It will be appreciated that the thermocouples can be located in the repair material being installed inside the pipe or located with the repair material installation device.) The controller may also contain one or more temperature gauges. It may also contain one or more circuit switches (not shown), permitting electrical power to be alternatively directed to different heating circuits (heating components) within a repair device or actual repair material. This may be particularly advantageous in the repair of large diameter pipes.

detail repair material. This may be particularly advantageous in the repair of large diameter pipes.

In one embodiment, the controller may be utilized in conjunction with a programmable CPU or processing unit. For example, the controls may respond to data inputs from a laptop computer and the computer may record the time and temperature profiles of the cure cycle. Accordingly, the controller may contain a suitable data input component such as a USB port or fire wire connection.

In another embodiment, the controller also incorporates several operator safety features. These features include use of 120 VAC and 240 VAC power supplies, in conjunction with contacts and relays, to reduce the voltage at the controls to 12 volts. The operator is also protected from the high voltage power supply by a ground fault circuit interrupter (not shown). An additional safety component is the prominent emergency off switch. The time or hour meter can be used for prompting routine maintenance. A timer may also be used for tracking a heating cycle.

FIG. 3 illustrates an electrical and fluid schematic diagram of one embodiment of the invention. Power regulation may be achieved by a solid state SCR, allowing infinitely variable range of voltage to be delivered to the repair device or repair material ("load"). Due to the heat generated by the SCR, the controller includes two fans ("intake" and "exhaust"). The control function can be implemented utilizing a potentiometer or the controller may be configured to accept signals from a CPU or process controller (not shown). The SCR can control an intra-cycle "off" period. During this very short interval, an impedance measurement of the heating circuit can be taken. This measurement can be correlated to temperature.

As indicated, one embodiment of the controller includes the ability to monitor or control the temperature during the repair process. Monitoring can, of course, be combined with varying the power level to accurately maintain a desired heat level at differing sections or locations in conjunction to the repair material and location within the pipe. The silicon controlled rectifier (SCR) controls current flow from an electrical power source to the resistive heating elements using switching techniques. When the control signal is off, the SCR performs as an open switch and prevents the current from flowing from the SCR to the resistive heating elements. At this time, the impedance of the heating elements can be measured to identify the level of heat production. When the control signal is on, the SCR acts as a unidirectional switch and current can flow to the resistive heating elements in one direction. SCR power controls use three different switching modes; on-off, phase angle and zero-fired. On-off controls replicate the operation of an electro-mechanical contactor or relay. Phase angle control replicates the operation of variable transformers, providing variable control of the voltage impressed on the load. Because SCRs can be switched on at any time during each half cycle of the AC wave-form, the voltage to the resistive heating elements is infinitely variable from zero to 100%. Phase angle switching will be suitable and desired for control of the heating process controlled by the invention.

The impedance measurement referred to above can be the means for in-process temperature monitoring. A measuring system will be employed to provide a feedback signal to the SCR power supply. The conductive fibers present in the resistive heating elements have a dual purpose. During the "on" cycle of the SCR, these fibers will provide the heat necessary for processing. During the "off" cycle of the SCR, these fibers will be utilized as sensing electrodes to provide information back to the impedance measuring system, and in turn, to the SCR.

A direct correlation exists between the conductivity of the heating elements and temperature that enables an accurate depiction of heat generation to be determined continuously throughout the repair process. In this technique, data from the monitoring will be used as input for statistical process control (SPC). Software can be developed to identify the time at which critical points related to a specific event occur. This in turn will provide feedback to a component that will send a proportional signal to the SCR.

Temperature control and monitoring can also be achieved by use of thermocouples in the repair device bladder or repair material. The schematic includes a thermocouple read out and thermocouple input. Of course, electrically conductive signal leads will be needed between the controller and the thermocouple.

In the schematic illustrated in FIG. 3, the fluid pressure control 604A (shown to be pressurized air) is manually controlled. It will be appreciated that in other embodiments, the fluid pressure can be electronically controlled, including a control processor. This control can be integrated to the electrical heating cycle. In another embodiment, the controller of the invention can include a multiple pole switch to direct electric power to variable independent heating zones of a tool. A cross sectional view of such a bladder 102 having 4 heating zone components 261, 262, 263, 264 is illustrated in FIG. 4. A similar repair device is illustrated in FIG. 7A. Also illustrated in FIG. 4 is the relationship of the bladder to the interior of the pipe wall 185.

The schematic also illustrates the ability to control 480 volts of power. This may require use of a booster transformer pack, preferably in an outdoor "weather proof" casing. This booster pack 650, depicted in FIG. 7, doubles the voltage with a resulting decrease in amperage.

outdoor "weather proof" casing. This booster pack 650, depicted in FIG. 7, doubles the voltage with a resulting decrease in amperage.

FIGS. 5 and 5A illustrate another embodiment of the invention that can include motor controls 631, 632 for a spool or winches (winding mechanisms) attached to tether components used in the deployment or retraction of repair devices from the pipe system.

FIG. 7 illustrates a system and the relationship of the controller 600 within the system to the repair device 102, the electrical power supply 270 and the fluid supply source 190. Also illustrated is the electrical power cable 247 between the power supply and the booster 650 and the fluid supply hose 191 between the fluid supply and the controller, as well as the fluid hose 160 from the controller to the repair device. The electric cables 245A, 245B comprising both legs of the electric circuit created in the repair device are also illustrated. FIG. 7 further illustrates the tethers 302, 303 controlling movement of the repair device within the pipe 185, along with winches 312, 313 and the power cables 322, 323 extending from the controller.

FIG. 7A provides a detail of an embodiment of the connective components between the controller (not shown) and the repair device 102. Illustrated is a combined fluid hose 160 and electric cable 245 within a structure 246. Also illustrated are the two tethers 302, 303 at each end of the repair device, multiple heating components or zones 261, 262, 263 and connective wires 243, 244. Movement of the repair device within the pipe 185 is illustrated by the vector arrows 930, 940.

The method and system of the invention teaches using the controller with one or more repair devices that can convey repair material through the pipe to the repair location. These devices may also press the repair material to the inner pipe wall surface. Often the repair material is then heated. The heat is used to cure or mold the repair material to the pipe surface. These devices may include but are not limited to a bladder deployment canister, lateral interface devices, spot repair devices, as well as associated fluid compression or pumping/hydraulic components, hoses, electric cables and power supplies and fluid inflatable or electrically heatable bladder components. Examples of these devices or tools are described fully in pending application Ser. Nos. 10/182,889; 10/256,294; 10/174,188; and 11/313,170 which are incorporated by reference herein.

In one embodiment of the method taught by the invention, the control device is used in conjunction with a bladder deployment canister, a power supply and air compressor. FIG. 8 illustrates the electrical relationship between the bladder device component of the deployment canister (a repair device) and the controller 600. Illustrated is the electrical contact 712 of the canister housing (not shown) proximate to the open end 710A of the inverted bladder 740. (The open end of the bladder is attached to the bladder deployment port 710 of the canister as shown in FIG. 8B.) The inflatable and heatable bladder comprises a heating component 760 and an inflation component 710. The repair material is also illustrated 810. It will be appreciated that the repair material will be on the outside surface of the everted bladder. Also illustrated is the electrically connective subcomponent 713 at the closed end of the bladder and electrical wires 733, 734 forming the two legs of the electrical circuit with the heating component and the controller.

FIG. 8A illustrates a detail of the attachment of the open bladder end to the canister. The relationship of the bladder 740 and electrically conductive components of the canister 712, 733, 734, 770 with the controller 600 are again illustrated. Electrical cables 245A, 245B from the controller are in electrical communication with the electrical wires 733, 734 through the connective component 770. Also illustrated is a circular clamp device 748 holding the open end of the bladder to the bladder deployment port 710. The wall of the canister 609 and an o-ring 749 forming part of the fluid sealable connection between the open bladder end and the canister are also illustrated.

FIG. 8B illustrates a cross sectional view of an embodiment of the canister 700 and rotatable spool 760 used to convey and deploy the bladder through the bladder access port 710.

FIG. 8C illustrates a prior art view of the canister repair device showing a controller mechanism 600A placed on the canister housing. Illustrated are the fluid connecting components 601, 602 and an electrical connective component 771. The bladder deployment canister may be positioned proximate to the pipe access port. It will be appreciated that the controller of the invention permits the operator to control the repair function at a location remote from the pipe access.

The bladder deployment canister may provide storage, transportation and deployment of a flexible, heatable and inflatable bladder or repair material. The bladder component may comprise a fluid inflatable bladder having a cylindrical shape that is closed at one end and an open or closeable second end. The bladder has an interior wall surface and an exterior wall surface. The bladder incorporates electrically conductive closeable second end. The bladder has an interior wall surface and an exterior wall surface. The bladder incorporates electrically conductive material that, when energized with electric current controlled via the controller, can create impedance or resisitive heat (hereinafter "resistive heating") and a sub-component to attach an elongated tether sub-component on the inside bladder wall proximate to the closed bladder end. The tether sub-component has a first end and a second end. The second open end of the bladder can be sealably attached to an opening on the canister component. (See FIGS. 8 through 8B.) Some or all of these components may also be integral to the installed repair materials. For example, the repair material may contain the heating, inflation or temperature monitoring elements, all of which are left in place after completion of the repair.

The canister component, like the bladder, may be fluid sealable. The canister is not expandable and maintains a rigid or fixed volume. The interior of the canister (hereinafter "annulus") can be placed in fluid communication (via the controller) with an external fluid pressure or fluid vacuum source. The canister annulus contains a rotatable spool sub-component in communication with a rotating control mechanism. (See FIGS. 6 and 8B.) The spool also has a mechanism to attach the second tether end. Operation of the spool and tether can be controlled by the controller. The canister also contains an opening ("bladder deployment port") dimensioned to allow the bladder to pass through to be spooled on the spool or deployed out of the canister with fluid pressure. The bladder can be pulled into the canister and spooled on the internal spool and first spooling a portion of the tether (not shown), the closed end of the bladder being inverted into the remainder of the bladder by the pulling action of the spooling tether. In this manner, the flexible bladder operates like a sock being turned inside out. The canister opening also contains mechanisms for sealably attaching the second open end of the bladder. It will be appreciated that the bladder and canister are to be in fluid sealed communication. The canister also contains an electrical power sub-component to convey electrical current from a power source to the electrically conductive material of the bladder.

In utilizing the controller, the operator can activate the air compressor to pump air into the canister repair device, causing the bladder to extend and evert out from the canister. The operator may control the rate of inflation to achieve proper bladder deployment. The operator, using the controller, may also release the winding mechanism controlling the deployment/retraction tether. It will be appreciated that the winding component may be used when the deflated bladder is retracted into the deployment canister.

In one embodiment, when the operator has extended the bladder out of a canister, repair material can be placed on the exterior bladder surface. See FIG. 6, Steps 1 & 2.) The length of the bladder deployed can be controlled via the controller utilizing a gauge and the fluid regulator component.

The repair material can be flexible fibrous material containing heat reactive resin or polymer, either thermal setting or thermal plastic (hereinafter "resin"). The resin can be applied after the material is placed on the bladder or the repair material can be pre-impregnated.

Adjusting the motor controller (see FIG. 5A), the operator may retract the bladder, now containing the repair material, into the canister. FIG. 6, Step 3. The operator may decrease the fluid pressure or completely deflate the bladder. This may be accomplished by adjusting the fluid pressure controller that may, in turn, activate a pressure release valve or a vacuum pump in communication with the bladder and canister. In one embodiment, the tool retraction step may incorporate use of a tether (not shown) attached to the inside of the bladder and proximate to the closed end. The invention can control the winding mechanism(s) that may be attached to the tether, thereby allowing the operator to control the retraction of the bladder and repair material into the canister. It will be appreciated that the bladder can carry the repair material to the selected location within the pipe.

The controller can be utilized in multiple ways. The operational procedures as depicted in FIG. 6, Steps 1 through 7 can be summarized as follows:

Step 1. Unroll or festoon pre-impregnated repair material in preparation for loading into Canister. A staging area equal to the length of the repair is needed. This "loading" procedure can be performed off-site. Stable resin matrix allows up to 8 hours of "out-time" in cool conditions.

Step 2. Attach electrical power supply and hook-up air supply to controller and canister and set the fluid pressure controls to create a positive pressure within the canister. By increasing the fluid pressure and placing the motor controller in "neutral" or "forward", the inflation heating bladder is everted from the canister through the bladder access port and into the repair material. The motor controller controls the spool within the canister. The motor controller therefore can be used to control speed and length of the bladder everted from the canister.

The operator can, from a safe location, increase the fluid pressure to deploy or inflate the bladder or repair material. The fluid pressure is increased within the fixed volume of the canister. The increasing pressure will force the inverted bladder proximate to the inversion hose end to push outward to create a larger volume within the combined and fluid sealed canister and bladder. Stated another way, the operator increases the internal volume of the closed canister bladder system by increasing the fluid pressure. This expansion can be facilitated by the controlled release of the tether attached to the bladder and windable spool. This will loosen the collapsed bladder and tether spooled around the spindle.

Step 3. With bladder fully extended through the length of repair material, set the motor controls to "reverse" and adjust the fluid pressure controller to an "exhaust" setting or otherwise to a negative pressure. This adjustment may automatically open a pressure relief valve. In another embodiment, the exhaust setting may activate a vacuum pump. In another embodiment, the end of the repair material may be tucked into the reverting (inverting) face of the bladder, and is pulled into the bladder as it is spooled back into the canister. The motor controller may also control the rewinding of the tether and inverted bladder onto the spool. The motor controller will be placed in "reverse".

Step 5. Position the bladder access port (or alternatively the end of an inversion hose attached to the bladder access port) at the pipe access port. Attach the electrical power supply and the fluid supply as in Step 2.

The loading procedures (Step 2) may determine where the repair material will actually begin to unfurl. In other words, the location of loading the repair material on the deployed bladder in Step 2 above may be varied. This can be especially useful when inserting through clean-outs, tee's and wye's. In one embodiment, the controller may include a footage counter (component to measure the length of the bladder deployed from the canister). A consumable, temperature sensor (in communication with the controller) can also be inserted into the host pipe to provide feedback to the power controls (not shown).

Step 5. Set the fluid pressure controls to create a positive pressure in the canister sufficient to commence eversion. Eversion speed may be controlled via adjustment of fluid pressure and turning of the spool. In one embodiment, the motor controls (positioned in "forward") may contain a variable speed component. The operator, utilizing the controller, continues to maintain a pressure level by addition of additional fluid volume in response to the everting bladder.

Step 6 illustrates a continuation of this process, with the repair material now on the outside surface of the bladder, extending into the pipe. When the bladder and repair material are deployed to a desired distance within the pipe, the operator can stop the addition of additional fluid and stop the release of additional lengths of tether, thereby holding the inflated bladder at a stationary position within the pipe. A footage counter located on the controller can indicate complete deployment of material on the everting bladder.

The fluid pressure can be further increased to the deployed segment of bladder inflate the bladder in a radial direction, thereby pressing the bladder wall, with the repair material, to the inside pipe wall surface.

In one embodiment, the controller may incorporate a CPU or process controller. A display monitor and data recorder can also be employed. In such an embodiment, the temperature sensor located proximate to the repair material is connected to the controller and a programmable electronic controller may implement the cure of the repair material. Complete cure is indicated on the controller. It will be appreciated that the controller (and operator) may be positioned away from the pipe access port.

In the described and illustrated embodiment the operator may energize the electrically conductive material (not shown) within the bladder with electric current. This can be accomplished using the power controller. This will create the resisitive heat that can cure the heat responsive resin. The operator can control the rate of heat increase and the amount of heat generated by utilizing the potentiometer or power controller to regulate the amount of electrical current.

The controller may monitor the temperature of the bladder or repair material by various methods, including but not limited to thermocouples within selected location on the bladder or by one or more consumable thermocouples placed in the repair material and in detachable communication with the control device. Utilizing the controls, the temperature can be maintained for a selected time to allow cure of a thermosetting resin within the repair material or molding of thermoplastic resin impregnated repair material to the interior of the pipe. The operator can adjust the current to also control the rate of cool down. Upon completion of this cure process or molding step, the power controller may be adjusted to zero or "off" and the operator may commence the repair device removal steps.

Step 7. With cure complete, set fluid controller to a decreased pressure setting at least sufficient to reduce the bladder diameter or to collapse the

Step 7. With cure complete, set fluid controller to a decreased pressure setting at least sufficient to reduce the bladder diameter or to collapse the bladder. The spool can be controllably rotated to rewind the tether and bladder, re-inverting the heating inflation bladder back into canister. This can be accomplished by setting the motor controller to "reverse". Step 7 illustrates the removal of the repair bladder device from the pipe. The removal step is the same as illustrated in FIG. 6, Step 3, but the pipe repair material, now cured, remains in a rigid or fixed position pressed against the inner pipe wall surface.

Other in situ pipe repair devices that are controlled by the invention may not utilize a bladder deployed from a fluid sealed canister. Such a device is the spot repair bladder illustrated in FIGS. 9 and 9A. FIG. 9 illustrates a perspective view of a spot repair device 102 used in conjunction with the invention. Included in the illustration are the tethers 302, 303, the connective wires 243, 244 in communication with the heating element 260 disposed within the bladder and combined into the electrical cable 245 connected to the controller (not shown). FIG. 9A is a detailed illustration of one end of the spot repair device and the connecting components to the controller. Included in the illustration are the fluid conveying hose 160 and the electrical cable 245 combined into a single subcomponent 246 communicating with the controller. The electrical wires 243, 244 communicating with the heating component and combined into the electrical cable 245 are also illustrated.

FIGS. 10A through 10E illustrate the steps of a repair process utilizing the spot repair device controlled by the controller of the invention. With reference to FIGS. 10A through 10E, this device 102 containing the repair material 550 may be deployed into the pipe 185 by a tether 302 controlled by the controller (not shown). The device may be pulled within the pipe to the repair location by a winch or similar device. The winding motion of the winch is controlled by a first motor controller. The direction of movement is illustrated by vector arrow 930. When the operator has positioned the bladder proximate to the repair location 549, FIG. 10B, the operator can then utilize the fluid pressure control components of the controller to inflate the bladder, FIG. 10C, to press the repair material to the inner pipe wall surface. This step can be accomplished by adjusting the fluid pressure to a positive setting.

After adequate inflation is achieved (the operator being able to monitor the fluid pressure using the fluid pressure gauge), the operator is able to energize the heating component using the power controller. The amount of heat can be monitored and controlled by the operator utilizing the potentiometer or power controller in conjunction with thermocouples or the SCR device and impedance measurements. The duration of the heating can be measured by the timer contained within the invention. In other embodiments, the controller may incorporate a programmable CPU or process controller to control the amount and duration of heat and fluid pressure. A display monitor and data recorder can also be employed. After the operator has determined that the repair material has adequately been heated, for example, to affect a desired cure of a thermosetting resin matrix of the repair material, the electrical power can be reduced or turned off.

One step of the retraction process of the tool from the pipe is the reduction of pressure within the bladder. This step can be facilitated by creating a negative pressure by use of a vacuum pump controlled by the controller. The deflation of the bladder is important to the separation of the repair material from the outer surface of the bladder. After the operator has sufficiently deflated the bladder, FIG. 10D, the operator may then activate a second winding motor attached to a tether 303 connected to the bladder, thereby pulling the deflated bladder from the pipe. The retraction is shown in FIG. 10E by vector arrow 940.

In another embodiment, the controller may be used in the repair of the interface or connection of two pipes. The may be accomplished utilizing the Lateral Interface Device (a repair device) described in application Ser. No. 10/182,889.

While specific embodiments have been illustrated and described, numerous modifications are possible without departing from the spirit of the invention, and the scope of protection is only limited by the scope of the accompanying claims.

* * * * *

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Definitions

adjective

1. of or relating to ergonomics
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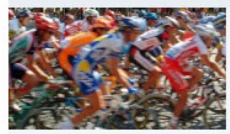

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