(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 590 611 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
08.01.2020 Bulletin 2020/02

(21) Application number: **19182868.0**

(22) Date of filing: **27.06.2019**

(51) Int Cl.:
B05D 3/02 *(2006.01)* ***B32B 7/027*** *(2019.01)*
F28F 19/02 *(2006.01)* ***F28F 21/08*** *(2006.01)*
B05D 5/00 (2006.01) *B05D 7/14 (2006.01)*

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(30) Priority: **02.07.2018 US 201816025453**

(71) Applicant: **Hamilton Sundstrand Corporation**
Charlotte, NC 28217-4578 (US)

(72) Inventor: **GAGE, Marc E.**
Feeding Hills, MA Massachusetts 01030 (US)

(74) Representative: **Dehns**
St. Bride's House
10 Salisbury Square
London EC4Y 8JD (GB)

(54) CORROSION RESISTANT COATING FOR A HIGH TEMPERATURE HEAT EXCHANGER

(57) A method of manufacturing a high temperature heat exchanger that includes providing a heat exchanger made of at least one of nickel and a nickel metal alloy, applying a silicone aluminum coating to the heat exchanger, drying the silicone aluminum coating at a first temperature for a first time period, and curing the silicone aluminum coating at a second temperature for a second time period, such that a ceramic coating is formed.

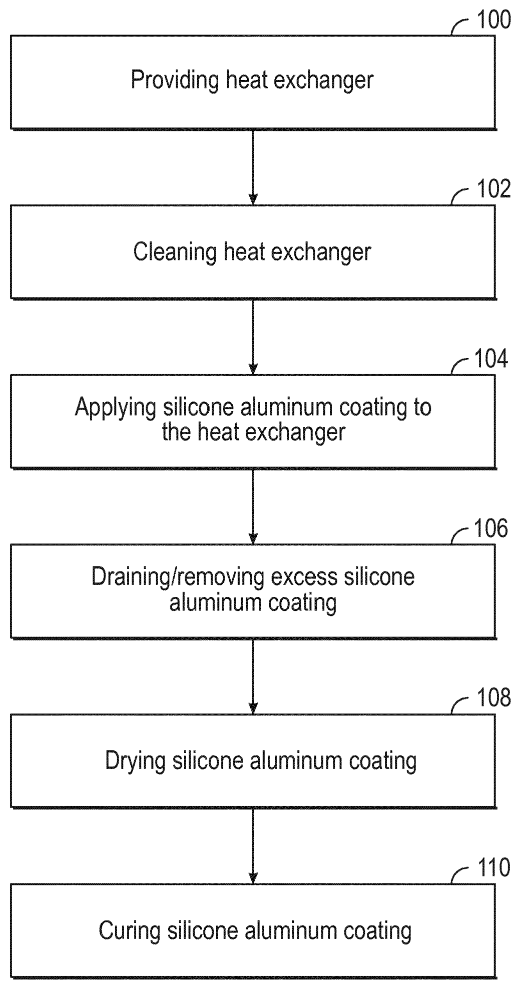

FIG. 1

Printed by Jouve, 75001 PARIS (FR)

Description

BACKGROUND

[0001] A variety of coatings may be applied to heat exchangers that may operate at elevated temperatures. The coatings are arranged to prevent corrosion while also improving the temperature resistance of the heat exchanger. However in some high temperature environments corrosive gases or materials may be present that may corrode the heat exchangers.

SUMMARY

[0002] Disclosed is a method of coating a metal substrate that includes applying a silicone aluminum coating to a metal substrate, drying the silicone aluminum coating at a first temperature for a first time period, and curing the silicone aluminum coating at a second temperature for a second time period. The second temperature being greater than the first temperature and the second time period being greater than the first time period.

[0003] Also disclosed is a method of manufacturing a high temperature heat exchanger that includes providing a heat exchanger made of at least one of nickel and a nickel metal alloy, applying a silicone aluminum coating to the heat exchanger, drying the silicone aluminum coating at a first temperature for a first time period, and curing the silicone aluminum coating at a second temperature for a second time period, such that a ceramic coating is formed.

[0004] These and other advantages and features will become more apparent from the following description taken in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] The subject matter which is regarded as the present disclosure is particularly pointed out and distinctly claimed in the claims at the conclusion of the specification. The foregoing and other features, and advantages of the present disclosure are apparent from the following detailed description taken in conjunction with the accompanying drawings in which:

FIG. 1 is a flowchart of an illustrative method of manufacturing a high temperature heat exchanger having a corrosion resistant coating.

DETAILED DESCRIPTION

[0006] Referring now to the Figures, where the present disclosure will be described with reference to specific embodiments, without limiting same, it is to be understood that the disclosed embodiments are merely illustrative of the present disclosure that may be embodied in various and alternative forms. The figures are not necessarily to scale; some features may be exaggerated or minimized to show details of particular components. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a representative basis for teaching one skilled in the art to variously employ the present disclosure.

[0007] A metal substrate such as a heat exchanger may be provided with a system such as an aircraft air management system or an environmental control system. The heat exchanger is provided for thermal management of the aircraft air management system of the environmental control system. The heat exchanger may operate in elevated temperatures such that the heat exchanger may be fabricated using nickel, nickel metal alloys, or other high temperature capable material that are capable of withstanding the elevated temperatures. The heat exchanger may be operated in a potentially corrosive environment due to the presence of chlorine, sulfur, or the like. Present coatings and coating processes that are used to prevent corrosion, such as in aluminum heat exchangers or on ferrous metal heat exchangers, are not suitable for operating temperatures within the range of 800°F and 1200°F.

[0008] The heat exchanger that may be made of nickel or nickel metal alloy substrate is coated with a silicone-aluminum coating that is converted into a ceramic coating due to the curing at an elevated temperature. The resultant ceramic coating improves the thermal protection or corrosion resistance of the nickel metal heat exchanger.

[0009] The coating may include aluminum flakes/aluminum particles that are combined with a silicone polymer emulsion or a silicone resin emulsion, such that the coating is an aluminum pigmented silicone coating. The aluminum flakes or aluminum particles may serve as a filler material or a pigment for the silicone polymer or the silicone resin. The silicone polymer emulsion or the silicone resin emulsion may contain trace amounts or may be intentionally provided with organic compounds or organic portions.

[0010] Aluminum pigmented silicone coatings improve the maximum temperature resistance of the resultant coating. The aluminum pigmented silicone coating have a unique property that make them suitable for the corrosion protection of nickel metal heat exchangers at elevated temperatures that enable the organic portions of the coating to be oxidized at elevated temperatures and subsequently be converted to a ceramic coating.

[0011] The conversion of the aluminum pigmented silicone coating at elevated temperatures converts the coating to a ceramic coating, which permits the nickel metal heat exchanger to continuously withstand high temperatures and inhibit corrosion within the operating environment. An example of this aluminum pigmented silicone coating may be WSA15-SN5001, however other aluminum pigmented silicone coatings are also possible. The use of the aluminum pigmented silicone coating also enables the thickness of the resultant ceramic coating to have a thickness that is substantially less than the thickness of other anti-corrosion coatings. For example, a thickness of the resulting ceramic coating of the present disclosure may be less than 1 mil (0.0254 mm) while still providing enhanced corrosion protection and temperature protection for nickel metal heat exchangers.

[0012] The silicone-aluminum coating may have a composition that includes (i) approximately 11.3% by weight of deionized or distilled water, (ii) approximately 0.6% by weight of a surfactant, (iii) approximately 11.3% by weight of an uncoated aluminum powder or aluminum particles (e.g. aluminum pigment), (iv) approximately 49.7% by weight of a silicone resin emulsion, (v) approximately 27% by weight of deionized or distilled water, and (vi) approximately 0.08% by weight of an antimicrobial or bactericide.

[0013] The silicone-aluminum coating composition may be prepared by blending and dissolving the water (i) and the surfactant (ii). Adding the filler material or dispersion (iii) (e.g. the aluminum pigment) to the resulting water solution, soaking, then agitating the dispersion. The dispersion may be agitated. A letdown is prepared by blending the silicone resin emulsion (iv), the water (v), and the antimicrobial/bactericide (vi). The letdown is allowed to dissolve and the dispersion is then added to the letdown. The resultant admixture is allowed to fully disperse, leading to the silicone-aluminum coating composition.

[0014] The heat exchanger may be manufactured at least partially using the following process. At block 100 a heat exchanger made of a nickel metal material is provided. The heat exchanger is a heat exchanger that is capable of performing in a high temperature and corrosive environment.

[0015] At block 102, the heat exchanger may be cleaned. The heat exchanger may be cleaned to prepare the surfaces of the heat exchanger to receive the silicone aluminum coating.

[0016] At block 104 the silicone aluminum coating is applied to the heat exchanger. The silicone aluminum coating maybe applied by filling, pouring, coating, or otherwise distributed about or within the heat exchanger. The silicone aluminum coating may be provided as a liquid. The exchanger may also be dipped or immersed within the silicone aluminum coating.

[0017] At block 106, draining/removing excess silicone aluminum coating from the heat exchanger is accomplished. In at least one embodiment, an airflow may be introduced through passages of the heat exchanger to remove excess silicone aluminum coating from the passages. The airflow may be provided by a blower that blows air down or through the passages.

[0018] At block 108, the silicone aluminum coating may be dried for a first time period at a first temperature. The first time period may be approximately 45 minutes. The first temperature may be approximately 300°F (149°C).

[0019] At block 110, the heat exchanger coated with the silicone aluminum coating may be fired or cured within a furnace at a second temperature for second time period. The furnace may be an ambient air furnace or a controlled atmosphere furnace. The second temperature may be within the range of 800°F (427°C) to 1200°F (650°C). Higher temperatures may be suitable as well, but have not been investigated. Preferably, the second temperature may be approximately 1200°F (650°C). The second time period may be approximately four hours. It was surprisingly discovered that curing the silicone aluminum coating on a nickel metal heat exchanger for approximately four hours at 1200°F (650°C) provided a thin ceramic coating of less than 1 mil (0.0254 mm).

[0020] The curing of the silicone aluminum coating at the second temperature for the second time period leads to the conversion of the silicone aluminum coating to a ceramic coating by the oxidation of the organic portions of the silicone aluminum coating. The ceramic coating is a corrosion resistant coating that provides a barrier to inhibit corrosion of the nickel metal heat exchanger while also improving the temperature resistance of the nickel metal heat exchanger.

[0021] The heat exchanger may also be made of other materials besides nickel or a nickel metal alloy that may reduce the weight, increase the volume, and decrease the cost of the heat exchanger while providing the same heat transfer performance as the nickel metal heat exchanger.

[0022] While the present disclosure has been described in detail in connection with only a limited number of embodiments, it should be readily understood that the present disclosure is not limited to such disclosed embodiments. Rather, the present disclosure can be modified to incorporate any number of variations, alterations, substitutions or equivalent arrangements not heretofore described, but which are commensurate with the scope of the present disclosure. Additionally, while various embodiments of the present disclosure have been described, it is to be understood that aspects of the present disclosure may include only some of the described embodiments. Accordingly, the present disclosure is not to be seen as limited by the foregoing description.

Claims

1. A method of coating a metal substrate, comprising:

   applying a silicone aluminum coating to a metal substrate;
   drying the silicone aluminum coating at a first temperature for a first time period; and
   curing the silicone aluminum coating at a second temperature for a second time period, the second temperature being greater than the first temperature and the second time period being greater than the first time period.

2. The method of claim 1, wherein the first temperature is 300°F (149°C).

3. The method of claims 1 or 2, wherein the second temperature is 1200°F (650°C).

4. The method of any preceding claim, wherein the second time period is four hours.

5. The method of any preceding claim, wherein the silicone aluminum coating includes aluminum particles combined with at least one of a silicone polymer emulsion and a silicone resin emulsion.

6. The method of any preceding claim, wherein the metal substrate is a nickel metal heat exchanger.

7. The method of any preceding claim, wherein curing the silicone aluminum coating at a second temperature for a second time period converts the silicone aluminum coating to a ceramic coating, and preferably wherein the ceramic coating has a thickness of less than 1 mil (0.0254 mm).

8. A method of manufacturing a high temperature heat exchanger, comprising:

   providing a heat exchanger made of at least one of nickel and a nickel metal alloy;
   applying a silicone aluminum coating to the heat exchanger;
   drying the silicone aluminum coating at a first temperature for a first time period; and
   curing the silicone aluminum coating at a second temperature for a second time period, such that a ceramic coating is formed.

9. The method of claim 8, further comprising: cleaning the heat exchanger.

10. The method of claims 8 or 9, further comprising: removing excess silicone aluminum coating.

11. The method of any of claims 8-10, wherein the second temperature is greater than the first temperature and the second time period is greater than the second time period.

12. The method of any of claims 8-11, wherein the second temperature is greater than 800°F (427°C).

13. The method of any of claims 8-13, wherein the second temperature is at least 1200°F (650°C).

14. The method of any of claim 8-13, wherein the silicone aluminum coating includes aluminum particles combined with at least one of a silicone polymer emulsion and a silicone resin emulsion.

15. The method of any of claims 8-14 wherein the ceramic coating has a thickness of less than 1 mil (0.0254 mm).

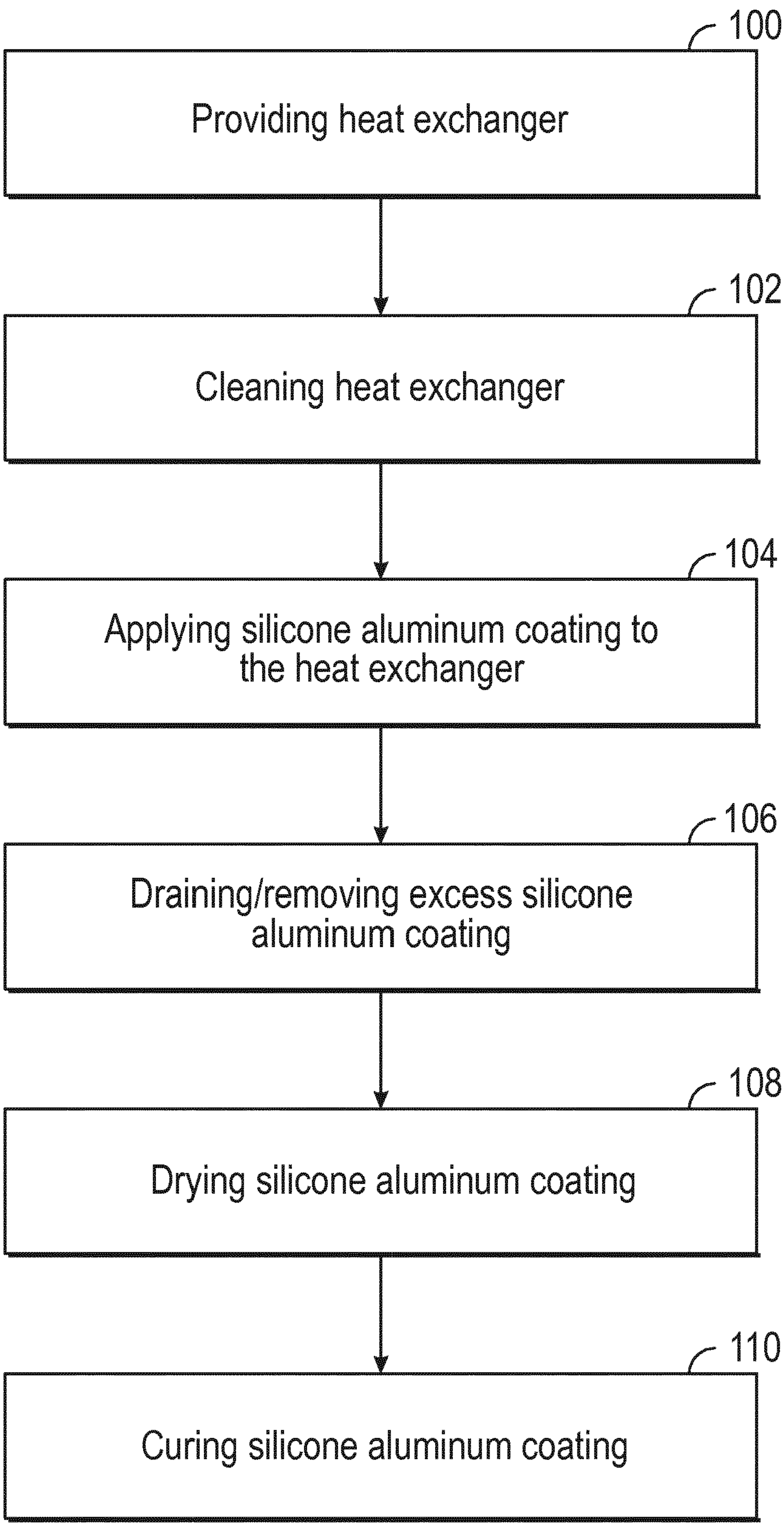
100
Providing heat exchanger
102
Cleaning heat exchanger
104
Applying silicone aluminum coating to the heat exchanger
106
Draining/removing excess silicone aluminum coating
108
Drying silicone aluminum coating
110
Curing silicone aluminum coating

FIG. 1

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 19 18 2868

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y A	US 2014/005294 A1 (GAGE MARC E [US] ET AL) 2 January 2014 (2014-01-02) * paragraph [0001] - paragraph [0003] * * paragraph [0005] * * paragraph [0035] - paragraph [0041] *	1,2,4,5 6 3,7-15	INV. B05D3/02 B32B7/027 F28F19/02 F28F21/08
Y A	EP 3 339 466 A1 (KELVION SP Z O O [PL]) 27 June 2018 (2018-06-27) * paragraph [0001] * * paragraph [0012] - paragraph [0013] * * paragraph [0015] * * paragraph [0021] - paragraph [0023] *	6 1-5,7-15	ADD. B05D5/00 B05D7/14
X A	JP H09 133366 A (SHARP KK) 20 May 1997 (1997-05-20) * abstract * * paragraph [0022] - paragraph [0026] * * paragraph [0030] * * paragraph [0037] *	1,2,5,7 3,4,6, 8-15	
X A	US 2015/275044 A1 (ROTH MARCEL [DE] ET AL) 1 October 2015 (2015-10-01) * paragraph [0001] * * paragraph [0014] * * paragraph [0038] - paragraph [0039] * * paragraph [0046] - paragraph [0047] * * paragraph [0067] * * paragraph [0077] * * paragraph [0081] *	1-5,7 6,8-15	TECHNICAL FIELDS SEARCHED (IPC) B05D B32B F28F

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	26 November 2019	Maxisch, Thomas

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 19 18 2868

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

26-11-2019

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2014005294 A1	02-01-2014	NONE	
EP 3339466 A1	27-06-2018	NONE	
JP H09133366 A	20-05-1997	JP 3304249 B2	22-07-2002
		JP H09133366 A	20-05-1997
US 2015275044 A1	01-10-2015	AU 2013363910 A1	09-07-2015
		CA 2894388 A1	26-06-2014
		CN 104903412 A	09-09-2015
		EP 2743320 A1	18-06-2014
		ES 2542103 T3	30-07-2015
		JP 6329966 B2	23-05-2018
		JP 2016508865 A	24-03-2016
		KR 20150096506 A	24-08-2015
		US 2015275044 A1	01-10-2015
		WO 2014095643 A1	26-06-2014

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82