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(54) DEICING SYSTEM INTEGRATED WITH AN AIR MANAGEMENT SYSTEM AND ADVANCED INLET AIR CONNECTION VALVE

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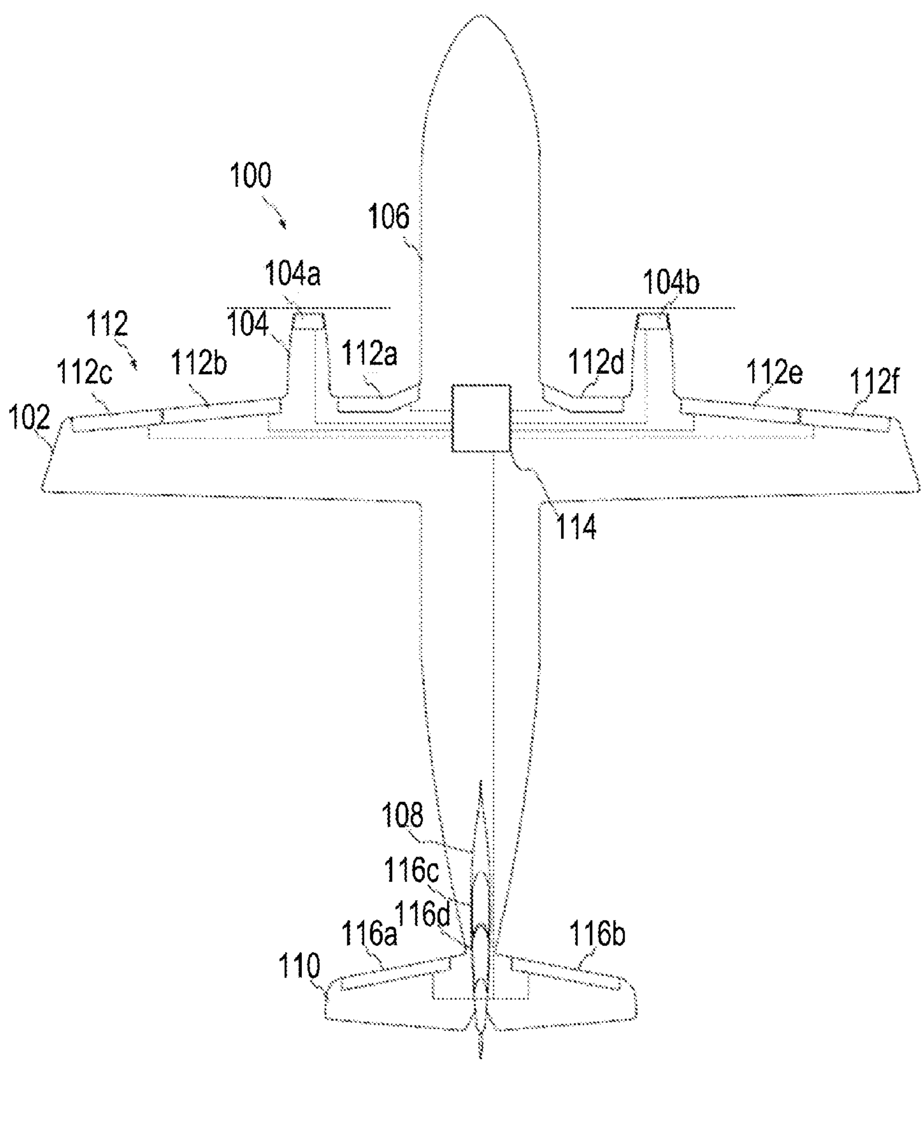
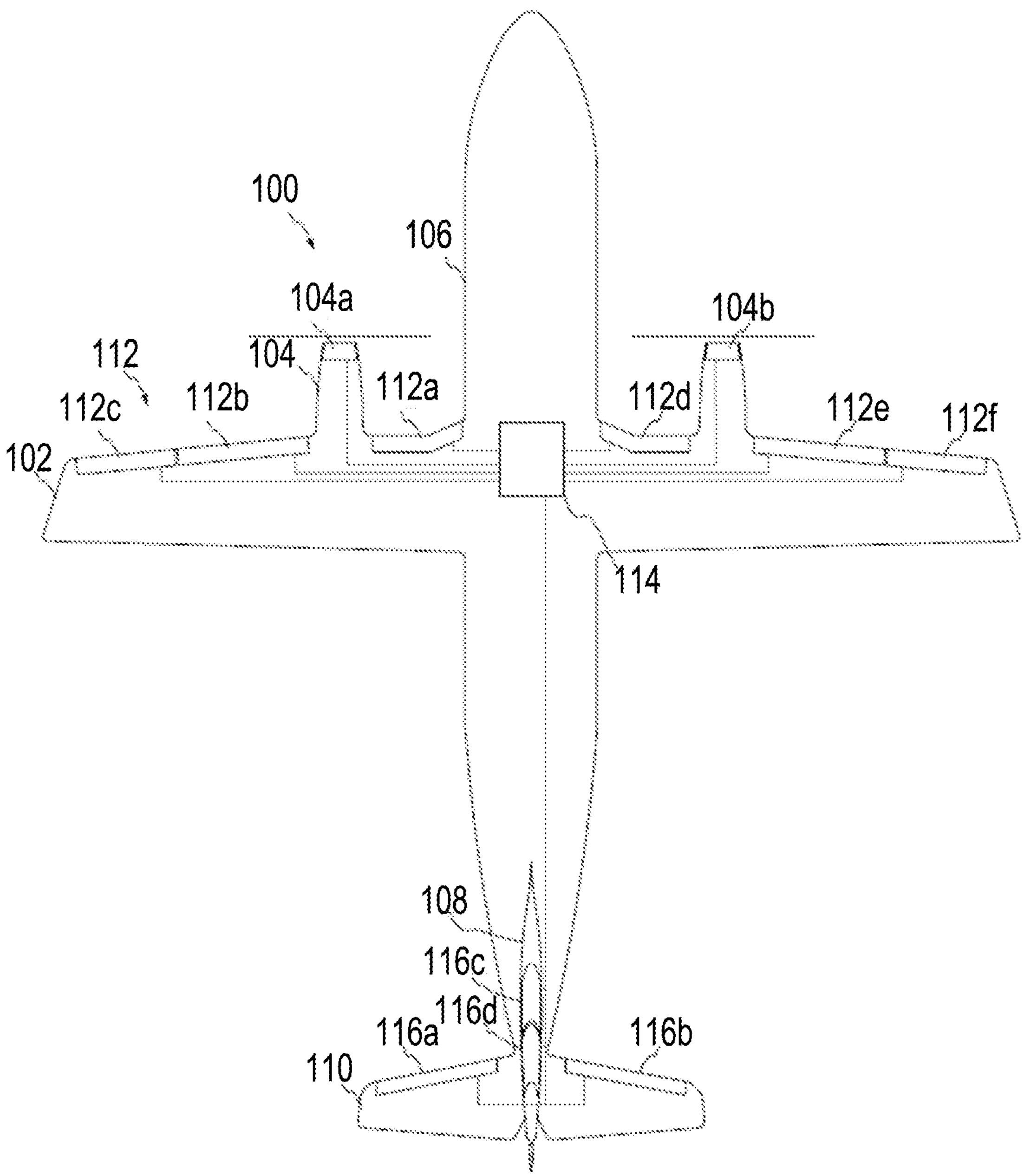
(57) **ABSTRACT**

A pneumatic de-icing system is provided. In some embodiments, the pneumatic de-icing system includes a de-icer flow valve, an accumulator, and a source control valve. The source control valve is configured to supply pressurized air to the at least one de-icer flow valve from either the accumulator or a pressurized cabin depending on a differential air pressure between an air pressure in the pressurized cabin and an ambient air pressure surrounding an aircraft. In some embodiments, pneumatic de-icing system includes a de-icing assembly, a pneumatic inlet valve, a de-icer flow valve, and an ejector. The de-icer flow valve is configured to supply pressurized air to the pneumatic inlet valve during an icing event. The ejector is configured to supply a vacuum to the pneumatic inlet valve.

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106
104a
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110

FIG.1

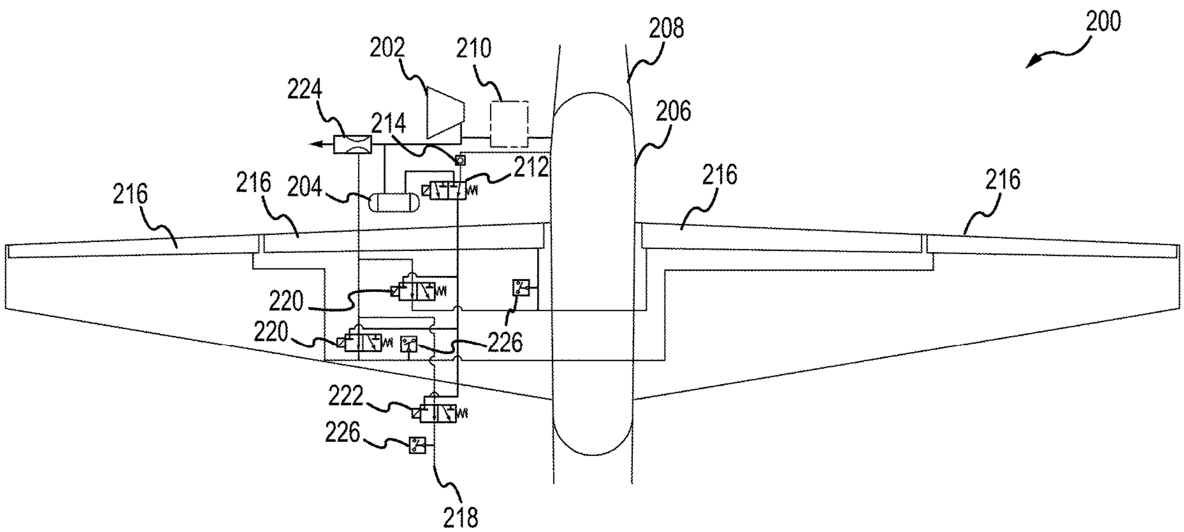
200
202
210
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FIG.2

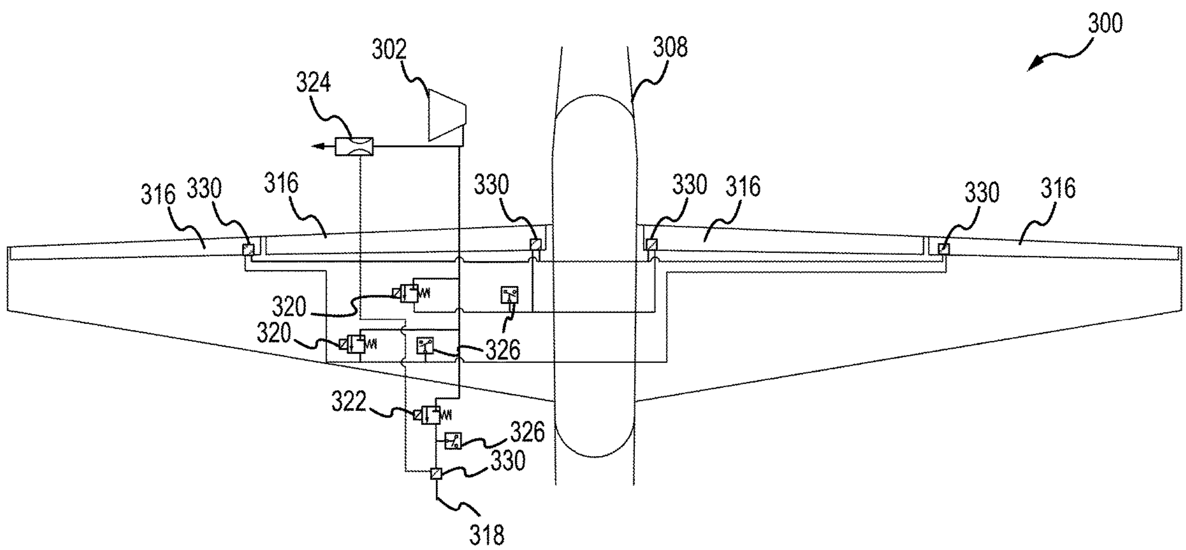
300
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FIG.3

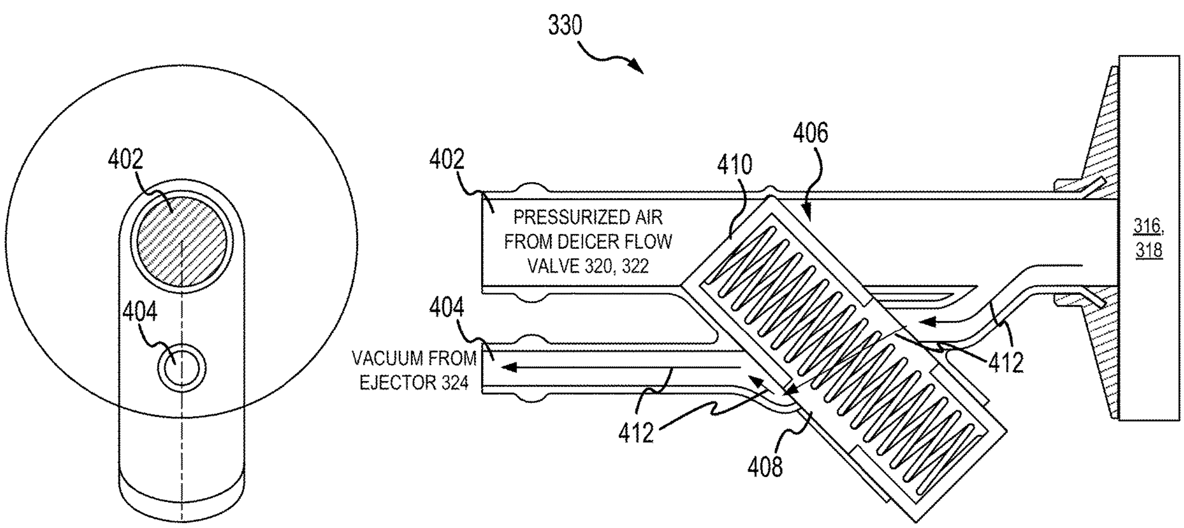
330
402
404
402
406
410
PRESSURIZED AIR
FROM DEICER FLOW
VALVE 320, 322
316,
318
404
VACUUM FROM
EJECTOR 324
412
412
408

FIG.4A

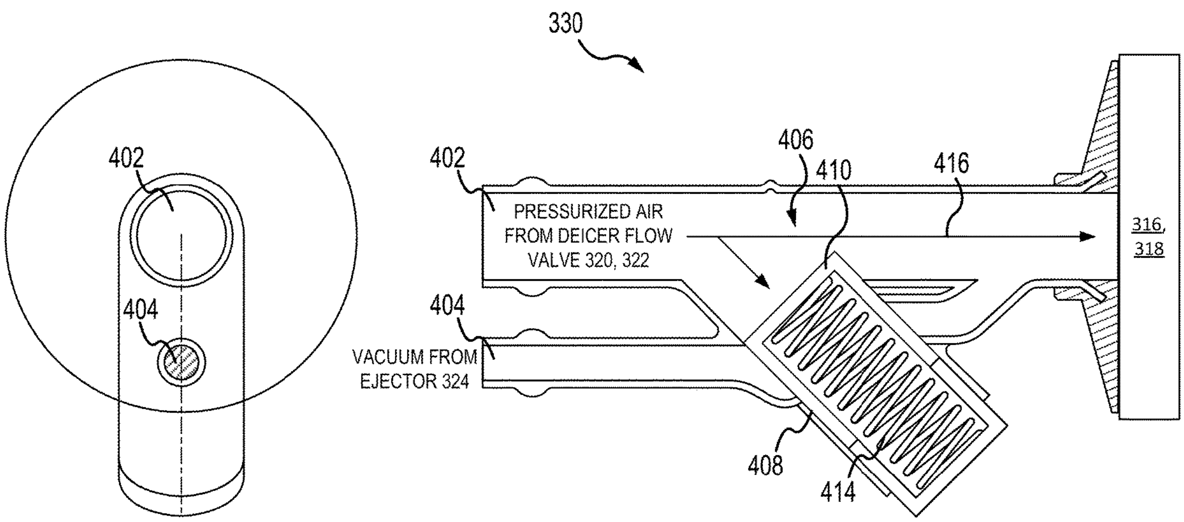
330
402
404
402
406
410
416
PRESSURIZED AIR
FROM DEICER FLOW
VALVE 320, 322
316,
318
404
VACUUM FROM
EJECTOR 324
408
414

FIG.4B

DEICING SYSTEM INTEGRATED WITH AN AIR MANAGEMENT SYSTEM AND ADVANCED INLET AIR CONNECTION VALVE

FIELD

[0001] The present disclosure generally relates to an ice protection system and more specifically to a pneumatic de-icer with integrated inlet valve and a deicing system connected with Air Management System/Environmental Control System as pressurization source for energy optimization and independency of the bleed air source from the engine.

BACKGROUND

[0002] Ice protection systems (IPS) allow aircraft pilots to exit icing conditions and avoid accidents due to rapid ice accumulation on leading surfaces of an aircraft. Various modes of IPS include pneumatic, electro-thermal, and electro-mechanical expulsion systems. Pneumatic de-icing systems use engine bleed air to inflate elastomeric de-icers, generating shear stress to break and shed ice formed on leading edges. Electro-thermal de-icing systems convert electrical energy to heat the leading-edge surfaces and shed ice by melting the ice at the ice-leading edge interface. Electro-mechanical de-icing systems use electrical energy to actuate various elements/mechanisms on the leading-edge surface to impart shear stress to ice formation and shed the ice.

SUMMARY

[0003] A pneumatic de-icing system is disclosed herein. The pneumatic de-icing system includes a de-icer flow valve, an accumulator, and a source control valve. The source control valve is fluidly coupled to the at least one de-icer flow valve. The source control valve is configured to supply pressurized air to the at least one de-icer flow valve from either the accumulator or a pressurized cabin depending on a differential air pressure between an air pressure in the pressurized cabin and an ambient air pressure surrounding the aircraft.

[0004] In various embodiments, responsive the differential air pressure between the air pressure in the pressurized cabin and the ambient air pressure surrounding the aircraft being less than 1 pound per square inch (PSI) (6895 newtons/square meter), the source control valve is configured to supply the pressurized air to the at least one de-icer flow valve from the accumulator.

[0005] In various embodiments, responsive to the differential air pressure between the air pressure in the pressurized cabin and the ambient air pressure surrounding the aircraft being between 4 pounds per square inch (PSI) (2.758e+04 newtons/square meter) and 10 PSI (6.895e+04 newtons/square meter), the source control valve is configured to supply the pressurized air to the at least one de-icer flow valve from the pressurized cabin.

[0006] In various embodiments, the pneumatic de-icing system further includes at least one de-icing assembly. In various embodiments, the at least one de-icer flow valve is fluidly coupled to the at least one de-icing assembly. In various embodiments, the at least one de-icer flow valve is configured to, responsive to an icing event, supply the pressurized air to the at least one de-icing assembly to inflate the at least one de-icing assembly.

[0007] In various embodiments, the pneumatic de-icing system further includes an ejector. In various embodiments, the ejector is fluidly coupled to the at least one de-icer flow valve. In various embodiments, the at least one de-icer flow valve is configured to, responsive to an absences of the icing event, supply a vacuum to the at least one de-icing assembly via the ejector to deflate the at least one de-icing assembly.

[0008] In various embodiments, the at least one de-icing assembly is a pneumatic de-icing assembly on at least one of a wing, a vertical stabilizer, a horizontal stabilizer, or other external surface of the aircraft on which supercooled droplets may impinge.

[0009] In various embodiments, the pneumatic de-icing system further includes a pressurizing source. In various embodiments, the pressurizing source is fluidly coupled to the accumulator and the pressurized cabin. In various embodiments, the pressurizing source is configured to supply the pressurized air to both the accumulator and the pressurized cabin.

[0010] In various embodiments, the pneumatic de-icing system further includes an ejector. In various embodiments, the ejector is fluidly coupled to the pressurizing source. In various embodiments, the ejector is configured to utilize a portion of the pressurized air from the pressurizing source to generate a vacuum.

[0011] Also disclosed herein is an aircraft. The aircraft includes a pressurized cabin and a pneumatic de-icing system. The pneumatic de-icing system includes a de-icer flow valve, an accumulator, and a source control valve. The source control valve is fluidly coupled to the at least one de-icer flow valve. The source control valve is configured to supply pressurized air to the at least one de-icer flow valve from either the accumulator or the pressurized cabin depending on a differential air pressure between an air pressure in the pressurized cabin and an ambient air pressure surrounding the aircraft.

[0012] In various embodiments, responsive the differential air pressure between the air pressure in the pressurized cabin and the ambient air pressure surrounding the aircraft being less than 1 pound per square inch (PSI) (6895 newtons/square meter), the source control valve is configured to supply the pressurized air to the at least one de-icer flow valve from the accumulator.

[0013] In various embodiments, responsive to the differential air pressure between the air pressure in the pressurized cabin and the ambient air pressure surrounding the aircraft being between 4 pounds per square inch (PSI) (2.758e+04 newtons/square meter) and 10 PSI (6.895e+04 newtons/square meter), the source control valve is configured to supply the pressurized air to the at least one de-icer flow valve from the pressurized cabin.

[0014] In various embodiments, the pneumatic de-icing system further includes at least one de-icing assembly. In various embodiments, the at least one de-icer flow valve is fluidly coupled to the at least one de-icing assembly. In various embodiments, the at least one de-icer flow valve is configured to, responsive to an icing event, supply the pressurized air to the at least one de-icing assembly to inflate the at least one de-icing assembly.

[0015] In various embodiments, the pneumatic de-icing system further includes an ejector. In various embodiments, the ejector is fluidly coupled to the at least one de-icer flow valve. In various embodiments, the at least one de-icer flow valve is configured to, responsive to an absences of the icing event, supply a vacuum to the at least one de-icing assembly via the ejector to deflate the at least one de-icing assembly.

[0016] In various embodiments, the at least one de-icing assembly is a pneumatic de-icing assembly on at least one of a wing, a vertical stabilizer, a horizontal stabilizer, or other external surface of the aircraft on which supercooled droplets may impinge.

[0017] In various embodiments, the pneumatic de-icing system further includes a pressurizing source. In various embodiments, the pressurizing source is fluidly coupled to the accumulator and the pressurized cabin. In various embodiments, the pressurizing source is configured to supply the pressurized air to both the accumulator and the pressurized cabin.

[0018] In various embodiments, the pneumatic de-icing system further includes an ejector. In various embodiments, the ejector is fluidly coupled to the pressurizing source. In various embodiments, the ejector is configured to utilize a portion of the pressurized air from the pressurizing source to generate a vacuum.

[0019] Also disclosed herein is a pneumatic de-icing system. The pneumatic de-icing system includes a de-icing assembly, a pneumatic inlet valve, a de-icer flow valve, and an ejector. The pneumatic inlet valve is fluidly coupled to the de-icing assembly. The de-icer flow valve is fluidly coupled to a first port of the pneumatic inlet valve. The de-icer flow valve is configured to supply pressurized air to the pneumatic inlet valve during an icing event. The ejector is fluidly coupled to a second port of the pneumatic inlet valve. The ejector is configured to supply a vacuum to the pneumatic inlet valve.

[0020] In various embodiments, responsive to the icing event, the pressurized air from the de-icer flow valve translates a poppet style check valve in the pneumatic inlet valve to an open state blocking the second port and allowing the pressurized air to inflate the de-icing assembly.

[0021] In various embodiments, responsive to an absences of the icing event and an absence of the pressurized air being supplied from the de-icer flow valve, a poppet style check valve in the pneumatic inlet valve translates to a closed state blocking the first port and allowing the vacuum from the ejector to deflate the de-icing assembly.

[0022] In various embodiments, a spring in the poppet style check valve closes the pneumatic inlet valve blocking the first port in response to the absence of the pressurized air being supplied from the de-icer flow valve.

[0023] The foregoing features and elements may be combined in any combination, without exclusivity, unless expressly indicated herein otherwise. These features and elements as well as the operation of the disclosed embodiments will become more apparent in light of the following description and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] The subject matter of the present disclosure is particularly pointed out and distinctly claimed in the concluding portion of the specification. A more complete understanding of the present disclosure, however, may best be obtained by referring to the following detailed description and claims in connection with the following drawings. While the drawings illustrate various embodiments employing the principles described herein, the drawings do not limit the scope of the claims.

[0025] FIG. **1** illustrates an aircraft including a de-icing assembly on the wings, in accordance with various embodiments.

[0026] FIG. **2** illustrates a pneumatic de-icing system that utilizes pressurized air from either an accumulator (pressure tank) or a pressurized cabin of the aircraft, in accordance with various embodiments.

[0027] FIG. **3** illustrates a pneumatic de-icing system that provides a pneumatic inlet valve for inflating pneumatic de-icers and a vacuum supply to maintain the pneumatic de-icers in the deflated state, in accordance with various embodiments.

[0028] FIGS. **4**A and **4**B illustrate a pneumatic inlet valve, in accordance with various embodiments.

DETAILED DESCRIPTION

[0029] The following detailed description of various embodiments herein makes reference to the accompanying drawings, which show various embodiments by way of illustration. While these various embodiments are described in sufficient detail to enable those skilled in the art to practice the disclosure, it should be understood that other embodiments may be realized and that changes may be made without departing from the scope of the disclosure. Thus, the detailed description herein is presented for purposes of illustration only and not of limitation. While these exemplary embodiments are described in sufficient detail to enable those skilled in the art to practice the invention, it should be understood that other embodiments may be realized and that logical, chemical, and mechanical changes may be made without departing from the spirit and scope of the invention. For example, the steps recited in any of the method or process descriptions may be executed in any order and are not necessarily limited to the order presented. Furthermore, any reference to singular includes plural embodiments, and any reference to more than one component or step may include a singular embodiment or step. Also, any reference to attached, fixed, connected, or the like may include permanent, removable, temporary, partial, full or any other possible attachment option. Additionally, any reference to without contact (or similar phrases) may also include reduced contact or minimal contact. It should also be understood that unless specifically stated otherwise, references to "a," "an," or "the" may include one or more than one and that reference to an item in the singular may also include the item in the plural. Further, all ranges may include upper and lower values and all ranges and ratio limits disclosed herein may be combined.

[0030] An aircraft must be pushed through the air to generate lift. Aircraft wings may generate most of the lift associated with holding the aircraft in the air. Accordingly, aircraft wings may be shaped as an airfoil. An airfoil may be a cross-sectional shape of an object whose motion through a fluid is capable of generating lift. The air may resist aircraft motion in the form of aerodynamic drag. Turbine engines or reciprocating engines/turboprops with propellers may provide thrust to overcome drag and push the aircraft forward. A wing's aerodynamic efficiency may be expressed as a lift-to-drag ratio. A high lift-to-drag ratio may be associated with a smaller thrust to propel the wings through the air at sufficient lift, and vice versa.

[0031] Ice formation on a leading edge of a wing, as well as other aircraft structures, such as vertical stabilizers, horizontal stabilizers, or other external surface of the aircraft on which supercooled droplets may impinge, may disrupt or destroy the smooth flow of air along the aircraft structures, increasing drag while decreasing the ability of the wing to create lift. Accordingly, ice formation on the leading edge of an aircraft structures may prevent an aircraft from taking off, or worse, may interfere with flight.

[0032] Pneumatic de-icers have typically been supplied with a vacuum to maintain the pneumatic de-icers in the deflated state during all stages of flight except when the de-icing system is turned on and actively inflating the de-icers. Responsive to the de-icing system being turned on, pressurized air at specific time intervals is supplied to the de-icers, and vacuum re-applied between pressurizations while flying in atmospheric icing conditions. The vacuum and air are supplied by an engine driven vacuum pump for aircraft using reciprocating engines. For both turbo prop and jet aircraft, the pressurized air is supplied by bleed air from the compressor section of the turbine engine. Vacuum may come from several sources including a separate vacuum pump, inlet to a compressor system, ejector driven by the compressed air (pressurized air driven venturi vacuum generator), or ejector flow control valves, which have a venturi built into the inflation valve. With a move to designs of new aircraft being electrically reliant, the availability of bleed air from turbine engine compressors may be limited or nonexistent. Accordingly, an alternative low-power pressurized air supply is needed to inflate pneumatic de-icers to remove ice from the aircraft at specific times while flying in atmospheric icing conditions. Additionally, a vacuum supply is needed to maintain pneumatic de-icers in the deflated state.

[0033] Disclosed herein is a pneumatic de-icing system that utilizes pressurized air from an electrically driven environmental control system (ECS) compressor or other similar compressor that supplies air to both an accumulator (pressure tank) and a pressurized cabin of the aircraft. In various embodiments, at low altitude, responsive to cabin air pressure being near external ambient air pressure, under commands of a controller, air from the ECS compressor may be routed to the accumulator (pressure tank) and the air from the accumulator may be utilized in inflating the pneumatic de-icing system. In various embodiments, the accumulator may be sized to even out a demand on the ECS compressor. In that regard, in various embodiments, the accumulator is basically a bottle to collect and hold pressurized fluid, in this case air. When the de-icer is inflated, part of the volume of air is distributed from the accumulator, and part of the volume is distributed from an air source, i.e. the compressor. The sizing of the accumulator is based on a calculation of how much air volume is required to inflate the de-icer, how much air is available from the air source, and the difference volume of air required from the accumulator, thus the size of the accumulator. In various embodiments, at higher altitudes responsive to little to no excess pressurized air being available from the ECS compressor, i.e. there is a differential air pressure between inside and outside of the pressurized cabin, under commands from the controller, air from the pressurized cabin, which acts as a large accumulator, may be utilized in inflating the pneumatic de-icing system. In that regard, in various embodiments, exhaust air from the cabin may be utilized in inflating the pneumatic de-icing system. Accordingly, in various embodiments, the pneumatic de-icing system utilizes a set of valves that allows air to be pulled from the accumulator or the cabin depending on the available air pressure difference between the external ambient and the cabin or the accumulator. In various embodiments, a source control valve would be used to control, under commands from the controller, which source would be used thereby addressing the inflation of pneumatic de-icers to remove ice from the aircraft at specific times while flying in atmospheric icing conditions.

[0034] In order to inflate pneumatic de-icers and provide vacuum supply to maintain pneumatic de-icers in the deflated state when not inflated, in various embodiments, a pneumatic inlet valve is provided that includes a pressurized air port and a vacuum port. In various embodiments, pressurized air is supplied through a flow control valve. In various embodiments, a continuous vacuum is provided from one of various sources including a separate vacuum pump, inlet to a compressor system, ejector driven by the compressed air (pressurized air driven venturi vacuum generator), or ejector flow control valves (EFCV), which all EFCVs have a venturi built into the pneumatic control valve. In various embodiments, the pneumatic inlet valve includes a first connection for pressurized air and a second connection for low pressurized air (vacuum). In various embodiments, the two connections are joined within the pneumatic inlet valve into a single connection before being introduced into the pneumatic de-icer. In various embodiments, in an area of the pneumatic inlet valve where the two unique connections are joined together, the pneumatic inlet valve includes a poppet style check valve that controls the flow of either the pressurized air to the de-icer or a vacuum flow to the de-icer responsive to an absence of pressurized air being supplied. In various embodiments, the check valve is biased in the closed position, blocking the tubing between the de-icer and the pressurized air port. In various embodiments, responsive to pressurized air being supplied, via commands from a controller, to the de-icer through the pressurized air port of the pneumatic inlet valve, the check valve is pushed open allowing the pressurized air to pass. In various embodiments, responsive to the pressurized air being stopped, the check valve moves back to the closed position, allowing vacuum to be reapplied to the de-icer.

[0035] Referring now to FIG. **1**, a top view of an aircraft **100** is illustrated, in accordance with various embodiments. Aircraft **100** includes wings **102**, engines **104**, a fuselage **106**, a vertical stabilizer **108**, and horizontal stabilizers **110**, among other control surfaces. Aircraft **100** further includes a plurality of de-icing assemblies **112** including de-icing assemblies **112***a*, **112***b*, **112***c* on a first wing **102**, de-icing assemblies **112***d*, **112***e*, **112***f* on a second wing **102**, de-icing assemblies **104***a* and **104***b* on engines **104**, de-icing assemblies **116***c* and **116***d* on vertical stabilizer **108**, and de-icing assemblies **116***a* and **116***b* on horizontal stabilizers **110**. In various embodiments, de-icing assemblies **112***a-f* may be located on a leading edge of each wing **102** (as illustrated in FIG. **1**), de-icing assemblies **104***a* and **104***b* may be located on engine inlets of each engine **104**, de-icing assemblies **116***c* and **116***d* may be located on a leading edge of vertical stabilizer **108**, de-icing assemblies **116***a* and **116***b* may be located on a leading edge of horizontal stabilizers **110** to prevent the buildup of ice on the leading edges. In various embodiments, de-icing assemblies **112***a*, **112***d* may be located at a proximal end of wings **102** adjacent the fuselage **106**, de-icing assemblies **112***c*, **112***f* may be located at a distal end of wings **102**, and de-icing assemblies **112***b*, **112***e* may be located between de-icing assemblies **112***a*, **112***d* and de-icing assemblies **112***c*, **112***f*, respectively.

[0036] In various embodiments, de-icing assemblies **112** may be located on an external surface of wings **102**, de-icing assemblies **104***a* and **104***b* may be located on an external surface of engine inlets of each engine **104**, de-icing assemblies **116***c* and **116***d* may be located on an external surface of vertical stabilizer **108**, de-icing assemblies **116***a* and **116***b* may be located on an external surface of horizontal stabilizers **110**. For simplicity and ease of discussion, de-icing assemblies **112** will be described as being coupled to the leading edge of wings **102**, though other locations are considered.

[0037] In various embodiments, each of the de-icing assemblies **112***a*-**112***f* may be individually coupled to a controller **114**. In various embodiments, controller **114** may comprise one or more processors configured to implement various logical operations in response to execution of instructions, for example, instructions stored on a non-transitory, tangible, computer-readable medium. The one or more processors can be a general-purpose processor, a microprocessor, a microcontroller, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device, discrete or transistor logic, discrete hardware components, or any combination thereof. In various embodiments, controller **114** may further comprise memory to store data, executable instructions, system program instructions, and/or controller instructions to implement the control logic of controller **114**.

[0038] System program instructions and/or controller instructions may be loaded onto a non-transitory, tangible computer-readable medium having instructions stored thereon that, in response to execution by the controller **114**, cause the controller **114** to perform various operations. The term "non-transitory" is to be understood to remove only propagating transitory signals per se from the claim scope and does not relinquish rights to all standard computer-readable media that are not only propagating transitory signals per se. Stated another way, the meaning of the term "non-transitory computer-readable medium" and "non-transitory computer-readable storage medium" should be construed to exclude only those types of transitory computer-readable media which were found in In Re Nuijten to fall outside the scope of patentable subject matter under 35 U.S.C. § 101.

[0039] Referring to FIG. **2**, in accordance with various embodiments, a pneumatic de-icing system that utilizes pressurized air from either an accumulator (pressure tank) or a pressurized cabin of the aircraft, is illustrated. In various embodiments, the pneumatic de-icing system **200** includes environmental control system (ECS) compressor **202** that supplies air to both an accumulator **204**, i.e. a pressure tank, and a cabin **206** of an aircraft **208**. In that regard, in various embodiments, ECS compressor **202** may be fluidly coupled to accumulator **204**. Also in that regard, in various embodiments, ECS compressor **202** may further be fluidly coupled to cabin **206** via ECS control hardware **210**. In various embodiments, ECS control hardware **210** controls the air pressure of the cabin **206**. In various embodiments, accumulator **204** and cabin **206** may be fluidly coupled to a source control valve **212**, which is under control of a controller, such as controller **114** of FIG. **1**. In various embodiments, a check valve **214** may be fluidly coupled and positioned between the cabin **206** and the source control valve **212**. In various embodiment check valve **214** prevents a backflow of pressurized air from the source control valve **212** to the cabin **206**. In various embodiments, the source control valve **212**, under control of the controller, controls whether pressurized air from the accumulator **204** or from the cabin **206** is utilized to inflate de-icing assemblies **216**, **218** during an icing event. In that regard, in various embodiments, the source control valve **212** is fluidly coupled to de-icing assemblies **216**, **218** only when de-icer flow valve **220** is positioned by the controller to be open. In various embodiments, the de-icing assemblies **216** are de-icing assemblies positioned on wings of the aircraft whereas the de-icing assemblies **218** are de-icing assemblies positioned on a vertical stabilizer and/or horizontal stabilizers.

[0040] In that regard, in various embodiments, at low altitude, responsive to air pressure in pressurized cabin **206** being at or near external ambient air pressure, i.e. less than 1 pound per square inch (PSI) (6895 newtons/square meter) difference between the air pressure in cabin **206** and the external ambient air pressure, under commands of a controller, the source control valve **212** is switched so that air from the accumulator **204** may be utilized in inflating the de-icing assemblies **216**, **218**. In various embodiments, at higher altitudes responsive to little to no excess pressurized air available from the ECS compressor **202**, i.e. there is a differential air pressure between inside and outside of the cabin **206**, under commands from the controller, the source control valve **212** is switched so that air from cabin **206**, which acts as a large accumulator may be utilized in inflating the de-icing assemblies **216**, **218**. In various embodiments, the differential air pressure may be between 4 PSI (2.758e+04 newtons/square meter) and 10 PSI (6.895e+04 newtons/square meter). In various embodiments, the differential air pressure may be between 5 PSI (3.447e+04 newtons/square meter) and 9 PSI (6.205e+04 newtons/square meter). In various embodiments, the differential air pressure may be 7 PSI (4.826e+04 newtons/square meter). In that regard, in various embodiments, exhaust air from the cabin **206** may be utilized in inflating the de-icing assemblies **216**, **218**.

[0041] In various embodiments, while the source control valve **212**, under control of the controller, controls whether pressurized air from the accumulator **204** or pressurized air from the cabin **206** is utilized in inflating the de-icing assemblies **216**, **218**, de-icer flow valves **220**, **222**, under control of the controller, control whether a pressurized air is being supplied to the de-icing assemblies **216**, **218** or a vacuum is being supplied to the de-icing assemblies **216**, **218**. In that regard, in various embodiments, responsive to detecting an icing event, the de-icer flow valves **220**, **222** are commanded by the controller to supply pressurized air to the de-icing assemblies **216**, **218** thereby inflating the de-icing assemblies **216**, **218**. In various embodiments, responsive to not detecting an icing event or an icing event ending, the de-icer flow valves **220**, **222** is commanded by the controller to switch to a vacuum to the de-icing assemblies **216**, **218** thereby deflating the de-icing assemblies **216**, **218**. Accordingly, in various embodiments, each of the de-icer flow valves **220**, **222** is fluidly coupled to the source control valve **212**. Further, in various embodiments, the de-icer flow valves **220** are fluidly coupled to the de-icing assemblies **216** and the de-icer flow valve **222** is fluidly coupled to the de-icing assemblies **218**. Moreover, each of the de-icer flow valves **220**, **222** is fluidly coupled to ejector **224**. In various embodiments, the ejector **224** is fluidly coupled to the ECS compressor **202**. In various embodiments, the ejector **224** is configured to utilize a portion of the pressurized air from the ECS compressor **202** to generate a vacuum, i.e. a venturi pressurized air driven vacuum. In that regard, responsive to not detecting the icing event or the icing event ending, the ejector **224** generates a vacuum that deflates the de-icing assemblies **216**, **218** via the de-icer flow valves **220**, **222**. In various embodiments, air pressure switches **226** provide a positive indication to the pilot/copilot that the pneumatic de-icing system **200** has adequate air pressure during the inflation portion of the de-icing cycle, and that pressure has been removed at all other times on the de-icing assemblies **216**, **218**. It is noted that while some of the components of the pneumatic de-icing system **200** are depicted outside the aircraft **208**, the depiction is only for schematic illustration and all the components are positioned within the aircraft **208**.

[0042] Referring to FIG. **3**, in accordance with various embodiments, a pneumatic de-icing system that provides a pneumatic inlet valve for inflating pneumatic de-icers and a vacuum supply to maintain the pneumatic de-icers in the deflated state, is illustrated. In various embodiments, the vacuum may be a low power vacuum supply as described in U.S. Patent Publication No. 2003/0122037 A1, which is incorporated by reference herein in its entirety for all purposes. In various embodiments, the pneumatic de-icing system **300** includes pressurizing source **302**, such as an environmental control system (ECS) compressor or engine bleed, among others, that supplies air to de-icing assemblies **316**, **318** during an icing event. In various embodiments, the de-icing assemblies **316** are de-icing assemblies positioned on wings of the aircraft whereas the de-icing assemblies **318** are de-icing assemblies positioned on a vertical stabilizer or horizontal stabilizers. In that regard, pressurizing source **302** is fluidly coupled to each of the de-icer flow valves **320**, **322** and the de-icer flow valves **320**, **322** are fluidly coupled to respective one of the de-icing assemblies **316**, **318**. In various embodiments, de-icer flow valves **320**, **322**, under control of the controller, control pressurized air is being supplied to the de-icing assemblies **316**, **318**. In that regard, responsive to detecting an icing event, de-icer flow valves **320**, **322**, commanded by the controller, supply pressurized air to the de-icing assemblies **316**, **318** thereby inflating the de-icing assemblies **316**, **318**. In various embodiments, air pressure switches **326** provide a positive indication to the pilot/copilot that the pneumatic de-icing system **300** has adequate air pressure during the inflation portion of the de-icing cycle, and that pressure has been removed at all other times on the de-icing assemblies **316**, **318**.

[0043] In various embodiments, responsive to not detecting an icing event or an icing event ending, the de-icer flow valves **320**, **322** would be commanded by the controller to discontinue providing the pressurized air to the de-icing assemblies **316**, **318** thereby allowing the de-icing assemblies **316**, **318** to deflate. In that regard, each of the de-icing assemblies **316**, **318** is fluidly coupled to ejector **324**. In various embodiments, the ejector **324** is fluidly coupled to the pressurizing source **302**. In various embodiments, the ejector **324** is configured to utilize a portion of the pressurized air from the ECS compressor to generate a vacuum, i.e. a venturi pressurized air driven vacuum. In that regard, responsive to not detecting an icing event or an icing event ending, the ejector **324** generates, via a command by the controller, a vacuum that deflates the de-icing assemblies **316**, **318**. In various embodiments, air pressure switches **326** provide a positive indication to the pilot/copilot that the pneumatic de-icing system **300** has adequate air pressure during the inflation portion of the de-icing cycle, and that pressure has been removed at all other times on the de-icing assemblies **316**, **318**. It is noted that while some of the components of the pneumatic de-icing system **300** are depicted outside of the aircraft **308**, the depiction is only for schematic illustration and all of the components are positioned within the aircraft **308**.

[0044] In various embodiments, located between the de-icer flow valves **320**, **322** that provide pressurized air to inflate the de-icing assemblies **316**, **318** and between the ejector **324** that provides a vacuum that deflates the de-icing assemblies **316**, **318** is a pneumatic inlet valve **330** that includes a pressurized air port and a vacuum port. With further reference to FIGS. **4**A and **4**B, in accordance with various embodiments, a pneumatic inlet valve such as pneumatic inlet valve **330** of FIG. **3**, is illustrated. In various embodiments, the pneumatic inlet valve **330** includes a first port **402** for pressurized air and a second port **404** for low pressurized air (vacuum). In various embodiments, the two connections are joined within the pneumatic inlet valve into a single connection **406** before being introduced into the de-icing assemblies **316**, **318**. In various embodiments, in an area of the pneumatic inlet valve **330** where the two unique connections are joined together, the pneumatic inlet valve **330** includes a poppet style check valve **408** that controls the flow of either the pressurized air to the de-icer or a vacuum flow to the de-icing assemblies **316**, **318** responsive to an absence of pressurized air being supplied. In various embodiments, as illustrated in FIG. **4**A, the poppet style check valve **408** is biased in the closed position, blocking the tubing between the de-icing assemblies **316**, **318** and pressurized air from the de-icer flow valves **320**, **322** via blocking mechanism **410** of the poppet style check valve **408** as well as blocking the pressurized air from the de-icer flow valves **320**, **322** from the vacuum source, i.e. ejector **324**. In the closed position, the pneumatic inlet valve **330** is configured to allow the vacuum from the ejector **324** to deflate the de-icing assemblies **316**, **318**, as shown by arrows **412**. In various embodiments, as illustrated in FIG. **4**B, responsive to pressurized air being supplied via the de-icer flow valves **320**, **322**, the poppet style check valve **408** is configured to be pushed open, compressing a spring **414** allowing the pressurized air from the de-icer flow valves **320**, **322** to pass to inflate the de-icing assemblies **316**, **318**, as shown by arrows **416**, while blocking mechanism **410** blocks the tubing between the de-icing assemblies **316**, **318** and the vacuum from the ejector **324**. In that regard, in various embodiments, the pressurized air from the de-icer flow valves **320**, **322** causes the blocking mechanism **410** to translate downward blocking the tubing between the de-icing assemblies **316**, **318** and the vacuum from the ejector **324**. In various embodiments, responsive to the pressurized air from the de-icer flow valves **320**, **322** stopping, the spring **414** expands causing the blocking mechanism **410** of the poppet style check valve **408** to block the tubing between the de-icing assemblies **316**, **318** and line for the pressurized air from the de-icer flow valves **320**, **322** thereby allowing vacuum to be reapplied to the de-icing assemblies **316**, **318**.

[0045] Benefits, other advantages, and solutions to problems have been described herein with regard to specific embodiments. Furthermore, the connecting lines shown in the various figures contained herein are intended to represent exemplary functional relationships and/or physical couplings between the various elements. It should be noted that many alternative or additional functional relationships or physical connections may be present in a practical system. However, the benefits, advantages, solutions to problems, and any elements that may cause any benefit, advantage, or solution to occur or become more pronounced are not to be construed as critical, required, or essential features or elements of the disclosure. The scope of the disclosure is accordingly to be limited by nothing other than the appended claims, in which reference to an element in the singular is not intended to mean "one and only one" unless explicitly so stated, but rather "one or more." Moreover, where a phrase similar to "at least one of A, B, or C" is used in the claims, it is intended that the phrase be interpreted to mean that A alone may be present in an embodiment, B alone may be present in an embodiment, C alone may be present in an embodiment, or that any combination of the elements A, B and C may be present in a single embodiment; for example, A and B, A and C, B and C, or A and B and C. Different cross-hatching is used throughout the figures to denote different parts but not necessarily to denote the same or different materials.

[0046] Systems, methods, and apparatus are provided herein. In the detailed description herein, references to "one embodiment," "an embodiment," "various embodiments," etc., indicate that the embodiment described may include a particular feature, structure, or characteristic, but every embodiment may not necessarily include the particular feature, structure, or characteristic. Moreover, such phrases are not necessarily referring to the same embodiment. Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it is submitted that it is within the knowledge of one skilled in the art to affect such feature, structure, or characteristic in connection with other embodiments whether or not explicitly described. After reading the description, it will be apparent to one skilled in the relevant art(s) how to implement the disclosure in alternative embodiments.

[0047] Numbers, percentages, or other values stated herein are intended to include that value, and also other values that are about or approximately equal to the stated value, as would be appreciated by one of ordinary skill in the art encompassed by various embodiments of the present disclosure. A stated value should therefore be interpreted broadly enough to encompass values that are at least close enough to the stated value to perform a desired function or achieve a desired result. The stated values include at least the variation to be expected in a suitable industrial process, and may include values that are within 10%, within 5%, within 1%, within 0.1%, or within 0.01% of a stated value. Additionally, the terms "substantially," "about" or "approximately" as used herein represent an amount close to the stated amount that still performs a desired function or achieves a desired result. For example, the term "substantially," "about" or "approximately" may refer to an amount that is within 10% of, within 5% of, within 1% of, within 0.1% of, and within 0.01% of a stated amount or value.

[0048] Furthermore, no element, component, or method step in the present disclosure is intended to be dedicated to the public regardless of whether the element, component, or method step is explicitly recited in the claims. No claim element herein is to be construed under the provisions of 35 U.S.C. 112(f) unless the element is expressly recited using the phrase "means for." As used herein, the terms "comprises," "comprising," or any other variation thereof, are intended to cover a non-exclusive inclusion, such that a process, method, article, or apparatus that comprises a list of elements does not include only those elements but may include other elements not expressly listed or inherent to such process, method, article, or apparatus.

[0049] Finally, it should be understood that any of the above-described concepts can be used alone or in combination with any or all of the other above-described concepts. Although various embodiments have been disclosed and described, one of ordinary skill in this art would recognize that certain modifications would come within the scope of this disclosure. Accordingly, the description is not intended to be exhaustive or to limit the principles described or illustrated herein to any precise form. Many modifications and variations are possible in light of the above teaching.

What is claimed is:

1. A pneumatic de-icing system, the pneumatic de-icing system comprising:

a de-icer flow valve;

an accumulator; and

a source control valve, wherein the source control valve is fluidly coupled to the de-icer flow valve and wherein the source control valve is configured to supply pressurized air to the de-icer flow valve from either the accumulator or a pressurized cabin depending on a differential air pressure between an air pressure in the pressurized cabin and an ambient air pressure surrounding an aircraft.

2. The pneumatic de-icing system of claim **1**, wherein, responsive the differential air pressure between the air pressure in the pressurized cabin and the ambient air pressure surrounding the aircraft being less than 1 pound per square inch (PSI) (6895 newtons/square meter), the source control valve is configured to supply the pressurized air to the de-icer flow valve from the accumulator.

3. The pneumatic de-icing system of claim **1**, wherein, responsive to the differential air pressure between the air pressure in the pressurized cabin and the ambient air pressure surrounding the aircraft being between 4 pounds per square inch (PSI) (2.758e+04 newtons/square meter) and 10 PSI (6.895e+04 newtons/square meter), the source control valve is configured to supply the pressurized air to the de-icer flow valve from the pressurized cabin.

4. The pneumatic de-icing system of claim **1**, further comprising:

at least one de-icing assembly, wherein the de-icer flow valve is fluidly coupled to the at least one de-icing assembly and wherein the de-icer flow valve is configured to, responsive to an icing event, supply the pressurized air to the at least one de-icing assembly to inflate the at least one de-icing assembly.

5. The pneumatic de-icing system of claim **4**, further comprising:

an ejector, wherein the ejector is fluidly coupled to the de-icer flow valve and wherein the de-icer flow valve is configured to, responsive to an absences of the icing event, supply a vacuum to the at least one de-icing assembly via the ejector to deflate the at least one de-icing assembly.

6. The pneumatic de-icing system of claim **4**, wherein the at least one de-icing assembly is a pneumatic de-icing assembly on at least one of a wing, a vertical stabilizer, a horizontal stabilizer, or other external surface of the aircraft on which supercooled droplets may impinge.

7. The pneumatic de-icing system of claim **1**, further comprising:

a pressurizing source, wherein the pressurizing source is fluidly coupled to the accumulator and the pressurized cabin and wherein the pressurizing source is configured to supply the pressurized air to both the accumulator and the pressurized cabin.

8. The pneumatic de-icing system of claim **7**, further comprising:

an ejector, wherein the ejector is fluidly coupled to the pressurizing source and wherein the ejector is configured to utilize a portion of the pressurized air from the pressurizing source to generate a vacuum.

9. An aircraft, comprising:

a pressurized cabin; and

a pneumatic de-icing system, the pneumatic de-icing system comprising:

a de-icer flow valve;

an accumulator; and

a source control valve, wherein the source control valve is fluidly coupled to the de-icer flow valve and wherein the source control valve is configured to supply pressurized air to the de-icer flow valve from either the accumulator or the pressurized cabin depending on a differential air pressure between an air pressure in the pressurized cabin and an ambient air pressure surrounding the aircraft.

10. The aircraft of claim **9**, wherein, responsive the differential air pressure between the air pressure in the pressurized cabin and the ambient air pressure surrounding the aircraft being less than 1 pound per square inch (PSI) (6895 newtons/square meter), the source control valve is configured to supply the pressurized air to the de-icer flow valve from the accumulator.

11. The aircraft of claim **9**, wherein, responsive to the differential air pressure between the air pressure in the pressurized cabin and the ambient air pressure surrounding the aircraft being between 4 pounds per square inch (PSI) (2.758e+04 newtons/square meter) and 10 PSI (6.895e+04 newtons/square meter), the source control valve is configured to supply the pressurized air to the de-icer flow valve from the pressurized cabin.

12. The aircraft of claim **9**, wherein the pneumatic de-icing system further comprises:

at least one de-icing assembly, wherein the de-icer flow valve is fluidly coupled to the at least one de-icing assembly and wherein the de-icer flow valve is configured to, responsive to an icing event, supply the pressurized air to the at least one de-icing assembly to inflate the at least one de-icing assembly.

13. The aircraft of claim **12**, wherein the pneumatic de-icing system further comprises:

an ejector, wherein the ejector is fluidly coupled to the de-icer flow valve and wherein the de-icer flow valve is configured to, responsive to an absences of the icing event, supply a vacuum to the at least one de-icing assembly via the ejector to deflate the at least one de-icing assembly.

14. The aircraft of claim **12**, wherein the at least one de-icing assembly is a pneumatic de-icing assembly on at least one of a wing, a vertical stabilizer, a horizontal stabilizer, or other external surface of the aircraft on which supercooled droplets may impinge.

15. The aircraft of claim **9**, wherein the pneumatic de-icing system further comprises:

a pressurizing source, wherein the pressurizing source is fluidly coupled to the accumulator and the pressurized cabin and wherein the pressurizing source is configured to supply the pressurized air to both the accumulator and the pressurized cabin.

16. The aircraft of claim **15**, wherein the pneumatic de-icing system further comprises:

an ejector, wherein the ejector is fluidly coupled to the pressurizing source and wherein the ejector is configured to utilize a portion of the pressurized air from the pressurizing source to generate a vacuum.

17. A pneumatic de-icing system, the pneumatic de-icing system comprising:

a de-icing assembly;

a pneumatic inlet valve, wherein the pneumatic inlet valve is fluidly coupled to the de-icing assembly;

a de-icer flow valve, wherein the de-icer flow valve is fluidly coupled to a first port of the pneumatic inlet valve and wherein the de-icer flow valve is configured to supply pressurized air to the pneumatic inlet valve during an icing event;

an ejector, wherein the ejector is fluidly coupled to a second port of the pneumatic inlet valve and wherein the ejector is configured to supply a vacuum to the pneumatic inlet valve.

18. The pneumatic de-icing system of claim **17**, wherein, responsive to the icing event, the pressurized air from the de-icer flow valve translates a poppet style check valve in the pneumatic inlet valve to an open state blocking the second port and allowing the pressurized air to inflate the de-icing assembly.

19. The pneumatic de-icing system of claim **17**, wherein, responsive to an absences of the icing event and an absence of the pressurized air being supplied from the de-icer flow valve, a poppet style check valve in the pneumatic inlet valve translates to a closed state blocking the first port and allowing the vacuum from the ejector to deflate the de-icing assembly.

20. The pneumatic de-icing system of claim **19**, wherein a spring in the poppet style check valve closes the pneumatic inlet valve blocking the first port in response to the absence of the pressurized air being supplied from the de-icer flow valve.

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