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FLUID SEPARATOR HAVING FLUID RECIRCULATION PASSAGE AND PLURAL OUTLET PASSAGES

Abstract

A fluid separator device includes an outer wall member defining an interior, an inlet end with an inlet, and an outlet end with a first outlet and a second outlet. Additionally, the fluid separator includes a fluid flow path system defined within the interior. The fluid flow path system includes a first flow path extending in a first downstream direction from the inlet and through an inner flow member toward at least one of the first and second outlet. The fluid flow path system further includes a second flow path that is at least partly defined between the outer wall member and the inner flow member. The second flow path extends in a second downstream direction from the outlet end toward the inlet end, the second flow path configured to receive flow from the first flow path.

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Background/Summary

CROSS REFERENCE TO RELATED APPLICATION
[0001] The present application claims benefit of prior filed India Provisional Patent Application No. 20241009872, filed Feb. 13, 2024, which is hereby incorporated by reference herein in its entirety.
TECHNICAL FIELD
[0002] The technical field generally relates to a fluid separator and, more particularly, relates to a fluid separator having a fluid recirculation passage and plural outlet passages.
BACKGROUND
[0003] It is known to provide a fluid separator in some fluid systems. During operation, the separator may receive a fluid that contains multiple components, and the separator may affect flow of one component relative to the flow of the other, thereby providing some degree of separation of the components.
[0004] In some systems, for example, a turbine stage (i.e., expander) of a turbomachine may receive an exhaust stream containing air, water vapor, and liquid droplets. The liquid droplets may negatively affect operations of the turbine stage, may decrease operating efficiency, may cause premature wear, or cause other problems. Thus, it may be preferable to provide the system with a device that removes the liquid droplets before they enter the turbine stage.
[0005] However, existing fluid separating devices suffer from certain deficiencies. They may not effectively separate the components in some operating conditions. In some cases, the fluid separating device may disrupt flow to the downstream device (e.g., a turbine/expander stage of a turbomachine). Fluid separating devices may also be difficult or otherwise inefficient to manufacture. Furthermore, some fluid separating devices may be bulky, heavy, and/or contain a large number of parts, which may be detrimental to the larger system.
[0006] Accordingly, it is desirable to provide a fluid separator that effectively separates one component of a fluid stream from others (e.g., separating liquid water droplets from an exhaust stream) across a wide range of operating conditions without significantly affecting flow to the downstream device. It is also desirable to provide a fluid separator that may be manufactured efficiently. Also, it is desirable to provide a fluid separator that is relatively lightweight, compact, and/or manufactured with a relatively small number of parts. Other desirable features and characteristics will become apparent from the subsequent detailed description and the appended claims, taken in conjunction with the accompanying drawings and this background.
BRIEF SUMMARY
[0007] A fluid separator device is disclosed that is configured for separating a part of a fluid mixture from another part of the fluid mixture. The fluid separator device includes an outer wall member that defines an interior of the fluid separator device. The interior defines a longitudinal axis of the fluid separator device. The separator device includes an inlet end that defines a fluid inlet that is fluidly connected to the interior and that is configured to receive the fluid mixture. The separator device also includes an outlet end separated at a distance from the inlet end along the longitudinal axis. The outlet end defines a first fluid outlet from the interior. The longitudinal axis extends through the first fluid outlet. Moreover, the separator device includes an outlet pipe that is supported within the interior and within the first fluid outlet. The outlet pipe defines a second fluid outlet from the interior. Also, the separator device includes an inner flow member that is supported within the interior. Additionally, the fluid separator includes a fluid flow path system defined within the interior. The fluid flow path system includes a first flow path extending in a first downstream

direction from the fluid inlet and through the inner flow member toward at least one of the first fluid outlet and the second fluid outlet. The fluid flow path system further includes a second flow path that is at least partly defined between the outer wall member and the inner flow member. The second flow path extends in a second downstream direction from the outlet end toward the inlet end. The second flow path is configured to receive flow from the first flow path.

[0008] In another example embodiment, a method of manufacturing a fluid separator device that is configured for separating a part of a fluid mixture from another part of the fluid mixture is disclosed. The method includes providing an outer wall member that defines an interior of the fluid separator device. The interior defines a longitudinal axis of the fluid separator device. The method further includes providing an inlet end that defines a fluid inlet that is fluidly connected to the interior and that is configured to receive the fluid mixture. Also, the method includes providing an outlet end separated at a distance from the inlet end along the longitudinal axis. The outlet end defines a first fluid outlet from the interior. The longitudinal axis extends through the first fluid outlet. Also, the method includes supporting an outlet pipe within the interior and within the first fluid outlet. The outlet pipe defines a second fluid outlet from the interior. The method further includes supporting an inner flow member within the interior. Also, the method includes defining a fluid flow path system within the interior. The fluid flow path system includes a first flow path in a first downstream direction from the fluid inlet and through the inner flow member toward at least one of the first fluid outlet and the second fluid outlet. The fluid flow path system also includes a second flow path that is at least partly defined between the outer wall member and the inner flow member. The second flow path extends in a second downstream direction from the outlet end toward the inlet. The second flow path is configured to receive flow from the first flow path.

[0009] In an additional embodiment, a fuel cell system is disclosed that includes a fuel cell stack, a turbomachine with a turbine section, and a fluid separator device fluidly connected to the fuel cell stack and configured to receive a fluid mixture from the fuel cell stack. The fluid separator device is fluidly connected upstream to the turbine section. The fluid separator device is configured for separating a part of the fluid mixture from another part of the fluid mixture to provide a separated exhaust stream from the fuel cell stack to the turbine section. The fluid separator device includes an outer wall member that defines an interior of the fluid separator device. The interior defines a longitudinal axis of the fluid separator device. The fluid separator device includes an inlet end that defines a fluid inlet that is fluidly connected to the interior and that is configured to receive the fluid mixture. Additionally, the fluid separator device includes an outlet end separated at a distance from the inlet end along the longitudinal axis. The outlet end defines a first fluid outlet from the interior. The longitudinal axis extends through the first fluid outlet. Also, the fluid separator device includes an outlet pipe that is supported within the interior and within the first fluid outlet. The outlet pipe defines a second fluid outlet from the interior. The fluid separator device includes an inner flow member that is supported within the interior. Moreover, the fluid separator device includes a fluid flow path system defined within the interior. The fluid flow path system includes a first flow path extending in a first downstream direction from the fluid inlet and through the inner flow member toward at least one of the first fluid outlet and the second fluid outlet. Also, the fluid flow path system includes a second flow path that is at least partly defined between the outer wall member and the inner flow member. The second flow path in a second downstream direction from the outlet end toward the inlet end. The second flow path is configured to receive flow from the first flow path.

Description

BRIEF DESCRIPTION OF DRAWINGS

[0010] The various embodiments will hereinafter be described in conjunction with the following drawing figures, wherein like numerals denote like elements, and wherein:

[0011] FIG. **1** is a schematic view of a fuel cell system, which includes a fluid separator device according to example embodiments of the present disclosure;

[0012] FIG. **2** is a longitudinal section view of the fluid separator device of FIG. **1** according to example embodiments of the present disclosure;

[0013] FIG. **3** is an exploded, perspective, and partially cross-sectional view of a plurality of first features of the fluid separator device of FIGS. **1** and **2**, which are shown to illustrate a method of manufacture of the fluid separator device according to example embodiments;

[0014] FIG. **4** is an exploded perspective view of a plurality of second features of the fluid separator device of FIGS. **1** and **2**, which are shown to further illustrate the method of manufacture of the fluid separator device according to example embodiments;

[0015] FIG. **5** is an exploded, perspective, and partially cross-sectional view of the plurality of first and second features of the fluid separator device of FIGS. **1** and **2**, which are shown to further illustrate the method of manufacture of the fluid separator device according to example embodiments;

[0016] FIG. **6** is a perspective view of a swirl element of the fluid separator device of FIGS. **1-5** according to example embodiments; and

[0017] FIG. **7** is a perspective view of a swirl element of the fluid separator device of FIGS. **1-5** according to further example embodiments of the present disclosure.

DETAILED DESCRIPTION

[0018] The following Detailed Description is merely exemplary in nature and is not intended to limit the various embodiments or the application and uses thereof. Furthermore, there is no intention to be bound by any theory presented in the preceding background or the following detailed description.

[0019] Broadly, example embodiments disclosed herein include a fluid separator for separating one part of a fluid mixture (e.g., liquid water droplets) from another (e.g., water vapor/air). The fluid separator of the present disclosure may include an inlet end with an inlet and an outlet end with a plurality of outlets. The inlet end and the outlet end may be separated along a longitudinal axis. The fluid separator may also include a first flow path that extends along the longitudinal axis. Furthermore, the fluid separator may include a second flow path. Fluid entering the first flow path may flow partly along the first flow path from the inlet to the outlet(s). Liquid water droplets may flow within air and branch from the first flow path and into the second flow path to be drained therefrom, and the air in the second flow path may recirculate back into the first flow path. The fluid separator may also include a swirl member within the first flow path that swirls the fluid within the first flow path, for example, to direct liquid water droplets toward the second flow path. Furthermore, at least one of the outlets may be configured to define a low pressure area for outletting water vapor from the separator.

[0020] FIG. **1** is a schematic view of a fuel cell system **100** that includes a fluid separator **101** (i.e., de-mister, fluid separating device, etc.) that may be configured according to embodiments of the present disclosure. The fluid separator **101** may be fluidly connected to a fuel cell stack **104** of the fuel cell system **100**. The fluid separator **101** may receive an exhaust stream **109** from the fuel cell stack **104** during operation. The fluid separator **101** may be operable/configured to separate out liquid fluid droplets (e.g., water droplets) from the exhaust stream **109** and outlet a separated exhaust stream **111** that is provided downstream to a turbine section **115** of a turbomachine **117**.

[0021] It will be appreciated that the fluid separator **101** of the present disclosure may be included in other fuel cell systems **100** (as well as other fluid systems) without departing from the scope of the present disclosure. In some embodiments, the fuel cell system **100** may be included in a vehicle, such as a car, truck, sport utility vehicle, van, motorcycle, etc. However, it will be appreciated that the fuel cell system **100** may be configured for a different use without departing from the scope of the present disclosure.

[0022] The fuel cell stack **104** may contain a plurality of fuel cells. Hydrogen may be supplied to the fuel cell stack **104** from a tank **106**, and air may be supplied to the fuel cell stack **104** to generate electricity by a known chemical reaction. The fuel cell stack **104** may generate electricity for an electrical device, such as an electric motor **105**. As stated, the fuel cell system **100** may be included in a vehicle; therefore, in some embodiments, the electric motor **105** may convert the electrical power to mechanical power to drive and rotate an axle (and, thus, one or more wheels) of the vehicle.
[0023] Compressed air may be provided to the fuel cell stack **104**, at least in part, by a compressor section **116** of the turbomachine **117**. The compressor section **116** may compress an inlet airstream **127** into a compressed airstream **129** that is directed to the fuel cell stack **104** for boosting the operating efficiency of the fuel cell system **100**.
[0024] In some embodiments, the turbomachine **117** may also include an e-machine, such as an electric motor **131**. A common shaft may extend between the compressor section **116**, the motor **131** and the turbine section **115**. Accordingly, the shaft may be driven in rotation by the turbine section **115** and/or the motor **131**, thereby rotatably driving a compressor wheel within the compressor section **116**.
[0025] Various components of the fuel cell system **100** may be controlled by a control system **134**. The control system **134** may be a computerized system with a processor, various sensors, and other components for electrically controlling operation of the fuel cell stack **104**, the motor **131**, and/or other features of the system **100**. In some embodiments, the control system **134** may define or may be part of the electrical control unit (ECU) of a vehicle.
[0026] FIG. **2** illustrates a fluid separator **1101** in detail according to example embodiments of the present disclosure. The fluid separator **1101** may correspond to the separator **101** of FIG. **1** and may be incorporated into the fuel cell system **100** in some embodiments.
[0027] The fluid separator **1101** may define a straight longitudinal axis **1102** that extends between an inlet end **1104** and an outlet end **1106** of the separator **1101**. In some embodiments, the fluid separator **1101** may be somewhat frusto-conic in shape and a majority of the fluid separator **1101** may include a plurality of walls **1112** with substantially consistent wall thicknesses. A number of the walls **1112** may be arcuate, contoured, and rounded about the axis **1102** in a circumferential direction. Also, a number of the walls **1112** may be substantially centered about the axis **1102**. Flow through the fluid separator **1101** will be discussed in detail; however, flow through the fluid separator **1101** may be substantially in a downstream direction along the axis **1102** from the inlet end **1104** toward the outlet end **1106**.
[0028] In some embodiments, the fluid separator **1101** may include an inlet member, such as an inlet tube **1114**, which defines a fluid inlet **1116** (i.e., a fluid inlet passage) therethrough. The fluid inlet **1116** may have a circular cross-section taken normal to the axis **1102**. The fluid inlet **1116** may be the sole fluid inlet into the fluid separator **1101**. The fluid inlet **1116** may be centered about the axis **1102** at the inlet end **1104**. The inlet tube **1114** may include an inlet lip **1120** and a downstream terminal end **1122**, which are separated along the axis **1102**. The inlet lip **1120** may be attached to a corresponding pipe, line, conduit, passage, etc. for fluidly connecting to the fuel cell stack **104** (FIG. **1**) such that the fluid inlet **1116** receives a fluid mixture **1124** therefrom. The mixture **1124** may include a combination of water vapor, liquid water droplets, and gaseous air provided by the fuel cell stack **104** (FIG. **1**).
[0029] The fluid separator **1101** may also include an outlet member, such as a first outlet tube **1136**, which defines a first fluid outlet **1138** (i.e., a first fluid outlet passage) therethrough. The first fluid outlet **1138** may have a circular cross-section taken normal to the axis **1102**. The first fluid outlet **1138** may be centered about the axis **1102** at the outlet end **1106**. The first outlet tube **1136** may include an upstream end **1140** and a downstream terminal lip **1142**, which are separated along the axis **1102**. The downstream terminal lip **1142** may be attached to a corresponding pipe, line, conduit, passage, etc. for fluidly connecting to the turbine section **115** (FIG. **1**). Also, as will be

discussed, the fluid separator **1101** may be configured to separate and substantially remove the liquid water droplets from the fluid mixture **1124** such that air and, in some cases, water vapor is outlet from the separator **1101**.

[0030] Furthermore, the fluid separator **1101** may include an outer wall member **1130**. The outer wall member **1130** may be hollow and somewhat cylindrical with substantially constant wall thickness. The outer wall member **1130** may define a majority of an interior **1146** of the separator **1101**. The outer wall member **1130** may generally include an inlet end wall **1132** disposed at the inlet end **1104**. The inlet end wall **1132** may be attached to and may extend transverse from the inlet tube **1114**, and the inlet tube **1114** may extend through the inlet end wall **1132** to fluidly connect the fluid inlet **1116** to the interior **1146**. The outer wall member **1130** may further include an outlet end wall **1134** disposed proximate the outlet end **1106**. The outlet end wall **1134** may be attached to and may extend transverse from the first outlet tube **1136**, and the first fluid outlet **1138** may be fluidly connected to the interior **1146**. Furthermore, the outer wall member **1130** may include an outer longitudinal wall **1144** extending between the inlet end wall **1132** and the outlet end wall **1134** substantially along the longitudinal axis.

[0031] The inlet end wall **1132** may include an inlet end wall surface **1150** that lies in a plane, and the plane may be angled with respect to the axis **1102**. The outer longitudinal wall **1144** may include a longitudinal wall surface **1152** that faces the axis **1102**, that extends circumferentially about the axis **1102**, and that extends generally along the axis **1102**. The longitudinal wall surface **1152** may gradually taper outward radially with respect to the longitudinal axis **1102** as the longitudinal wall surface **1152** extends along the longitudinal axis **1102** from the inlet end **1104** toward the outlet end **1106**. In other words, the radius of the longitudinal wall surface **1152** may gradually increase as the longitudinal wall surface **1152** extends along the longitudinal axis **1102** from the inlet end **1104** toward the outlet end **1106** (i.e., from the inlet end wall **1132** to the outlet end wall **1134**). The outlet end wall **1134** may include an outlet end wall surface **1156**. The outlet end wall surface **1156** may face substantially along the axis **1102** in an upstream direction (i.e., toward the inlet end **1104**). The outlet end wall surface **1156** may extend transverse to the axis **1102**, from the first outlet tube **1136** to the longitudinal wall surface **1152** of the outer longitudinal wall **1144**. The end wall surface **1156** may be tapered as it extends between the first outlet tube **1136** and the outer longitudinal wall **1144**. The end wall surface **1156** may taper outward radially with respect to the axis **1102** as the end wall surface **1156** extends along the longitudinal axis **1102** away from the inlet end **1104** and toward the outlet end **1106**. Thus, as shown in FIG. **2**, the inlet end wall surface **1150**, the longitudinal wall surface **1152**, and the outlet end wall surface **1156** may cooperatively define the interior **1146** of the fluid separator **1101**.

[0032] Furthermore, the fluid separator **1101** may include an inner flow member **1160**. The inner flow member **1160** may be frusto-conic in shape and may include an upstream end **1162**, a downstream end **1164**, an outer surface **1166** facing away from the axis **1102**, and an inner surface **1168** facing the axis **1102**. The upstream end **1162** and the downstream end **1164** may have a circular cross-section taken perpendicular to the axis **1102**. Also, the outer surface **1166** and the inner surface **1168** may be tapered. For example, for a majority of an axial length (along the axis **1102**) of the inner flow member **1160**, the outer surface **1166** and the inner surface **1168** may taper gradually outward radially as the inner flow member **1160** extends along the axis **1102** from the inlet end **1104** toward the outlet end **1106**. The inner flow member **1160** may be supported (e.g., fixed) within the interior **1146** defined by the outer wall member **1130**. For example, the fluid separator **1101** may include a plurality of brace members **1170** that extend from the downstream end **1164** of the inner flow member **1160** to the outlet end wall **1134** to support the inner flow member **1160**. The upstream end **1162** may be attached to (e.g., received over and attached to) the downstream terminal end **1122** of the inlet tube **1114** to further support the inner flow member **1160** within the interior **1146**.

[0033] The fluid separator **1101** may further include a swirler member **1172**. As shown in FIG. **6**, the swirler member **1172** may include a hub **1174** and a plurality of blades **1176** that radiate from the hub **1174** outward radially from the axis **1102**. In some embodiments, the hub **1174** may be conic or frusto-conic in shape with an upstream end **1178** (FIG. **2**) and a downstream end **1180**, which are spaced apart along the axis **1102**. The upstream end **1178** may be pointed in some embodiments, and the hub **1174** may flare outward radially toward the downstream end **1180**. The downstream end **1180** may be circular and may be normal to the axis **1102**. The blades **1176** may respectively include an inner radial end **1182**, which is fixed to the hub **1174**. The blades **1176** may extend radially outward from the inner radial end **1182** and may terminate at an outer radial end **1184** (FIG. **6**). As shown in FIG. **2**, the outer radial ends **1184** of the blades **1176** may be fixed to an opposing inner diameter surface of the terminal end **1122** of the inlet tube **1114**. Accordingly, the fluid mixture **1124** inlet via the inlet tube **1114** may flow across the swirler member **1172**.

[0034] The swirler member **1172** may be configured to at least partly direct flow of the mixture **1124** outward radially away from the axis **1102** as the mixture **1124** flows downstream along the axis **1102**. As will be discussed, the swirler member **1172** may cause the mixture **1124** to swirl as it flows downstream. As a result, centrifugal forces may move the liquid droplets in the mixture **1124** outward radially as the mixture **1124** flows downstream through the separator **1101**. The liquid droplets may separate somewhat from the water vapor and air within the flow of the mixture **1124**. Accordingly, the swirler member **1172** imparts at least some separation of the parts of the mixture **1124** during operation.

[0035] The swirler member **1172** may include any suitable number of blades **1176**. The blades **1176** may have a blade profile of any suitable type. In some embodiments, the blades **1176** may twist, extend helically about the axis **1102**, bend about an axis that is normal to the axis **1102**, and/or exhibit other blade profile characteristics. Also, the hub **1174** may have a variety of dimensions, surface profiles, and/or other characteristics without departing from the scope of the present disclosure. For example, additional embodiments of the swirler member **2172** are illustrated in FIG. **7**. The swirler member **2172** may have a different number of blades, and the blades may have a different blade profile (i.e., different blade shape, different blade contour, different dimensions, etc.) than that of the swirler member **1172** of FIG. **6**. In some embodiments, either the swirler member **1172** of FIG. **6** or the swirler member **2172** may be selected for use within the fluid separator **1101**, depending on the flow characteristics of the mixture **1124** within the system. For example, if operation of the fuel cell system **100** causes the exhaust stream **109** to flow at lower velocities, lower mass flow rates, lower inlet pressures, then the swirler member **1172** of FIG. **6** may be selected for use in the separator **1101**. In contrast, if the exhaust stream **109** flows at higher velocities, higher mass flow rates, higher inlet pressures, etc. then the swirler member **2172** of FIG. **7** may be selected for use in the separator **1101**.

[0036] Referring back to FIG. **2**, the fluid separator **1101** may further include an inner outlet pipe **1186**. The inner outlet pipe **1186** may be hollow and cylindrical with a circular cross section taken perpendicular to the axis **1102**. The inner outlet pipe **1186** may have a straight axis and may be centered about the axis **1102**. The inner outlet pipe **1186** may include an upstream end **1188**, a downstream end **1190**, an inner radial surface **1192** that faces inward toward the axis **1102**, and an outer radial surface **1194** that faces outward from the axis **1102**. The radius of the inner outlet pipe **1186** may remain substantially constant along the axis **1102**. The wall thickness of the inner outlet pipe **1186** may remain substantially constant along a majority of the axial length of the inner outlet pipe **1186**. The upstream end **1188** may flare outward radially from the axis **1102** slightly. The inner outlet pipe **1186** may be fixedly attached to the first outlet tube **1136**. For example, there may be one or more bridge supports **1193** that extend between the inner radial area of the first outlet tube **1136** and the outer radial area of the inner outlet pipe **1186**. As such, inner outlet pipe **1186** may be co-axial and centered within the first outlet tube **1136**. Also, the fluid inlet **1116**, the first fluid outlet **1138**, the second fluid outlet **1199**, and the inner flow member **1160** may be co-axial and centered with respect to the longitudinal axis **1102**. The downstream end **1190** of the inner outlet pipe **1186** may be received in the first fluid outlet **1138** of the first outlet tube **1136**. Also, the upstream end **1188** may be disposed within the interior **1146** defined by the outer wall member **1130**. More specifically, the upstream end **1188** may extend partially into the inner flow member **1160**. Stated differently, the upstream end **1188** of the inner outlet pipe **1186** may be disposed further upstream along the axis **1102** at a distance **1198** than the downstream end **1164** of the inner flow member **1160**. Accordingly, the inner outlet pipe **1186** may define a second fluid outlet **1199** from the interior **1146** of the fluid separator **1101**. It will be appreciated that the second fluid outlet **1199** may provide a lower pressure outlet for one or more components of the mixture **1124**. For example, the second fluid outlet **1199** may provide effective outlet for water vapor that has been separated from other parts of the flow as will be discussed.

[0037] The fluid separator **1101** may additionally include a drain **1171** that projects outwardly and at a positive angle **1175** from the axis **1102** and from the outer wall member **1130**, proximate the inlet end **1104**. A drain aperture **1173** may extend through the drain **1171** and through the outer wall member **1130** to fluidly communicate with the interior **1146**. The drain aperture **1173** may fluidly connect at the transition between the inlet end wall **1132** and the outer longitudinal wall **1144**. The inlet end wall **1132** may be angled toward the drain **1171** to direct liquid thereto. As will be discussed, the drain **1171** may be configured for draining liquid that has been separated from the fluid mixture **1124** and collected within the interior **1146**.

[0038] Furthermore, the fluid separator **1101** may include one or more recirculation apertures **1148**. There may be a number of recirculation apertures **1148** defined by gaps, holes, or other passages defined between the upstream end **1162** of the inner flow member **1160** and the downstream terminal end **1122** of the inlet tube **1114**. There may be a plurality of recirculation apertures **1148** that are spaced about the axis **1102**.

[0039] The fluid separator **1101** may, therefore, define and include a fluid flow path system **1126** within the interior **1146** that extends through the fluid separator **1101**. The fluid mixture **1124** may enter as the exhaust stream **109** into the inlet end **1104**, and the fluid mixture **1124** may contain air, gaseous water vapor, and liquid water droplets. The fluid separator **1101** may separate the liquid droplets from the air and gaseous water vapor. The separation may occur passively. The liquid droplets may be collected and drained from the separator **1101** via the drain **1171**.

[0040] More specifically, the fluid flow path system **1126** may include a first flow path **1128** (i.e., an axial flow path) extending substantially along the longitudinal axis **1102** in a first downstream direction from the fluid inlet **1116**, across the swirler member **1172**, and through the inner flow member **1160** toward the first fluid outlet **1138** and the second fluid outlet **1199**.

[0041] Also, the fluid flow path system **1126** may include one or more second flow paths, such as the second flow path **1129** indicated in FIG. **2**. As shown, the second flow path **1129** may be defined between the outer wall member **1130** and the inner flow member **1160**. The second flow path **1129** may be defined radially between the outer wall member **1130** and the inner flow member **1160**. The second flow path **1129** may also be defined axially (e.g., at one end) between the outer wall member **1130** and the inner flow member **1160**. Also, the second flow path **1129** may be defined partly by the recirculation aperture(s) **1148**. More specifically, the axial gap between the downstream end **1164** and the outlet end wall surface **1156** may define an upstream portion of the second flow path **1129**, where fluid flow branches away from the first flow path and the outlet end wall surface **1156** redirects flow back axially in a direction opposite the first flow path **1128**. The longitudinal wall surface **1152** and the outer surface **1166** may define the second flow path **1129** further downstream and may direct flow longitudinally generally from the outlet end **1106** and toward the inlet end **1104**. The inlet end wall surface **1150** may further define the second flow path **1129** further downstream and may redirect flow back axially toward the recirculation apertures **1148**. The recirculation apertures **1148** may fluidly connect the second flow path **1129** to the first flow path **1128**. Thus, flow through the recirculation apertures **1148** may rejoin the axial flow path **1128**. In some embodiments, the recirculation apertures **1148** may fluidly connect to the axial flow path **1128** at an axial position that is at or slightly downstream relative to the end **1180** of the swirler member **1172**.

[0042] In addition, the drain aperture **1173** may branch from the recirculation flow path **1129**. As such, the drain **1171** may define a liquid flow path as will be described.

[0043] During operation of the fuel cell system **100** (FIG. **1**), the fluid mixture **1124** may enter the separator **1101** via the inlet **1116**. The fluid mixture **1124** may contain liquid water droplets (indicated by droplet symbols in FIG. **2**), gaseous water vapor (as indicated by smaller dots in FIG. **2**), and gaseous air that flows therewith. The swirler member **1172** may swirl the flow causing the liquid droplets to move outward radially away from the axis **1102** as the mixture **1124** flows further downstream along the first flow path **1128**. Air and the liquid water may be diverted outward radially from the first flow path **1128** and into the second flow path **1129** as shown in FIG. **2**. This liquid water may drain from the drain apertures **1173**, and the air in the second flow path **1129** may rejoin the first flow path **1128**. Additionally, the gaseous water vapor in the mixture **1124** that enters the separator **1101** may flow across the swirler member **1172**. The second fluid outlet **1199** may define a lower pressure area of the outlet end **1106** that efficiently draws the gaseous water vapor out of the separator **1101**. The first fluid outlet **1138** may also provide an outlet from the first flow path **1128**. Thus, air in the mixture **1124** may flow directly from the inlet **1116** to the first and/or second fluid outlets **1138**, **1199**, and air in the mixture **1124** may also branch away from the first flow path **1128** and recirculate back thereto via the second flow path **1129**.

[0044] FIGS. **3-5** illustrate methods of manufacturing the separator **1101** according to example embodiments. As will be discussed, the separator **1101** may include features that increase modularity and/or allow the separator **1101** to be tailored to a specific system **100**. For example, the separator **1101** may be assembled from distinct parts/sections in an efficient and modifiable manner.

[0045] In some embodiments, one or more portions of the separator **1101** may be made from or contain a polymeric or composite material. For example, the separator **1101** may be made from a fiberglass reinforced polyamide resin in some embodiments. Furthermore, in some embodiments, the separator **1101** may be molded in some embodiments (e.g., formed via plastic injection molding). However, it will be appreciated that the separator **1101** may be formed otherwise without departing from the scope of the present disclosure.

[0046] As shown in FIG. **3**, inlet tube **1114** and outer wall member **1130** may be provided together (e.g., plastic injection molded) as a unitary, one-piece inlet part **3112**. In some embodiments, a first outlet end lip **3102** may be included for use in further assembly as will be discussed. Also, the swirler member may be selectively chosen, for example, from a group **3120** consisting of at least the swirler member **1172** of FIG. **6** and the swirler member **2172** of FIG. **7**. As an example, the swirler member **1172** of FIG. **6** may be selected and attached to the inlet tube **1114** to form an inlet end subassembly **3100**.

[0047] As mentioned above, the swirler member **1172** may be selected over the swirler member **2172**, for example, based on the flow velocity, inlet pressure, mass flow rate, and/or other operating condition that is expected during use. It will be appreciated that dimensions of the part **3112** may also be varied and selected for use in a similar fashion.

[0048] Additionally, as shown in FIG. **4**, the outlet end wall **1134**, the first outlet tube **1136**, and the inner outlet pipe **1186** may be provided together (e.g., plastic injection molded) as a unitary, one-piece outlet part **3114**. In some embodiments, a second outlet end lip **3103** may be included for use in further assembly as well be discussed. Also, the outlet part **3114** may include one or more tabs **3117** included thereon. The inner flow member **1160** may also be formed (e.g., plastic injection molded) to include corresponding tabs **3118** as shown. The pairs of tabs **3117**, **3118** may be connected together (e.g., via fasteners, adhesives, etc.) to attach the inner flow member **1160** to the outlet part **3114** and to define the brace members **1170** described above. Accordingly, the attached outlet part **3114** and inner flow member **1160** may cooperatively define an outlet end subassembly

3200.

[0049] Subsequently, as shown in FIG. **5**, the inlet end subassembly **3100** and the outlet end subassembly **3200** may be joined together to define the separator **1101**. For example, the first outlet end lip **3102** may be joined to the second outlet end lip **3103** (e.g., via fasteners, adhesives, etc.).

[0050] Accordingly, the separator **1101** may separate and remove liquid water from the exhaust stream **109** (FIG. **1**), and water vapor and air may be provided as the separated exhaust stream **111** to the turbine section **115** of the turbomachine **117**. There may be a relatively low pressure drop (i.e., a low pressure gradient) across the separator **1101** from the inlet end **1104** to the outlet end **1106**. Thus, the separator **1101** may provide efficient fluid flow across a wide range of operating conditions such that the system **100** operates at high efficiency. Also, the separator **1101** may be compact and lightweight. The separator **1101** may be manufactured efficiently with relatively few parts as well.

[0051] While at least one exemplary embodiment has been presented in the foregoing detailed description of the disclosure, it should be appreciated that a vast number of variations exist. It should also be appreciated that the exemplary embodiment or exemplary embodiments are only examples, and are not intended to limit the scope, applicability, or configuration of the disclosure in any way. Rather, the foregoing detailed description will provide those skilled in the art with a convenient road map for implementing an exemplary embodiment of the disclosure. It is understood that various changes may be made in the function and arrangement of elements described in an exemplary embodiment without departing from the scope of the disclosure as set forth in the appended claims.

Claims

1. A fluid separator device configured for separating a part of a fluid mixture from another part of the fluid mixture, the fluid separator device comprising: an outer wall member that defines an interior of the fluid separator device, the interior defining a longitudinal axis of the fluid separator device; an inlet end that defines a fluid inlet that is fluidly connected to the interior and that is configured to receive the fluid mixture; an outlet end separated at a distance from the inlet end along the longitudinal axis, the outlet end defining a first fluid outlet from the interior, the longitudinal axis extending through the first fluid outlet; an outlet pipe that is supported within the interior and within the first fluid outlet, the outlet pipe defining a second fluid outlet from the interior; an inner flow member that is supported within the interior; a fluid flow path system defined within the interior, the fluid flow path system including: a first flow path extending in a first downstream direction from the fluid inlet and through the inner flow member toward at least one of the first fluid outlet and the second fluid outlet; and a second flow path that is at least partly defined between the outer wall member and the inner flow member, the second flow path extending in a second downstream direction from the outlet end toward the inlet end, the second flow path configured to receive flow from the first flow path.

2. The fluid separator device of claim 1, further comprising a swirler member supported within the first flow path and configured to at least partly direct the first flow path outward radially from the longitudinal axis.

3. The fluid separator device of claim 2, further comprising a recirculation aperture extending through the inner flow member, the recirculation aperture fluidly connecting the second flow path to the first flow path and configured to recirculate flow from the second flow path to the first flow path.

4. The fluid separator device of claim 3, wherein the swirler member includes an upstream end, a downstream end, and a plurality of blades that radiate about the longitudinal axis; and wherein the recirculation aperture is fluidly connected to the first flow path at the downstream end of the swirler member.

5. The fluid separator device of claim 4, further comprising a drain aperture extending through the outer wall member that is fluidly connected to the second flow path and configured for draining a liquid component of the fluid mixture from the fluid separator device.
6. The fluid separator of claim 1, wherein the outer wall member includes an inner surface that at least partly defines the interior, the inner surface being tapered outward radially with respect to the longitudinal axis as the inner surface extends along the longitudinal axis from the inlet end toward the outlet end.
7. The fluid separator of claim 6, wherein the inner flow member includes an outer surface that is tapered outward radially with respect to the longitudinal axis as the outer surface extends along the longitudinal axis from the inlet end toward the outlet end.
8. The fluid separator of claim 1, wherein the inner flow member includes an inner surface that is tapered outward radially with respect to the longitudinal axis as the inner surface extends along the longitudinal axis from the inlet end toward the outlet end.
9. The fluid separator of claim 8, wherein the outlet pipe extends partially into the inner flow member.
10. The fluid separator of claim 1, wherein the outer wall member includes an inlet end wall surface proximate the inlet end and extending transverse to the longitudinal axis, an outlet end wall surface proximate the outlet end and extending transverse to the longitudinal axis, and a longitudinal wall surface extending between the inlet end wall surface and the outlet end wall surface along the longitudinal axis; and wherein the inlet end wall surface, the outlet end wall surface, and the longitudinal wall surface cooperatively define the interior.
11. The fluid separator of claim 10, wherein the outlet end wall surface is tapered outward radially with respect to the axis as the outlet end wall surface extends along the longitudinal axis away from the inlet end and toward the outlet end.
12. The fluid separator of claim 1, wherein the first fluid outlet and the second fluid outlet are co-axial and centered with respect to the longitudinal axis.
13. The fluid separator of claim 12, wherein the longitudinal axis is straight, and wherein the fluid inlet, the first fluid outlet, and the second fluid outlet are co-axial and centered with respect to the longitudinal axis.
14. The fluid separator of claim 13, wherein the fluid inlet, the first fluid outlet, the second fluid outlet, the inner flow member and the outer wall member are co-axial and centered with respect to the longitudinal axis.
15. A method of manufacturing a fluid separator device that is configured for separating a part of a fluid mixture from another part of the fluid mixture, the method comprising: providing an outer wall member that defines an interior of the fluid separator device, the interior defining a longitudinal axis of the fluid separator device; providing an inlet end that defines a fluid inlet that is fluidly connected to the interior and that is configured to receive the fluid mixture; providing an outlet end separated at a distance from the inlet end along the longitudinal axis, the outlet end defining a first fluid outlet from the interior, the longitudinal axis extending through the first fluid outlet; supporting an outlet pipe within the interior and within the first fluid outlet, the outlet pipe defining a second fluid outlet from the interior; supporting an inner flow member within the interior; defining a fluid flow path system within the interior, the fluid flow path system including: a first flow path extending in a first downstream direction from the fluid inlet and through the inner flow member toward at least one of the first fluid outlet and the second fluid outlet; and a second flow path that is at least partly defined between the outer wall member and the inner flow member, the second flow path extending in a second downstream direction from the outlet end toward the inlet end, the second flow path configured to receive flow from the first flow path.
16. The method of claim 15, further comprising supporting a swirler member within the first flow path and configured to at least partly direct the first flow path outward radially from the longitudinal axis.

17. The method of claim 16, further comprising selecting the swirler member from a group consisting of a first swirler member and a second swirler, the second swirler having a different blade profile from that of the first swirler member.

18. The method of claim 16, further comprising providing the outer wall member and the inlet end as a unitary, one-piece part and attaching the swirler member to the unitary, one-piece part to form a first subassembly of the fluid separator device.

19. The method of claim 18, further comprising providing the outlet end and the outlet pipe together as another unitary, one-piece part and attaching the inner flow member to the other unitary, one-piece part to form a second subassembly of the fluid separator device; and further comprising attaching the first subassembly to the second subassembly.

20. A fuel cell system comprising: a fuel cell stack; a turbomachine with a turbine section; and a fluid separator device fluidly connected to the fuel cell stack and configured to receive a fluid mixture from the fuel cell stack, the fluid separator device fluidly connected upstream to the turbine section, the fluid separator device configured for separating a part of the fluid mixture from another part of the fluid mixture to provide a separated exhaust stream from the fuel cell stack to the turbine section, the fluid separator device comprising: an outer wall member that defines an interior of the fluid separator device, the interior defining a longitudinal axis of the fluid separator device; an inlet end that defines a fluid inlet that is fluidly connected to the interior and that is configured to receive the fluid mixture; an outlet end separated at a distance from the inlet end along the longitudinal axis, the outlet end defining a first fluid outlet from the interior, the longitudinal axis extending through the first fluid outlet; an outlet pipe that is supported within the interior and within the first fluid outlet, the outlet pipe defining a second fluid outlet from the interior; an inner flow member that is supported within the interior; and a fluid flow path system defined within the interior, the fluid flow path system including: a first flow path extending in a first downstream direction from the fluid inlet and through the inner flow member toward at least one of the first fluid outlet and the second fluid outlet; and a second flow path that is at least partly defined between the outer wall member and the inner flow member, the second flow path extending in a second downstream direction from the outlet end toward the inlet end, the second flow path configured to receive flow from the first flow path.