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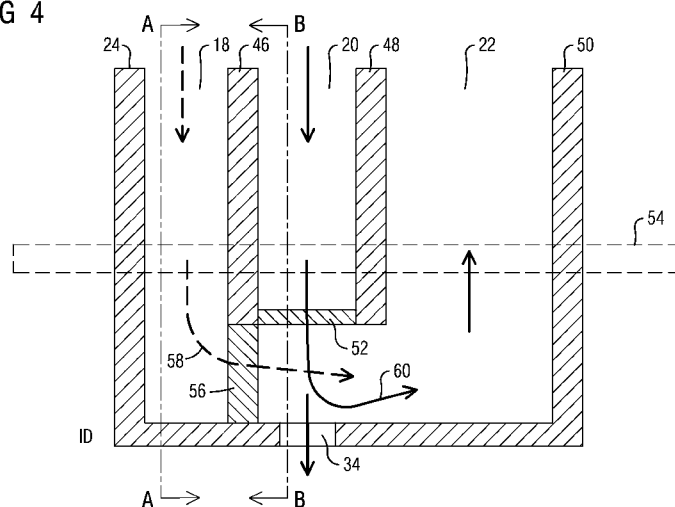
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(54) **Title:** TURBINE STATOR VANE COOLING CIRCUIT WITH FLOW STREAM SEPARATION

FIG 4



(57) **Abstract:** A turbine stator vane (10) having a cooling circuit (62) formed within the vane (10) including a plurality of channels, at least a first pass channel (12), a second pass channel (14), and a final pass channel (16) and an inter-stage purge hole (34). A first pass channel (12) comprises a first cavity (18) and a second cavity (20). The first cavity (18) is aligned along a leading edge (24) of the vane (10). A first rib (46) divides the first cavity (18) and the second cavity (20). A flow deflector fin (52) is positioned below the first rib (46) along a lower edge of the cooling circuit (62) and above a partial first rib extension (56) on the suction side wall (40) or pressure side wall (38) of the vane (10) into the substantially 180-degree turn, wherein the flow from the first cavity (18) is directed up through the second pass channel (14) and the flow from the second cavity (20) is directed partially down through the inter-stage purge hole (34) and partially up through the second pass channel (14).

TURBINE STATOR VANE COOLING CIRCUIT WITH FLOW STREAM SEPARATION

BACKGROUND

1. Field

[0001] The present invention relates to gas turbine engines, and more specifically
5 to turbine blades and vanes with internal cooling air circuits.

2. Description of the Related Art

[0002] In an industrial gas turbine engine, hot compressed gas is produced. The hot gas flow is passed through a turbine and expands to produce mechanical work used to drive an electric generator for power production. The turbine generally
10 includes multiple stages of stator vanes and rotor blades to convert the energy from the hot gas flow into mechanical energy that drives the rotor shaft of the engine. Turbine inlet temperature is limited to the material properties and cooling capabilities of the turbine parts. This is especially important for upstream stage turbine vanes and blades since these airfoils are exposed to the hottest gas flow in the system.

15 [0003] A combustion system receives air from a compressor and raises it to a high energy level by mixing in fuel and burning the mixture, after which products of the combustor are expanded through the turbine.

[0004] Since the turbine vanes and blades are exposed to the hot gas flow discharged from combustors within the combustion system, cooling methods are used
20 to obtain a useful design life cycle for the turbine blade or vane. Blade and vane cooling is accomplished by extracting a portion of the compressed air from the compressor and directing it to the turbine section, thereby bypassing the combustors. After introduction into the turbine section, this cooling air flows through passages formed in the airfoil portions of the blades and vanes.

25 [0005] In order to allow for higher temperatures, turbine vane and blade designers have proposed several complex internal blade cooling circuits to maximize the blade cooling through the use of convection cooling, impingement cooling and film cooling

of the blades. FIGS. 1 through 2 show a prior art turbine vane with an aft flowing triple pass cooling circuit designs. The vane cooling circuit includes a first pass cooling channel, a second pass cooling channel, and a third pass cooling channel. The cooling circuits flow from a leading edge aft ward towards a trailing edge of the vane.

5 [0006] Some of the main gas flow may flow into turbine rotor cavities. Pressure variations induced by the rotating parts cause recirculation within the cavities, thus drawing the hot gas flow towards a stator and rotor seals. Sufficient cooling air may be provided to protect these seals from the hot main gas.

10 [0007] An inter-stage cavity purge may exit from the cooling circuits to decrease the temperature in these cavities. However, the cooling air flowing through the cooling circuit is heated as it flows along the leading edge of the vane, increasing the cooling air flow temperature.

15 [0008] Typically, the vane segment may include an inner shroud attached to an interstage housing and an outer shroud along the stator casing and may be spaced apart from the inner shroud. The inner and outer shrouds are subject to high heat flux because of the high gas temperature in the shroud area of the turbine.

20 [0009] The cooling air from the cooling circuits enters from the outer shroud and flows radially inwardly through a leading edge cavity channel. After cooling the leading edge and picking up heat, a portion of the warm air may be bled out to the inner shroud cavity for the inter-stage cavity purge with the rest of the warm air making a 180-degree turn at the root and flowing radially outwardly in the mid channel to an upper span. The air from the mid channel makes another 180-degree turn at the outer diameter (OD) into a trailing edge channel and flows radially inwardly. The cooling air in the trailing edge cavity exits axially from the vane through trailing edge holes. While this cast-in serpentine design provides the purge flow to the inter-stage cavity purge flow without a separate jumper tube requirement, the cooling air at the bottom of the leading edge channel after picking up heat can be too hot to provide adequate cooling for the inter-stage cavity that is shown in Fig. 1.

[0010] Currently, a jumper tube from the outer shroud to the inner shroud has been

used in many turbine vanes to bring the colder air through the vane to the inter-stage cavity with less heat pickup. However, the jumper tube requires additional assembly at additional cost and only works for a generally linear airfoil.

SUMMARY

5 **[0011]** In one aspect of the present invention, a turbine stator vane comprising: a cooling circuit formed within the vane comprising a pressure side and a suction side to provide cooling for the vane comprising: a first pass channel comprising a first cavity and a second cavity, wherein the first cavity is aligned along a leading edge of the vane; a first rib divides the first cavity and the second cavity, an inter-stage purge
10 hole along a lower end of the cooling circuit; a second pass channel comprising a third cavity positioned aft of a substantially 180-degree turn of the cooling circuit at a root end of the vane; a second rib positioned between the second cavity and the third cavity; a final pass channel comprising a final cavity positioned aft of a substantially 180-degree turn of the cooling circuit at a tip end of the vane; a third rib positioned
15 between the third cavity and the final cavity; and a flow deflector fin positioned below the first rib along a lower edge of the cooling circuit and above a partial first rib extension on the suction side wall or pressure side wall of the vane into the substantially 180-degree turn, wherein the flow from the first cavity is directed up through the third cavity and the flow from the second cavity is directed down through
20 the inter-stage purge hole and the third cavity.

[0012] In another aspect of the present invention, a method for supplying cooling air flow to an inter-stage cavity of a turbine vane through flow stream separation, comprising: supplying cooling air flow into a cooling circuit formed within the vane comprising a pressure side and a suction side to provide cooling for the vane, the
25 cooling circuit comprising: a first pass channel comprising a first cavity and a second cavity, wherein the first cavity is aligned along a leading edge of the vane, a first rib divides the first cavity and the second cavity, an inter-stage purge hole along a lower end of the cooling circuit; a second pass channel comprising a third cavity positioned aft of a substantially 180-degree turn of the cooling circuit at a root end of the vane; a
30 second rib positioned between the second cavity and the third cavity; a final pass channel comprising a final cavity positioned aft of a substantially 180-degree turn of

the cooling circuit at a tip end of the vane; and a third rib positioned between the third cavity and the final cavity; directing hot cooling air flow from the first cavity adjacent to the pressure side or the suction side of the vane and directing cold cooling air flow from the second cavity down through the inter-stage purge hole and the third cavity adjacent to the opposite side of the vane as the hot cooling air flow through a flow deflector fin positioned below the first rib along a lower edge of the cooling circuit.

[0013] These and other features, aspects and advantages of the present invention will become better understood with reference to the following drawings, description and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] The invention is shown in more detail by help of figures. The figures show preferred configurations and do not limit the scope of the invention.

[0015] FIG 1 is a detailed side view of the flow path of a triple pass serpentine cooled turbine vane according to the prior art.

[0016] FIG 2 is a a cross sectional top view of a cooling circuit according to the prior art.

[0017] FIG 3 is a cross sectional top view of a cooling circuit of an exemplary embodiment of the present invention.

[0018] FIG 4 is a partial section view of an exemplary embodiment of the present invention along line C-C in Fig. 4.

[0019] FIG 5 is a partial section view of an exemplary embodiment of the present invention along line A-A in Fig. 5.

[0020] FIG 6 is a partial section view of an exemplary embodiment of the present invention along line B-B in Fig. 5.

[0021] FIG 7 is a partial section view of an alternate embodiment of the present

invention along line A-A in Fig. 5.

[0022] FIG 8 is a partial section view of an alternate embodiment of the present invention along line B-B in Fig. 5.

DETAILED DESCRIPTION

5 [0023] Broadly, an embodiment of the present invention provides a turbine stator vane having a cooling circuit formed within the vane including a plurality of channels, at least a first pass channel, a second pass channel, and a final pass channel and an inter-stage purge hole. A first pass channel comprises a first cavity and a second cavity. The first cavity is aligned along a leading edge of the vane. A first rib divides
10 the first cavity and the second cavity. A flow deflector fin is positioned below the first rib along a lower edge of the cooling circuit and/or the first rib is partially extended on the suction side wall or pressure side wall of the vane into the substantially 180-degree turn, wherein the flow from the first cavity is directed up through the second pass channel and the flow from the second cavity is directed down through the inter-
15 stage purge hole and the second pass channel.

[0024] A vane of a gas turbine receives high temperature gases from a combustion system in order to produce mechanical work of a shaft rotation. Due to the high temperature gases, a cooling system may be provided to reduce the temperature levels throughout the vane.

20 [0025] As is illustrated in Figures 3 through 8, a turbine stator vane 10 (not shown) may include a cooling circuit 62. The cooling circuit 62 may be formed within the vane 10. The vane 10 has a pressure side 38, a suction side 40, a root end 42, a tip end 44, a leading edge 24, and a trailing edge 26. The cooling circuit 62 is provided for cooling of the vane 10. In certain embodiments, the turbine stator vane 10 may
25 include a linear or non-linear vane airfoil configuration.

[0026] The cooling circuit 62 may include a plurality of pass channels. The pass channels may be presented in a serpentine style. A first pass channel 12 may split into two parallel cavities, a first cavity 18 and a second cavity 20. The first cavity 18 may be aligned along the leading edge 24 of the vane 10. A first rib 46 may divide the first

cavity 18 and the second cavity 20. The cooling circuit 62 may include an inter-stage purge hole 34 along a lower end of the cooling circuit 62. In certain embodiments, the inter-stage purge hole 34 may be positioned adjacent to the suction side wall 40.

5 [0027] The inter-stage purge hole 34 may provide access for cooling air flow 36 to provide cooling for an inter-stage cavity of the vane 10. Systems such as the ones shown in Figures 1 through 2 create cooling air flow 36 (not shown) that may be too hot to provide adequate cooling for the inter-stage cavity due to the increase in temperature in the first pass channel 12.

10 [0028] As is shown in Figures 4 through 9, a second pass channel 14 may be connected to the first pass channel 12. The second pass channel 14 may include a third cavity 22 positioned aft of a substantially 180-degree turn of the cooling circuit 62 at the root end 42 of the vane 10. A second rib 48 may be positioned between the second cavity 20 and the third cavity 22. The first cavity 18 and the second cavity 20 merge into the radially outward third cavity 22.

15 [0029] A final pass channel 16 may include a final cavity 28 positioned aft of a substantially 180-degree turn in the cooling circuit 62 at a tip end 44 of the vane 10. A third rib 50 may be positioned between the third cavity 22 and the final cavity 28. The final pass channel 16 may run a radial length of the vane 10 and open axially aft ward towards and through the trailing edge 26 of the vane 10. In certain embodiments, a
20 plurality of trailing edge pin banks and/or trailing edge exit holes may be aligned along the trailing edge 26 allowing for cooling air flow 36 to exit aft ward along the trailing edge 26 of the vane 10 and out of the vane 10.

[0030] In certain embodiments, a flow deflector fin 52 may be positioned in the lower end of second cavity 20 and above the partial first rib extension 56. The flow
25 deflector fin 52 may direct cooling air flow 36 exiting the second cavity 20 to stay adjacent to the suction side wall 40. In certain embodiments, the flow deflector fin 52 may be circumferentially oriented.

[0031] The flow deflector fin 52 may be attached to the suction side wall 40, such as by a casting method or the like. The flow deflector fin 52 may be attached at the

root end 42 to deflect a cold cooling air flow 60 exiting from the second cavity 20 to stay adjacent to the suction side wall 40 before the substantially 180-degree turn. The flow deflector fin 52 may be positioned below an inner shroud 54.

5 [0032] In certain embodiments the flow deflector fin 52 may be attached to the first rib 46 that may be partially extended on the suction side 40 of the blade 10 into the substantially 180-degree turn. The partial first rib extension 56 may shield the cold cooling air flow 60 exiting from the second cavity 20.

10 [0033] The hot cooling air flow 58 exiting the first cavity 18 may flow under the circumferential flow deflector fin 52 to prevent the direct mixing with cold cooling air flow 60 from the second cavity 20. A hot cooling air flow 58 from the first cavity 18 may stay adjacent to the pressure side wall 38 while the cold cooling air flow 60 from the second cavity 20 adjacent to the suction side wall 40 prior to the substantially 180-degree turn, and before the two flows stream mix together and enter into the radially outward third cavity 22 as cooling air flow 36.

15 [0034] In certain embodiments, the inter-stage purge hole 34 may be located adjacent to the suction side wall 40 at the root turn in the cooling circuit 62. The cold cooling air flow 60 from the second cavity 20 may be partially captured by the inter-stage purge hole 34 along the suction side wall 40.

20 [0035] A method for supplying cooling air flow 36 to an inter-stage cavity of a turbine vane 10 through flow stream separation in a cooling circuit 62 may include the supplying of cooling air flow 36 into the cooling circuit 62. The cooling air flow 36 may enter into the first pass channel 12 and may be divided into the first cavity 18 and parallel second cavity 20. The widths of the cavities may be the same, or may be of varying ratios.

25 [0036] The cooling air flow 36 that is sent through the first cavity 18 absorbs more heat from the higher heat flux leading edge 24 region than the cooling air flow 36 through the second cavity 20. Due to this positioning of the first cavity 18 and the second cavity 20, the hot cooling air flow 58 exiting from the first cavity 18 is hotter than the cold cooling air flow 60 exiting from the second cavity 20. The inter-stage

purge hole 34 may be located adjacent to the suction side wall 40. The flow deflector fin 52 may be attached to the suction side wall 40. The cold cooling air flow 60 coming from the second cavity 20 may exit the second cavity 20 and may be directed to feed the inter-stage purge hole 34 by the flow deflector fin 52. There is no need to
5 add a jumper tube. Both the hot cooling air flow 58 from the first cavity 18, and the cold cooling air flow 60 from the second cavity 20 not sent through the inter-stage purge hole 34 may be directed to and blend and follow the substantially 180-degree turn into the second pass channel 14.

[0037] In certain embodiments, the hot cooling air flow 58 from the first cavity 18
10 may stay adjacent to the suction side wall 40 while cold cooling air flow 60 from the second cavity 20 may be adjacent to the pressure side wall 38 prior to the substantially 180-degree turn. The inter-stage purge hole 34 and the flow deflector fin 52 may be positioned against the pressure side wall 38 of the cooling circuit 62 in these embodiments. The partial first rib extension 56 may also be adjusted to provide
15 direction for the cooling air flow 36 in these embodiments.

[0038] While specific embodiments have been described in detail, those with ordinary skill in the art will appreciate that various modifications and alternative to those details could be developed in light of the overall teachings of the disclosure. Accordingly, the particular arrangements disclosed are meant to be illustrative only
20 and not limiting as to the scope of the invention, which is to be given the full breadth of the appended claims, and any and all equivalents thereof.

CLAIMS

What is claimed is:

1. A turbine stator vane (10) comprising:
 - 5 a cooling circuit (62) formed within the vane (10) comprising a pressure side and a suction side to provide cooling for the vane (10) comprising:
 - a first pass channel (12) comprising a first cavity (18) and a second cavity (20), wherein the first cavity (18) is aligned along a leading edge (24) of the vane (10);
 - 10 a first rib (46) divides the first cavity (18) and the second cavity (20),
 - an inter-stage purge hole (34) along a lower end of the cooling circuit (62);
 - 15 a second pass channel (14) comprising a third cavity (22) positioned aft of a substantially 180-degree turn of the cooling circuit (62) at a root end (42) of the vane (10);
 - a second rib (48) positioned between the second cavity (20) and the third cavity (22);
 - 20 a final pass channel (16) comprising a final cavity (28) positioned aft of a substantially 180-degree turn of the cooling circuit (62) at a tip end (44) of the vane (10);
 - a third rib (50) positioned between the third cavity (22) and the final cavity (28); and
 - 25 a flow deflector fin (52) positioned below the first rib (46) along a lower edge of the cooling circuit (62) and above a partial first rib extension (56) on the suction side wall (40) or pressure side wall (38) of the vane (10) into the substantially 180-degree turn, wherein flow from the first cavity (18) is directed up through the third cavity (22) and the flow from the
 - 30 second cavity (20) is directed down through the inter-stage purge hole (34) and the third cavity (22).

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2. The turbine stator vane (10) according to claim 1, wherein the final pass channel (16) exits axially along the trailing edge of the vane (10).

3. The turbine stator vane (10) according to claims 1 or 2, wherein the inter-stage purge hole (34) is located adjacent to the suction side wall (40) or pressure side wall (38) opposite the location of the flow deflector fin (52).

4. The turbine stator vane (10) according to any of the claims 1-3, wherein the turbine rotor blade (10) comprises a non-linear vane airfoil configuration.

5. The turbine stator vane (10) according to any of the claims 1-4, wherein the flow deflector fin (52) is positioned below an inner shroud level (54).

10 6. A method for supplying cooling air flow (36) to an inter-stage cavity of a turbine vane 10 through flow stream separation, comprising:

supplying cooling air flow (36) into a cooling circuit (62) formed within the vane (10) comprising a pressure side (38) and a suction side (40) to provide cooling for the vane (10), the cooling circuit (62) comprising:

15 a first pass channel (12) comprising a first cavity (18) and a second cavity (20), wherein the first cavity (18) is aligned along a leading edge (24) of the vane (10), a first rib (46) divides the first cavity (18) and the second cavity (20),

20 an inter-stage purge hole (34) along a lower end of the cooling circuit (62);

a second pass channel (14) comprising a third cavity (22) positioned aft of a substantially 180-degree turn of the cooling circuit (62) at a root end (42) of the vane (10);

25 a second rib (48) positioned between the second cavity (20) and the third cavity (22);

a final pass channel (16) comprising a final cavity (28) positioned aft of a substantially 180-degree turn of the cooling circuit (62) at a tip end (44) of the vane (10); and

30 a third rib (50) positioned between the third cavity (22) and the final cavity (28);

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directing hot cooling air flow (58) flow from the first cavity (18) adjacent to the pressure side (38) or the suction side (40) of the vane (10) and directing cold cooling air flow (60) from the second cavity (20) down through the inter-stage purge hole (34) and the third cavity (22) adjacent to the opposite side of the vane (10) as the hot cooling air flow (58) through a flow deflector fin (52) positioned below the first rib (46) along a lower edge of the cooling circuit (62).

7. The method according to claim 6, wherein the final pass channel (16) exits axially along the trailing edge of the vane (10).

8. The method according to claims 6 or 7, wherein the inter-stage purge hole (34) is located adjacent to the suction sidewall (40) or pressure side wall (38) opposite the location of the flow deflector fin (52).

9. The method according to any of the claims 6-8, wherein the turbine stator vane (10) comprises a non-linear vane airfoil configuration.

10. The method according to any of the claims 6-9, wherein the flow deflector fin (52) is positioned below an inner shroud level (54).

FIG 1
PRIOR ART

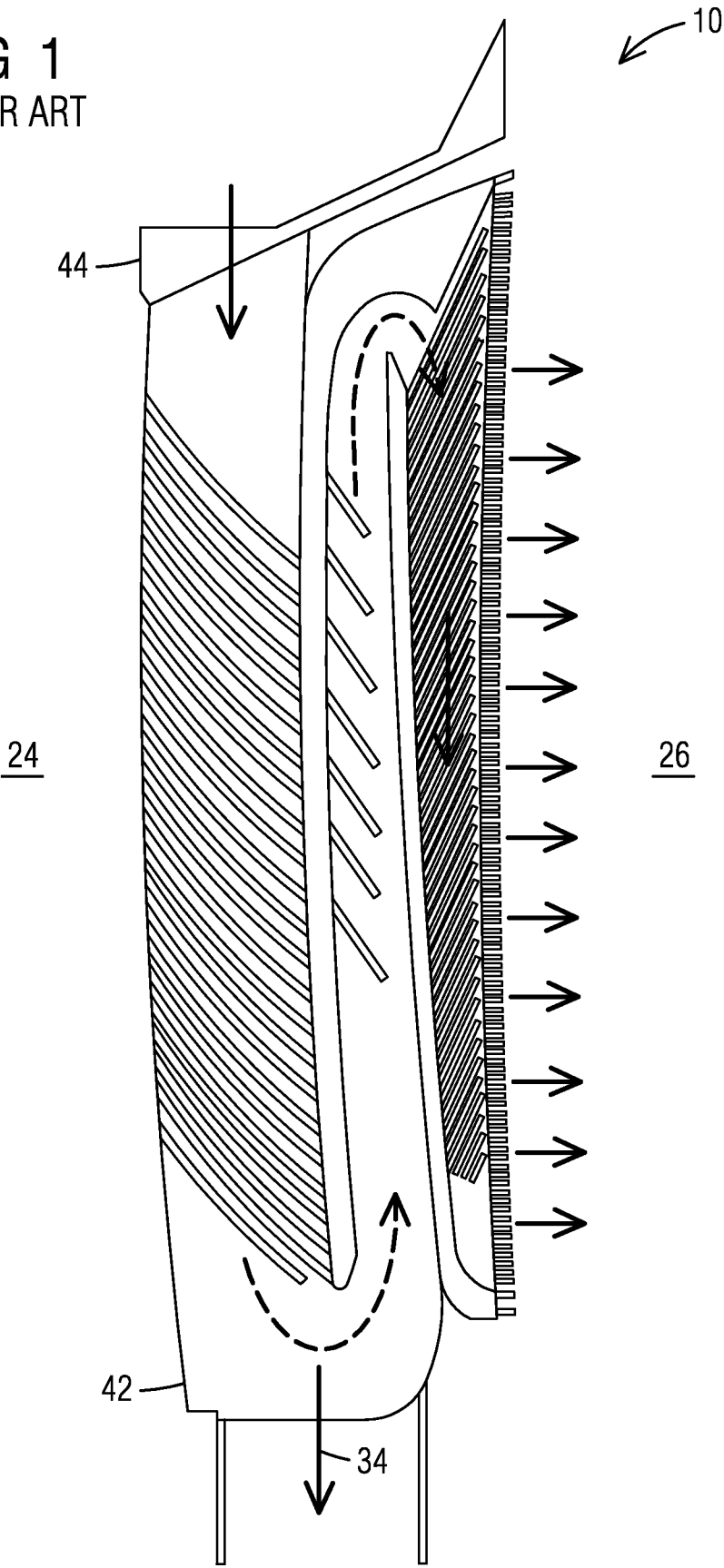


FIG 2
PRIOR ART

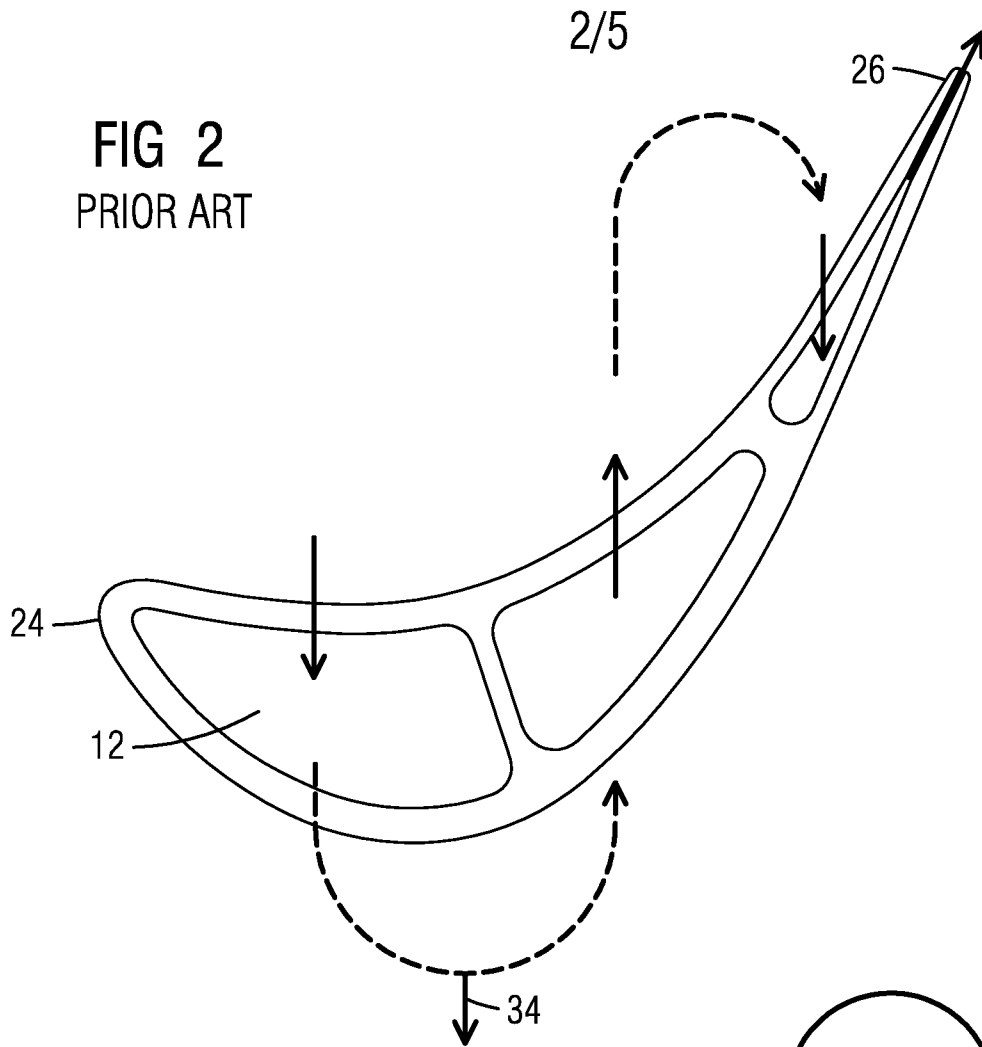


FIG 3

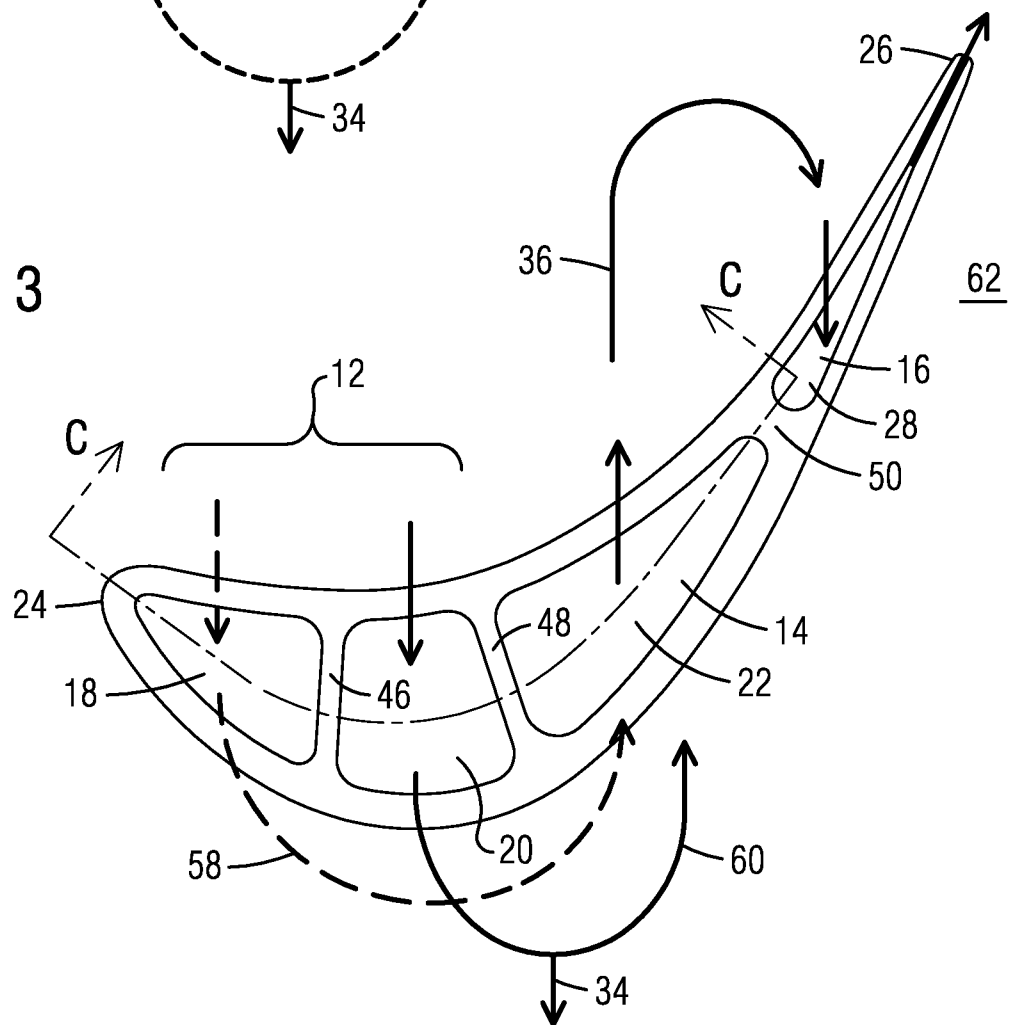
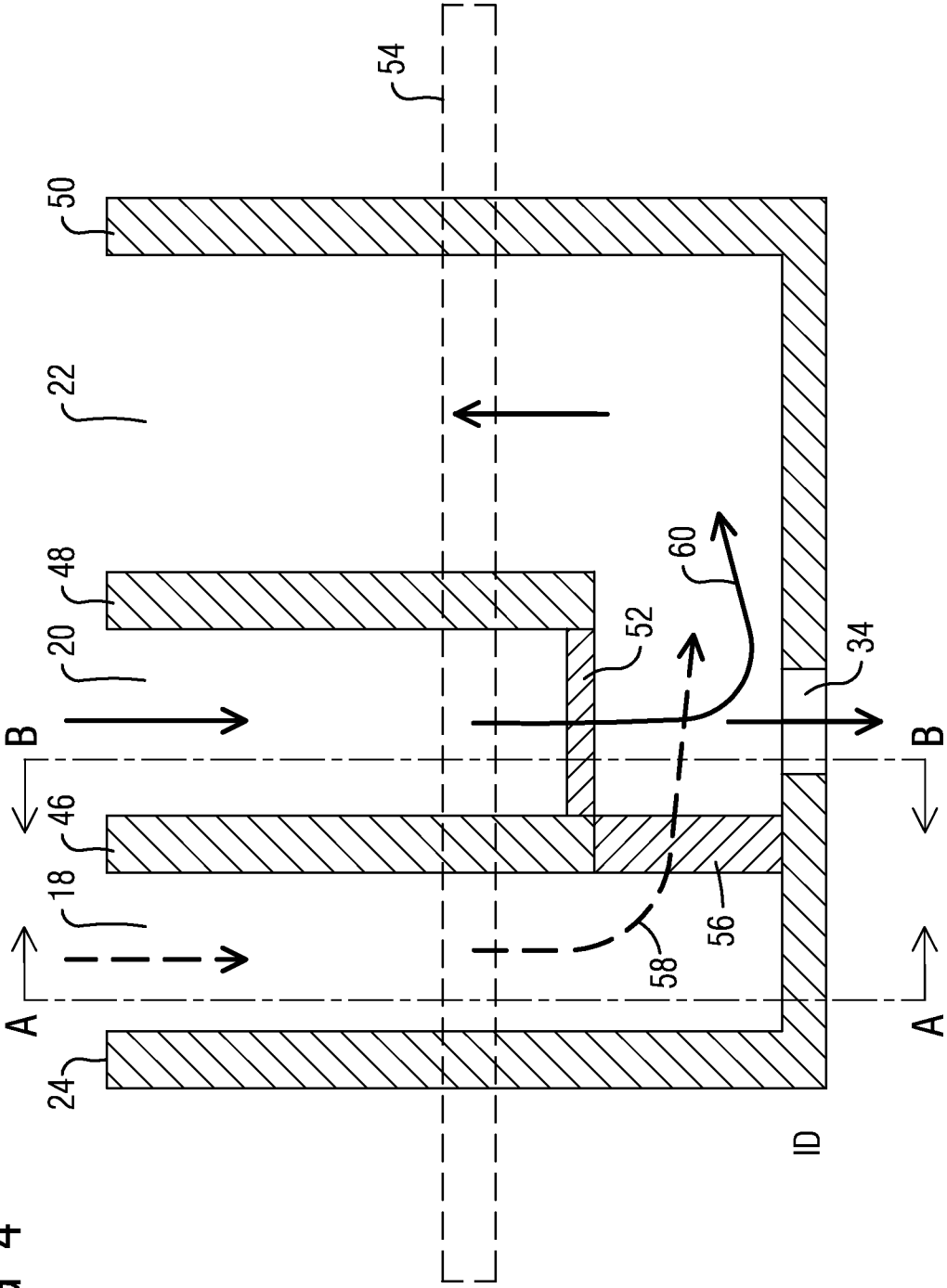


FIG 4



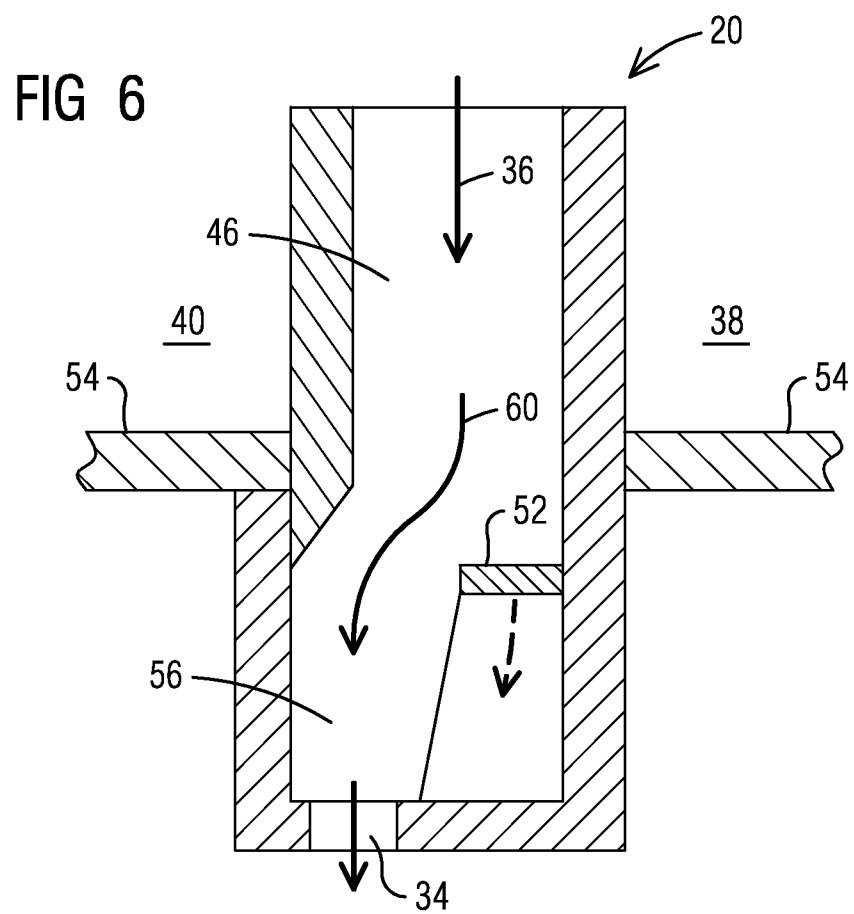
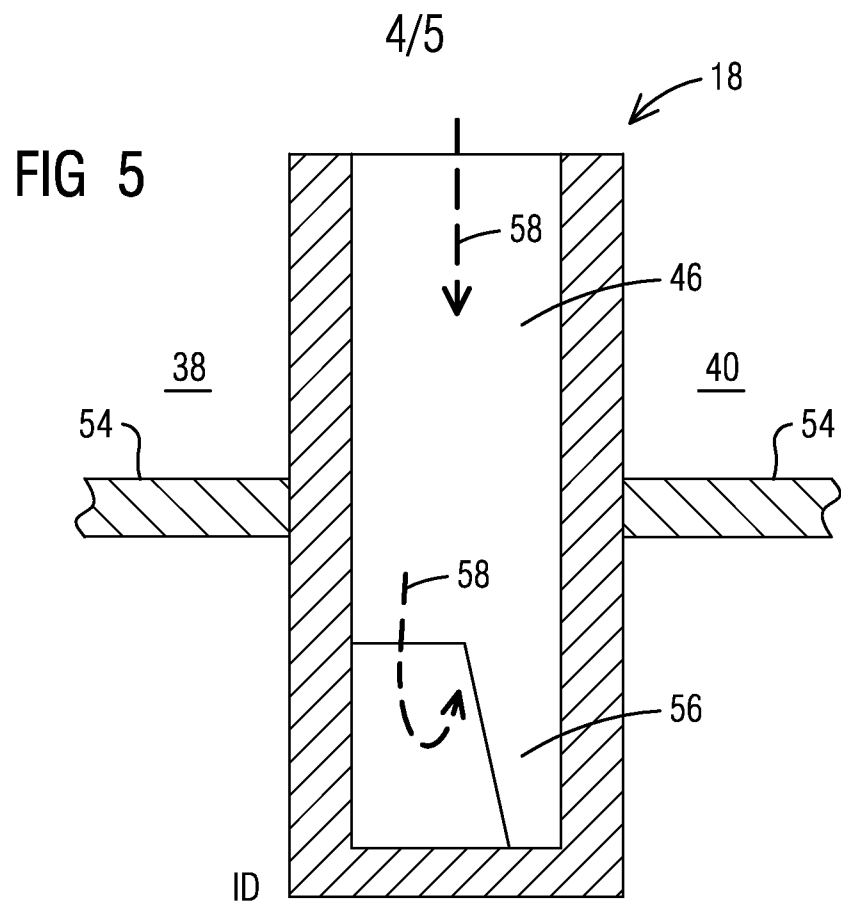


FIG 7

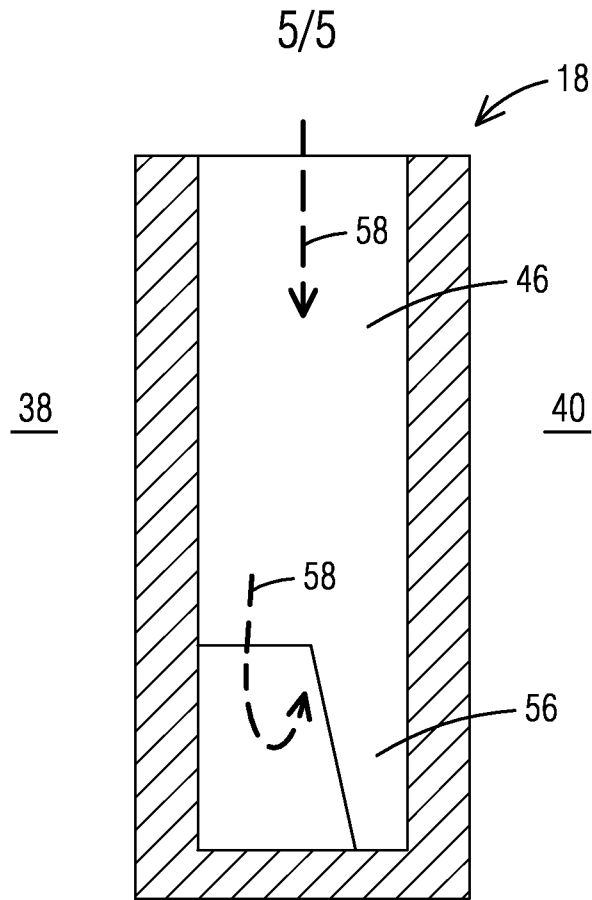
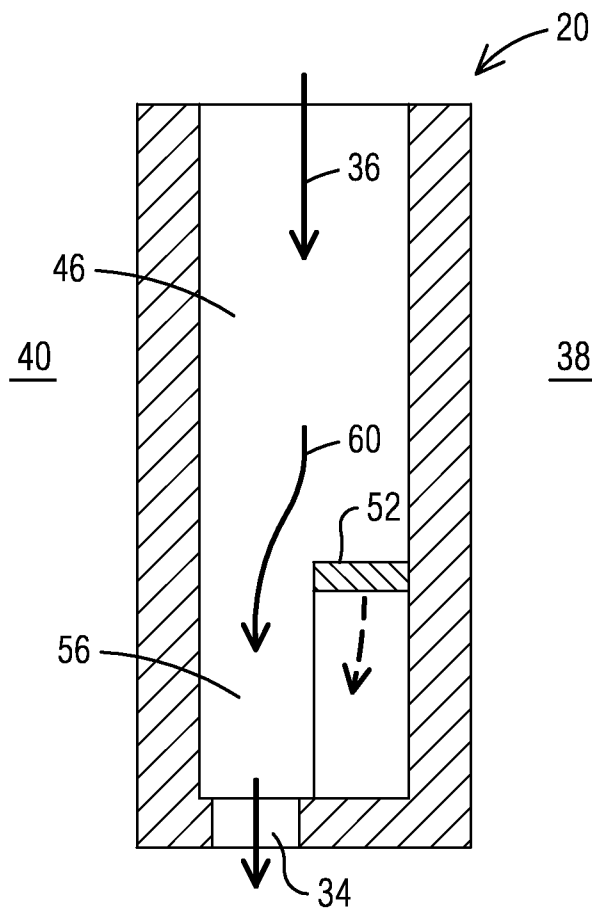


FIG 8



INTERNATIONAL SEARCH REPORT

International application No

PCT/US2015/038559

A. CLASSIFICATION OF SUBJECT MATTER
 INV. F01D5/18 F01D9/06
 ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
 F01D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 8 757 961 B1 (LIANG GEORGE [US]) 24 June 2014 (2014-06-24) column 3, line 6 - line 13; figure 4 -----	1-10
A	US 2005/031445 A1 (MCCLELLAND ROBERT J [US]) 10 February 2005 (2005-02-10) figure 2 -----	1-10
A	US 2009/185893 A1 (PROPHETER-HINCKLEY TRACY A [US]) 23 July 2009 (2009-07-23) paragraph [0020]; figures -----	1-10
A	US 8 702 375 B1 (LIANG GEORGE [US]) 22 April 2014 (2014-04-22) figures 2, 4 -----	1-10



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

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08/03/2016

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Georgi, Jan

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2015/038559

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 8757961	B1	24-06-2014	NONE
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