



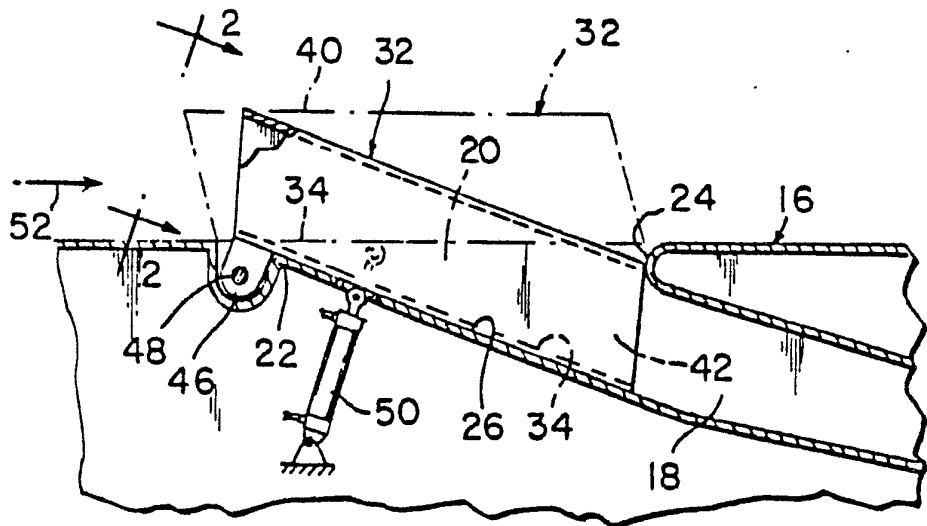
## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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<p>(21) International Application Number: PCT/US81/01667 (22) International Filing Date: 14 December 1981 (14.12.81) (31) Priority Application Number: 220,515 (32) Priority Date: 29 December 1980 (29.12.80) (33) Priority Country: US (71) Applicant: THE BOEING COMPANY [US/US]; Post Office Box 3707, Mail Stop 7E-25, Seattle, WA 98124 (US). (72) Inventor: VANDERLEEST, Siebold ; 9050 Seward Park Ave. S., Slip 11, Seattle, WA 98118 (US).</p>		<p>(74) Agents: DeVOGEL, Nicolaas et al.; Post Office Box 3707, Mail Stop 7E-25, Seattle, WA 98124 (US). (81) Designated States: DE (European patent), FR (European patent), GB (European patent), JP, NL (European patent), SE (European patent). <b>Published</b> <i>With international search report.</i></p>

(54) Title: AUXILIARY POWER UNIT SCOOP AND INLET

(57) Abstract

An air inlet (18-20) and scoop (32) for aircraft auxiliary power units to provide satisfactory performance thereof under all operational conditions, including full capability for in-flight starting at high altitudes, whereby operational difficulties caused by thick boundary layers and adverse pressure gradients between the inlet and the tail cone (12) in the vicinity of the inlet are overcome. The inlet opening (18) is contoured along its outer edges to conform to the aircraft fuselage and has a ramp trailing inwardly into the opening, starting at the fuselage and forming the bottom surface of the inlet. The inlet has generally parallel side walls (28 and 30) trailing inwardly, the inlet side walls (28 and 30) extending inwardly from the fuselage edges along the inlet (18) opening. A scoop (32) is hinged adjacent the fuselage at one end of the inlet opening, the aircraft (10) having means therein to operate the scoop (32) so as to open and close the inlet (18) opening. The scoop (32) has a closing surface (34) with respect to the inlet opening, which when in the closed position is contoured to conform with the fuselage, the closing wall (34) being continuous in the open and closed positions and generally limited to the extent of the inlet opening (20).



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## AUXILIARY POWER UNIT SCOOP AND INLET

Background of the Invention

Aircraft auxiliary power units have been, for example, gas turbines located in the aft fuselage. The  
05 turbines provide electrical power and compressed air on the ground, as well as in flight. They drive the air conditioning packs of the environmental control system, air driven hydraulic pumps and the starters for the wing  
engines. They also provide power for wing engine starts  
10 during flight, up to 14,000 feet. The auxiliary power unit generators provide electrical power to the airplane system when the main engine generators are not operating.

Typically, the air supply to the gas turbines enters through a 20° ramp inlet positioned in the tail cone.  
15 In the prior art, the inlets were generally of the flush type and did not provide sufficient pressure recovery to consistently start and/or operate the auxiliary power units in flight, such starting being required up to altitudes as high as 25,000 feet. The inability to  
20 start was due to thick boundary layers on the aft body; the boundary layers vary in thickness from five to twenty inches, for example.

Ogee wing defectors have been used to overcome the prior art problems, but they cause an excessive  
25 amount of drag.

Summary of the Invention

It was found that various types of scoops having side plates dissipated the boundary layer and substantially eliminated the adverse pressure gradient in the



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vicinity of the inlet between the inlet and the tail cone. It was also found that scoops without side plates did not recover sufficient inlet air to meet the requirements.

05 One type of successful scoop, according to the invention, is a rectangular box hinged at the forward end of an inlet. The box is open to have a passage there-  
through and when the inlet is closed the box extends  
10 outwardly of the fuselage, the inner wall of the box forming the inlet closure.

Other types of scoops, according to the invention, are hinged to the aircraft adjacent the aft end of the inlet opening. They have a closing wall contoured to the fuselage and have channel forming side plates contoured  
15 to the side walls of the inlet against which they fit on closing.

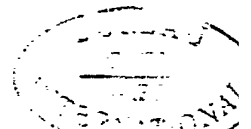
It was found that when the side plates of the scoop were relatively shallow toward the leading edge of the scoop, the scoop improved the inlet air recovery because  
20 the open scoop provided side spacing between the edges of the forward portions of the plates and the fuselage.

Another type of scoop, according to the invention, has longer or deeper side plates at the leading edge so that the side plates extend into slots in the aircraft  
25 to rigidly support the scoop in its open position.

Accordingly, it is an object of the invention to provide an improved scoop and inlet combination and method for in-flight auxiliary power units in which the scoop is adapted to open and admit sufficient air to  
30 start operation at any altitude up to 25,000 feet and operate satisfactorily up to 42,000 feet.

It is another object of the invention to provide improved scoops that dissipate relatively thick boundary layers and eliminate adverse pressure gradients between  
35 the inlet and the tail cone of an aircraft in the vicinity of the inlet.

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It is a further object of the invention to provide scoops for auxiliary power unit inlets, as described in the preceding paragraphs, that increase the air pressure recovery into the inlet in the order of 3 to 5 times  
05 that of the prior art inlets.

Further objects and advantages of the invention may be brought out in the following part of the specification wherein small details have been described for the competence of disclosure, without intending to limit the scope  
10 of the invention which is set forth in the appended claims.

#### Brief Description of the Drawings

Referring to the accompanying drawings which are for illustrative purposes:

15 Fig. 1 is a partially cross-sectional view of a rectangular scoop, according to the invention, which fits into the inlet in the open position and which extends along the fuselage in the closed position;

20 Fig. 2 is an end view of the scoop taken along the line 2-2 in Fig. 1;

Fig. 3 is a partially cross-sectional view of a scoop hinged at its after end to the fuselage in the inlet and having side plates of varying depths;

25 Fig. 4 is an end view of the scoop taken along the lines 4-4 in Fig. 3;

Fig. 5 is a partially cross-sectional view of a scoop and inlet in which the side plates extend into slots juxtaposed to the inlet when the inlet is closed and to a lesser amount when the inlet is open;

30 Fig. 6 is a partially cross-sectional end view taken substantially along the line 6-6 in Fig. 5;

Fig. 7 is a partially cross-sectional view of another embodiment of a scoop and inlet construction;

35 Fig. 8 is an elevational view of a large aircraft in which scoops and inlets for auxiliary power units are

illustrated as being in the vicinity of the tail cone;  
and

Fig. 9 is a schematic end view of a rectangular  
box-type inlet, as shown in Fig. 1, having internal  
05 stiffeners.

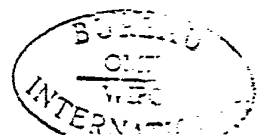
#### Description of the Preferred Embodiments

Referring again to the drawings, there is shown in  
Fig. 8 a large aircraft 10 in which auxiliary power units  
are typically installed in a tail cone 12 having their  
10 air inlets in positions such as 14 or 16, for example.  
In Fig. 1 a portion of a tail cone 16 is shown having  
an air inlet 18 and an inlet opening 20 in the fuselage,  
extending from a forward end at 22 to a rearward ellip-  
tical end 24. The inlet has an approximately 20° ramp  
15 along the surface 26 and has typical flat side walls, as  
at 28 and 30, Fig. 2, with which a rectangular scoop,  
generally designated as 32, is complementary. That is,  
the rectangular scoop 32, shown in its open position  
in full lines in Fig. 1, extends into the inlet to form  
20 a ramp surface at 34 along its inner wall and to form  
inner side walls 36 and 38 above the ramp. An outer  
wall 40 completes the rectangle, to form a rectangular  
passage 42 for the air into the inlet 18 for an  
auxiliary power unit in the tail cone.

25 The inlet scoop 32 is rotated on a forward hinge 46,  
pivoted at 48, from a closed position, shown in phantom  
outline, externally of the fuselage surface with which  
the wall 34 is contoured. The wall 34 closes the inlet  
opening 20 and when so closed, the scoop provides an air  
30 passage from the leading edge thereof to the trailing  
edge along the fuselage surface. The scoop is open and  
closed by means of an actuator 50.

The scoop may normally be open when the aircraft is  
on the ground and may be closed on take-off and opened  
35 at any altitude up to 25,000 feet. It has been found

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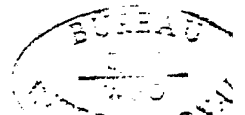
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successful to provide inlet pressure recoveries to properly operate the auxiliary power units in the aircraft. Scoops, as 32, have been made to be 5 inches or 2½ inches high along the walls 36 and 38 and 14½ to 17½ inches long. In the normal cruise position the inlet door formed by the wall 34 is closed, and the scoop is parallel to the flow as indicated by the arrow 52. When the auxiliary power unit is to be started at any altitude, the scoop 32 is rotated on its pivot by the actuator 50 to move the door wall 34 onto the ramp 26 inside the inlet 18, the side walls of the scoop being juxtaposed to the side walls of the inlet.

In Fig. 9, a schematic view is shown of a scoop 60 of the same type as the scoop 32 but with stiffeners 62 and 64 inserted for additional strength. It was found that the stiffeners 62 and 64 did not significantly reduce the air flow through the scoop.

In Figs. 3 and 4, there is an auxiliary power unit air inlet, generally designated as 70, having a fuselage opening extending from a leading edge at 72 to a trailing edge at 74, the latter formed with having elliptical cross-sectional surface. A ramp 76 has an inclination of about 20° with the fuselage surface 78. The inlet 70 has generally parallel side walls substantially perpendicular to a horizontal plane through the inlet opening. Outer edges of the walls 80 and 82 are flush with the fuselage and have the same contour. A scoop, generally designated as 86, is hinged to flanges 88 extending laterally outwardly of the inlet, ears 90 on the trailing end of the scoop being hinged by pivot 92. The scoop has an outer closing wall 94 which in the closed position is in contour with the fuselage. Extending inwardly from the wall 94 and generally at right angles thereto are channel forming side plates or walls 96 and 98, which are juxtaposed to the walls 80 and 82 of the inlet.

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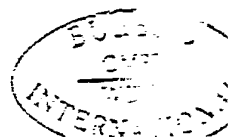
The walls 96 and 98 have a trailing portion terminating forwardly at a break 100, so that when the scoop is in the closed position the break edge closes substantially against the ramp surface 76. Forwardly of the break 100, the side plates have a forwardly tapering inner edge 102 which is adapted to fit along the ramp surface 76 when the door 94 is in the closed position.

The scoop 86 is adapted to be opened and closed by a pair of actuators 106, only one being shown. The actuators are laterally outwardly of the inlet so as to not interfere with the flow. Flexible seals are provided along the gaps, as forwardly of the elliptical at 74, and along the side wall surfaces to seal the door when it is closed, and to also provide a seal between the rear portion of the door around the hinges. The gap between the fuselage surface 78 and the edges at 102 of the scoop provide additional space to receive inlet air into the inlet.

The scoop or hinged door 86, for one installation, is about 17.5 inches long and 7 inches wide, and in the closed position completely seals off the inlet opening. The leading edge of the scoop in the open position is about 10.6 inches above the fuselage so as to provide sufficient inlet air pressure recovery.

The inlet and scoop in Fig. 7 are similar to that shown in Fig. 3, except here a scoop 110 has hinge members 112 extending from both side plates into the aircraft directly in alignment with the side plates of the scoop. The parallel hinge plates 112 are secured to the aircraft with a relatively large pin 114 to pivot at 116, the pivoting occurring by means of a linearly moving rod 118, pivotally engaged with the pin 116 at 120. Thus, as the rod 118 is moved linearly by an actuator, the pivot at 120 causes the pin 114 to be rotated to open and close the scoop 110.

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Here again, the scoop in the open position permits air to enter the inlet from the sides of the parallel walls of the scoop.

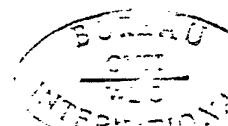
05 In Figs. 5 and 6 another embodiment of an inlet, generally designated as 130, and a scoop, generally designated as 132, are illustrated. Here, the inlet has a ramp 134 generally at 20° to the fuselage surface 136, the inlet having generally parallel side walls, as 138, trailing inwardly into the aircraft and  
10 extending outwardly to the fuselage edge with which they are in contour.

The scoop 132 has hinge members 140 trailing into the aircraft outwardly of the inlet, mounted on a pin 142, secured in the aircraft and on which the scoop  
15 pivots when actuated by a pair of actuators 144, both being laterally outside of the scoop side walls 146 and 148, to be out of the flow path through the inlet. The scoop has an outer or closing wall 150 which in the closing position is flush with the fuselage surface and  
20 sealingly engaged with the inlet opening extending from the ramp at 152 to the convex surface 156 of the inlet.

The channel forming plates 146 and 148 have a rearward portion having inner edges 158 which terminate forwardly at a break 160, and extending forwardly of  
25 the break are downwardly inclined edges 162, terminating at the leading edge of the scoop. The side plate portions outwardly of the edges 158 fit the contour of the side walls, as 138, of the inlet opening and the side plates forwardly of the break 160 fit into slots  
30 166 in the aircraft laterally of the inlet opening.

When the scoop is closed, the side plates rearwardly of the break 160 are in contour with the side walls of the inlet and the side plates forwardly of the break 160 fit into the slots to form a sealed relationship between  
35 the scoop and the opening. Similarly, there is a seal

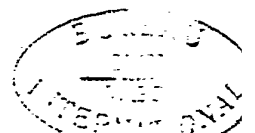
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along the trailing edges of the scoop in the hinge areas.

The effect of the leading edges of the scoop, extending into the slots when in the open position, is to provide support and stability for the scoop. Air  
05 passage through the scoop in the open position is between the side plates 146 and 148, the outer wall 150 and the ramp 134.

The invention and its attendant advantages will be understood from the foregoing description and it will be  
10 apparent that various changes may be made in the form, construction, and arrangements of the parts of the invention without departing from the spirit and scope thereof or sacrificing its material advantages, the  
arrangements hereinbefore described being merely by  
15 way of example. I do not wish to be restricted to the specific forms shown or uses mentioned except as defined in the accompanying claims.



## WHAT IS CLAIMED IS:

1. For use on an aircraft, an air inlet and scoop for an in-flight auxiliary power unit, the scoop being adapted to open and start operation at altitude and on the ground, comprising:

05 an inlet opening contoured along its outer edges to conform to the aircraft fuselage;

a ramp trailing inwardly into the opening starting from the fuselage and forming the bottom surface of the inlet;

10 the inlet opening having generally parallel side walls trailing inwardly along opposite edges of the ramp;

the side walls extending inwardly from the fuselage edges along the inlet opening;

15 a scoop hingedly engaged to said aircraft adjacent said fuselage and adjacent one end of said inlet opening; and

means in said aircraft to operate said scoop from positions in which said scoop opens and closes said inlet opening;

20 said scoop having a closing wall with respect to said inlet opening, said closing wall closing said opening in the closed position and being contoured to conform with the fuselage surface in the closed position;

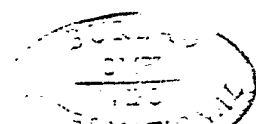
25 said closing wall being continuous in the open and closed positions and generally limited to the extent of said inlet opening.

2. The invention according to claim 1 in which:

said closing wall in said open position forms said ramp substantially directly inwardly transverse to the rearwardly direction;

05 said scoop being hinged to said aircraft adjacent the forward end of said inlet opening.

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3. The invention according to claim 2 in which:  
said scoop is externally of said aircraft in  
the closed position;  
said scoop having a cross section complemen-  
05 tary to said inlet to fit therein in the open position;  
said scoop having a passage therethrough to  
permit inlet air to move therethrough from the fuselage  
into the inlet.
4. The invention according to claim 3 in which:  
said scoop has a generally rectangular cross  
section; and  
a bottom surface thereof forming said closing  
05 wall.
5. The invention according to claim 4 in which:  
said scoop has structural supports therein  
providing flow passage portions therealong.
6. The invention according to claim 1 in which:  
said scoop is hinged to said aircraft adjacent  
the rearward ends of said inlet opening and said scoop.
7. The invention according to claim 6 in which:  
said closing wall is pivoted outwardly on its  
hinge to be spaced from said ramp to open said inlet  
opening;  
05 continuous scoop side walls extending inwardly  
from edges of said closing wall to form an inwardly  
opening channel in cross section;  
said scoop side walls being juxtaposed to  
respective inlet side walls in the closed position;  
10 said scoop side walls in the closed position  
terminating inwardly adjacent said hinge and having  
rearward inner edges spaced from said ramp, said inner

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edges extending forwardly to be closely adjacent said  
ramp and tapering along said ramp to a point at the  
15 forward end of said scoop and at the closing wall.

8. The invention according to claim 7 in which:  
said tapering inner edges of scoop side walls  
are spaced outwardly from said fuselage surface when said  
scoop is open.

9. The invention according to claim 8 in which:  
portions of said rearward inner edges are  
spaced outwardly from said fuselage surface when said  
scoop is open.

10. The invention according to claim 6 in which:  
said closing wall is pivoted outwardly on its  
hinge to be spaced from said ramp to open said inlet  
opening;

05 continuous scoop side walls extending inwardly  
from edges of said closing wall to form an inwardly  
opening channel in cross section;

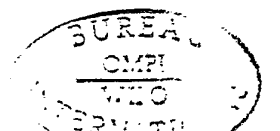
rearward portions of said scoop side walls  
being juxtaposed to respective inlet side walls in the  
10 closed position;

said rearward portions of said scoop side walls  
in the closed position terminating inwardly adjacent  
said hinge and having inner edges spaced from said ramp;  
said scoop side walls having forward portions  
15 extending from said rearward portions;

said forward portions extending inwardly with  
respect to said rearward portions and said ramp end  
having inner edges tapering rearwardly from the forward  
end of the scoop to the rearward portions;

20 inwardly extending slots on both sides of the  
ramp to receive said forward portions in the closed  
position.

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11. The invention according to claim 10 in which:  
portions of said rearward inner edges are  
spaced outwardly from said fuselage surface when said  
scoop is open.

12. A method of dissipating boundary layer and  
eliminating adverse pressure gradient adjacent an  
auxiliary power unit air inlet in an aircraft tail cone,  
comprising:

05 an inlet opening contoured along its outer  
edges to conform to the aircraft fuselage.

a ramp trailing inwardly into the opening  
starting from the fuselage and forming the bottom  
surface of the inlet;

10 the inlet having generally parallel side walls  
trailing inwardly and rearwardly along opposite edges of  
the ramp;

the side walls extending inwardly from the  
fuselage edges along the inlet opening;

15 hingedly engaging a scoop to said aircraft  
adjacent said fuselage and adjacent one end of said inlet  
opening;

20 providing in the aircraft means to operate the  
scoop from positions in which said scoop opens and closes  
said inlet opening; and

25 providing said scoop with a closing wall with  
respect to said inlet opening, said closing wall closing  
said opening in the closed position and being contoured  
to conform with the fuselage surface in the closed  
position;

said closing wall being continuous in the open  
and closed positions and generally limited to the extent  
of said inlet opening.

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13. The method according to claim 12 including:  
moving said closing wall to said open  
position to form a ramp substantially directly inwardly  
transverse to the rearwardly direction and inwardly of  
05 the open position,  
hinging said scoop to said aircraft adjacent  
the forward end of said inlet opening.

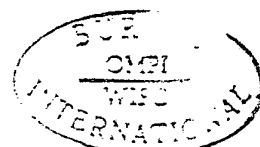
14. The method according to claim 13 including:  
moving said scoop to be externally of said  
aircraft in the closed position;  
said scoop having a cross section complementary  
05 to said inlet to fit therein in the open position;  
said scoop having a passage therethrough to  
permit inlet air to move therethrough from outside the  
fuselage into the inlet.

15. The method according to claim 14 in which:  
said scoop has a generally rectangular cross  
section; and  
a bottom surface thereof forming said closing  
05 wall.

16. The method according to claim 15 including:  
inserting structural supports in said scoop  
and providing flow passage portions therealong.

17. The method according to claim 12 including:  
hinging said scoop to said aircraft adjacent  
the rearward ends of said inlet opening and said scoop.

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18. The method according to claim 17 including:  
pivoting said closing wall outwardly on its  
hinge to be spaced from said ramp to open said inlet  
opening;

05 continuous scoop side walls extending inwardly  
from edges of said closing wall to form an inwardly  
opening channel in cross section;

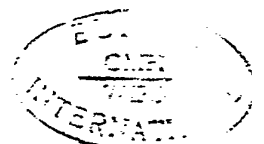
said scoop side walls being juxtaposed to  
respective inlet side walls in the closed position;

10 said scoop side walls in the closed position  
terminating inwardly adjacent said hinge and having  
rearward inner edges spaced from said ramp, said inner  
edges extending forwardly to be closely adjacent said  
ramp and tapering along said ramp to a point at the  
15 forward end of said scoop and at the closing wall.

19. The method according to claim 18 in which:  
said tapering inner edges of scoop side walls  
are substantially spaced outwardly from said fuselage  
surface when said scoop is open.

20. The method according to claim 18 including:  
spacing portions of said rearward inner edges  
outwardly from said fuselage surface when said scoop is  
open.

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21. The method according to claim 17 including:  
pivoting said closing wall outwardly on its  
hinge to be spaced from said ramp to open said inlet  
opening;

05 continuous scoop side walls extending inwardly  
from edges of said closing wall to form an inwardly  
opening channel in cross section;

rearward portions of said scoop side walls  
being juxtaposed to respective inlet side walls in the  
10 closed position;

said rearward portions of said scoop side  
walls in the closed position terminating inwardly  
adjacent said hinge and having inner edges spaced from  
said ramp;

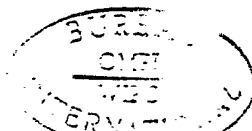
15 said scoop side walls having forward portions  
extending from said rearward portions;

said forward portions extending inwardly with  
respect to said rearward portions and said ramp and  
having inner edges tapering rearwardly from the forward  
20 end of the scoop to the rearward portions;

inwardly extending slots on both sides of  
the ramp to receive said forward portions in the closed  
position.

22. The method according to claim 21 in which:  
the forward portions extend partially into  
said slots in the open position at the forward ends to  
support the scoop.

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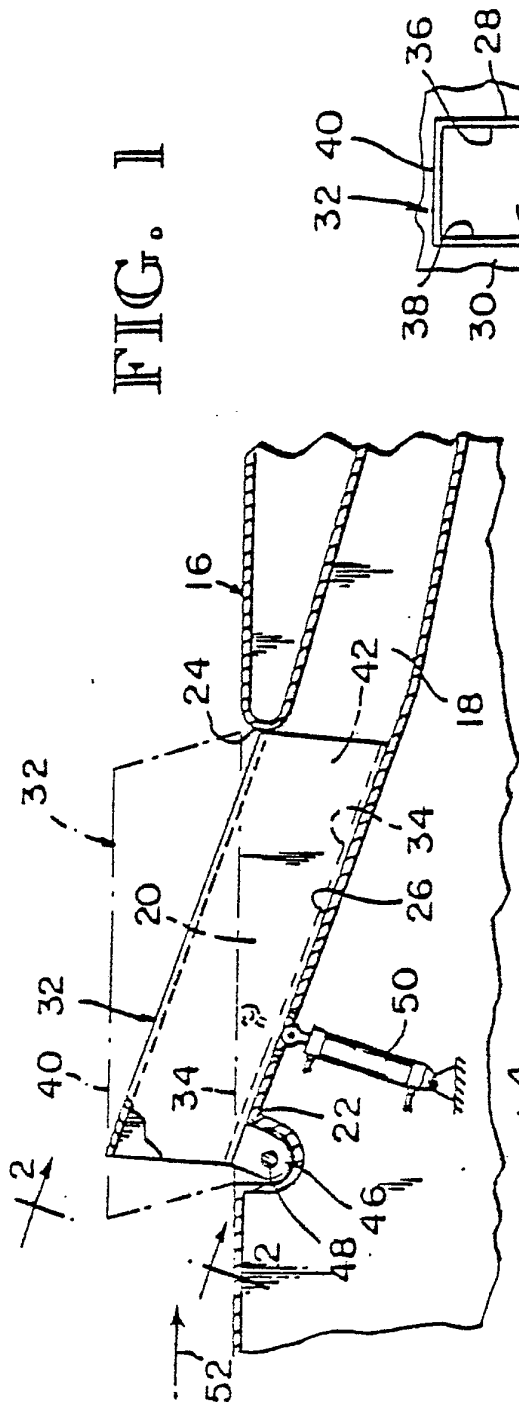


FIG. 1

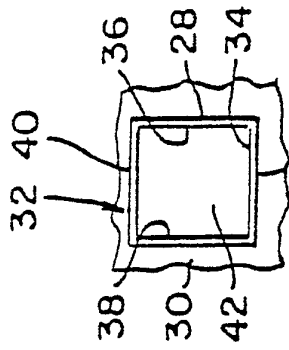


FIG. 2

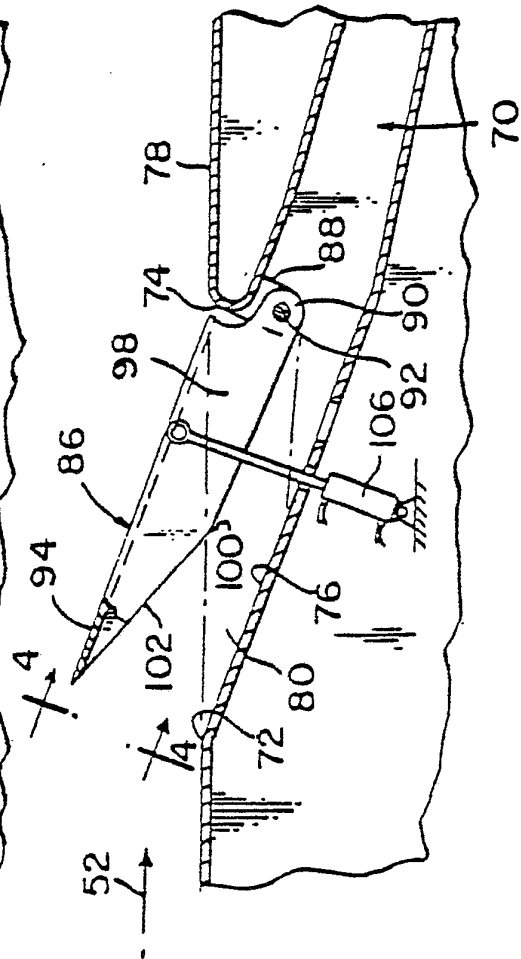
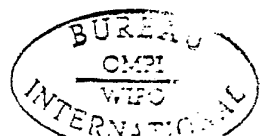


FIG. 3



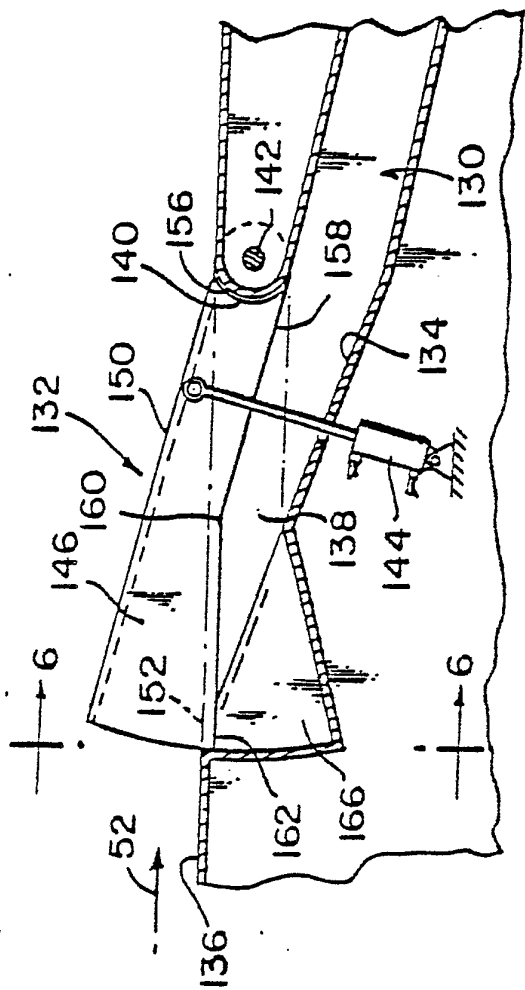


FIG. 5

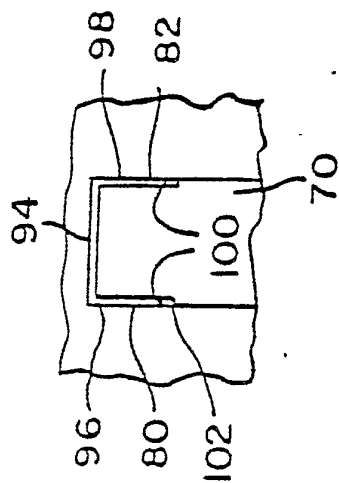


FIG. 4

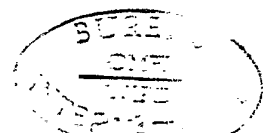


FIG. 6

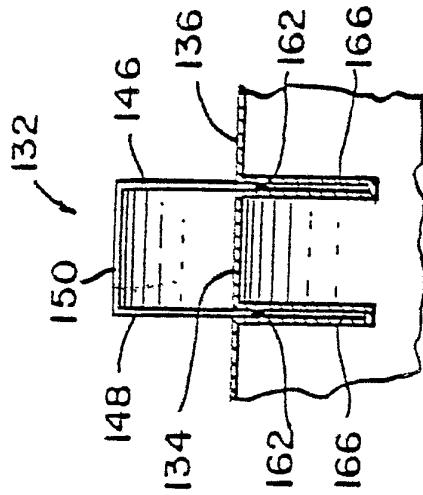


FIG. 7

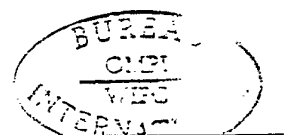
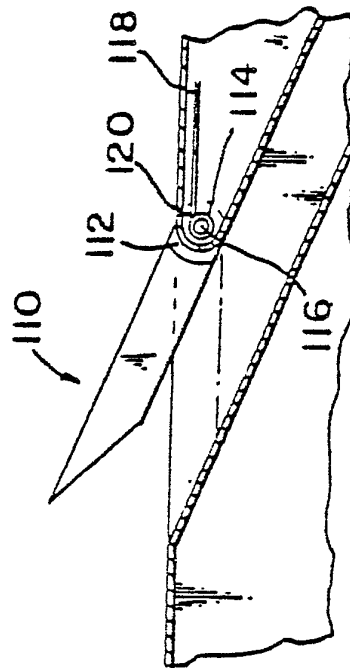


FIG. 8

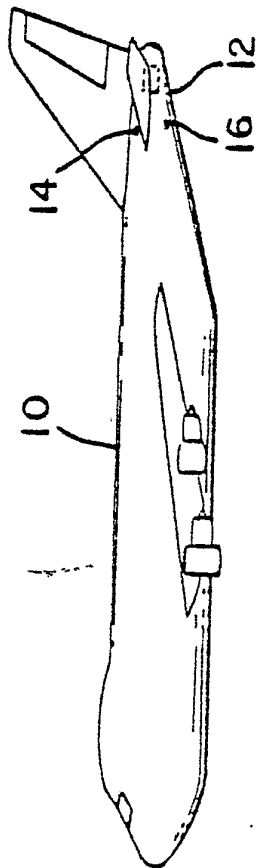
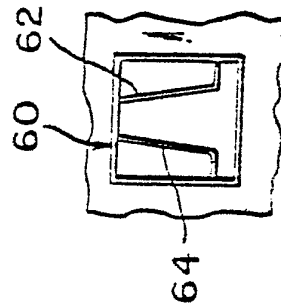
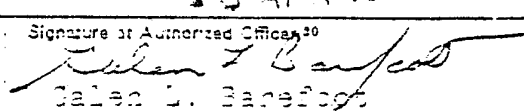


FIG. 9



# INTERNATIONAL SEARCH REPORT

International Application No PCT/US 81/01567

<b>I. CLASSIFICATION OF SUBJECT MATTER</b> (if several classification symbols apply, indicate all) *		
According to International Patent Classification (IPC) or to both National Classification and IPC		
Int. Cl. <sup>3</sup> B64D 33/02 U.S. Cl. 244/533		
<b>II. FIELDS SEARCHED</b>		
Minimum Documentation Searched <sup>4</sup>		
Classification System	Classification Symbols	
US	244/12,1, 12.3, 12.5, 15, 23R, 23B, 23D, 210, 53R, 53B, 53A, 58, 57, 73R; 60/230, 269, 210R, 39.14m, 39.14R; 137/15.1, 15.2; 415/Dlg. 7, 219R, 132; 40/33, 45, 47	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched <sup>4</sup>		
<b>III. DOCUMENTS CONSIDERED TO BE RELEVANT <sup>14</sup></b>		
Category <sup>15</sup>	Citation of Document, <sup>16</sup> with indication, where appropriate, of the relevant passages <sup>17</sup>	Relevant to Claim No. <sup>18</sup>
A	US, A, 2,812,980. Published 12 November 1957. Kadosch, et al.	
Y	US, A, 3,001,740. Published 26 September 1961. Montgomery.	7-9, 18-20
Y	US, A, 3,099,423. Published 30 July 1963. Wilde, et al.	6, 17
Y	US, A, 3,347,496. Published 17 October 1967. Opfer, Jr.	6, 17
X	US, A, 3,439,377. Published 13 January 1970. Pearson, et al.	1-2, 12-13
A	US, A, 3,659,424. Published 02 May 1972. Polk, Jr.	
A	US, A, 3,717,163. Published 20 February 1973. Herr.	
Y	US, A, 4,121,606. Published 24 October 1978. Holland.	10-11, 21-22
X	US, A, 4,174,083. Published 13 November 1978. Mohn.	1-2, 12-13
Y	US, A, 4,203,566. Published 20 May 1979. Lord.	10-11, 21-22
* Special categories of cited documents: <sup>15</sup>		
"A" document defining the general state of the art		"P" document disclosed prior to the international filing date but on or after the priority date claimed
"E" earlier document but published on or after the international filing date		"T" later document published on or after the international filing date or priority date and not in conflict with the application, but cited to understand the principle or theory underlying the invention
"O" document cited for special reason other than those referred to in the other categories		"X" document of particular relevance
"Q" document referring to an oral disclosure, use, exhibition or other means		
<b>IV. CERTIFICATION</b>		
Date of the Actual Completion of the International Search <sup>19</sup>	Date of Mailing of this International Search Report <sup>20</sup>	
29 March 1982	15 APR 1982	
International Searching Authority <sup>21</sup>	Signature of Authorized Officer <sup>20</sup>	
ISA/US	 Helen L. Barefoot	