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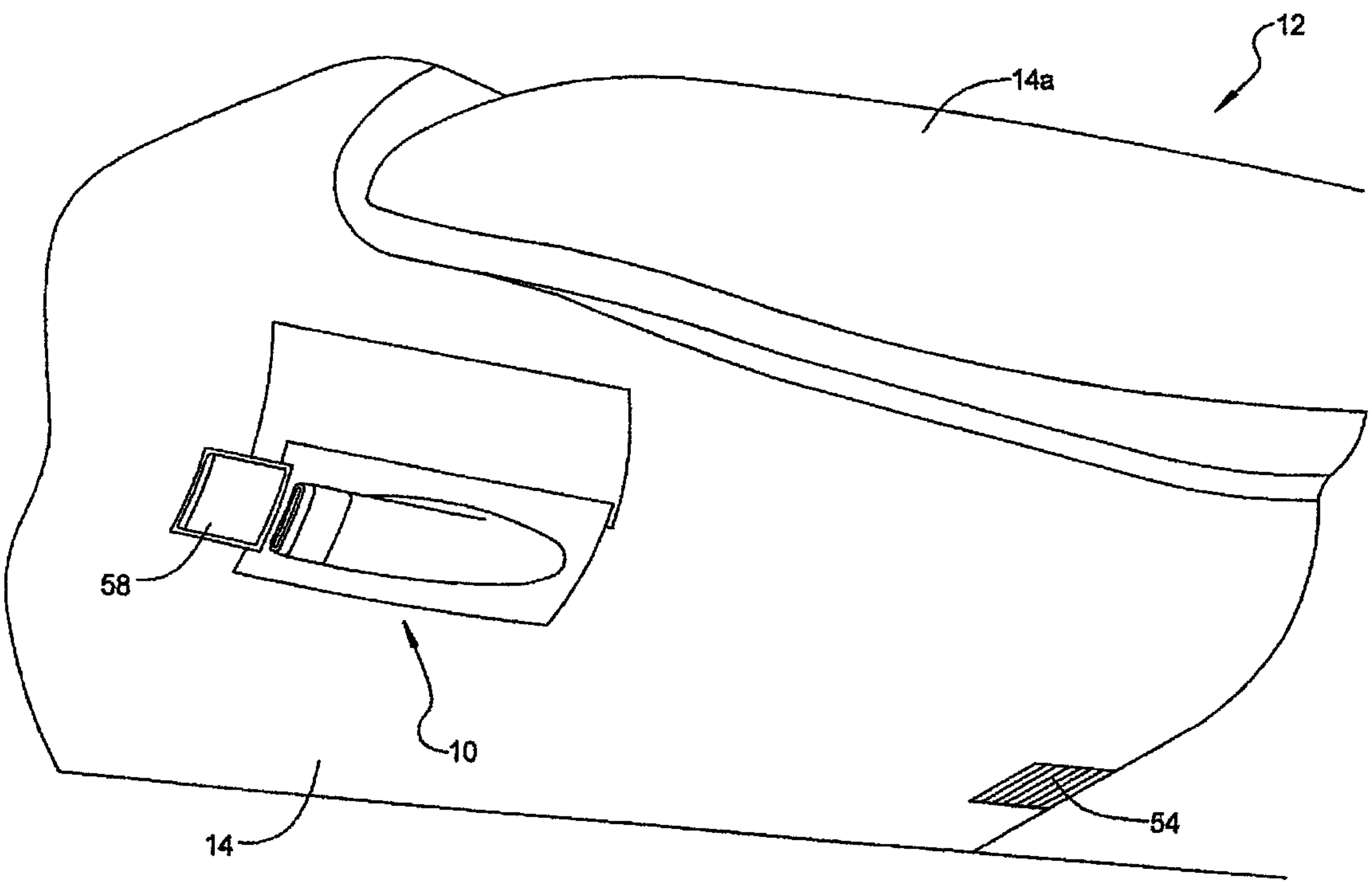


(57) Abrégé/Abstract:
An inlet apparatus and method for use with a cabin air compressor on a high speed, airborne mobile platform, such as a commercial or military aircraft. The apparatus includes a Pitot inlet of a desired shape that is supported outside an exterior surface of a fuselage of the aircraft by a diverter structure. The diverter structure diverts a low energy portion of a boundary layer so that the low energy portion does not enter the Pitot inlet. The Pitot inlet receives the higher energy portion of the boundary layer and channels a ram airflow to an inlet of a cabin air compressor. The apparatus provides a recovery factor (RF) of at least about 0.8 at a cabin air compressor (CAC) inlet face, which keeps the electric power required to drive the CAC within available power limits, while minimizing the drag of the inlet apparatus.

ABSTRACT OF THE DISCLOSURE

An inlet apparatus and method for use with a cabin air compressor on a high speed, airborne mobile platform, such as a commercial or military aircraft. The apparatus includes a Pitot inlet of a desired shape that is supported outside an exterior surface of a fuselage of the aircraft by a diverter structure. The diverter structure diverts a low energy portion of a boundary layer so that the low energy portion does not enter the Pitot inlet. The Pitot inlet receives the higher energy portion of the boundary layer and channels a ram airflow to an inlet of a cabin air compressor. The apparatus provides a recovery factor (RF) of at least about **0.8** at a cabin air compressor (CAC) inlet face, which keeps the electric power required to drive the CAC within available power limits, while minimizing the drag of the inlet apparatus.

AIR INLET AND METHOD FOR A HIGHSPEED MOBILE PLATFORM

CROSS-REFERENCE TO RELATED APPLICATIONS

FIELD

The present disclosure relates to ram air inlets used with airborne mobile platforms, and more particularly to highly efficient ram air inlets especially well adapted for use with high speed commercial jet aircraft to supply air to a subsystem of the aircraft.

BACKGROUND

Various commercial and military aircraft often make use of a cabin air (CA) inlet for the environmental control system (ECS) that such aircraft employ. Aircraft making use of a CA inlet employ ram air for cabin pressurization rather than bleed air from the engines. With such aircraft, the ram air captured by the CA inlet is often fed to an electric motor driven cabin air compressor (CAC), then conditioned to the desired temperature and pressure in an air conditioning pack, and then supplied to the air distribution system of the cabin.

An important requirement when using ram air to feed a cabin air compressor is achieving a minimum desired recovery factor (RF) at the CAC inlet face. In practice, it is desirable to achieve the maximum RF possible at the CAC inlet face in order to minimize the electric power required to drive the compressor(s) of the air conditioning pack. This is particularly important at the peak power condition because the generator, motors and other electrical equipment of the ECS need to be sized to meet the peak demand requirements of the aircraft. Ideally, the RF achieved at the CAC inlet face would be 1.0, but in practice it is typically considerably less than 1.0, and often around 0.05 – 0.7. On the other hand, however, a higher RF for a ram air inlet is generally associated with a higher drag. Therefore, a design challenge is present in providing an inlet for an environmental control system component of the aircraft, and more particularly for a cabin air inlet, that is able to achieve a predetermined minimum RF, while also minimizing the drag of the inlet.

In the presence of a thick fuselage boundary layer, flush mounted ram air inlets (rectangular or NACA planform) that are positioned flush against the exterior surface of the fuselage of the aircraft, and which are of the type used for supplying cooling air to an air conditioning pack heat exchanger, tend to yield a RF in the range of about 0.6 to 0.7. However, due to limitations on available compressor power, it is desirable to achieve a RF closer to 1.0, and at least about 0.8, to make most efficient use of the air inlet. Therefore, present day, flush mounted ram air inlets often fall short of the ideal performance parameters. Furthermore, at low mass flows, flush mounted ram air inlets are also prone to develop an undesirable Helmholtz type duct flow instability, which arises from a coupling between acoustic resonance in the duct and separation of the approaching boundary layer ahead of the inlet. Thus, a concurrent performance consideration, in connection with maximizing the RF performance of the inlet, is to minimize the drag associated with the implementation of the inlet while simultaneously providing an inlet that is able to delay the onset of flow instability to significantly lower mass flows.

Still a further concern is the ability of locating a cabin air inlet relative to the location of one or more additional inlets that are typically used in connection with an environmental control system on an aircraft. For example, on commercial and military aircraft, one or more inlets are used to supply airflow to one or more cabin air compressors, while one or more heat exchanger ram air inlets are also incorporated for supplying cooling air to a heat exchanger of an air conditioning pack on the aircraft. It would be desirable if the heat exchanger inlet could be placed relative to the cabin air inlet in a manner that modifies the boundary layer immediately upstream of the cabin air compressor. This would allow the optimum performance characteristics of the cabin air inlet to be met while still reducing drag associated with the cabin air inlet.

SUMMARY

In accordance with one aspect of the invention, the present disclosure relates to an air inlet apparatus and method for use with a high speed mobile platform. In one illustrative embodiment, the high speed mobile platform comprises a commercial or military aircraft.

In accordance with one aspect of the invention, there is provided an air inlet apparatus for use in supplying air to a cabin compressor of an environmental control system of a high speed airborne mobile platform. The apparatus includes a cabin compressor for supplying air to an environmental control system, and a a Pitot inlet in communication with an input of the cabin compressor, the Pitot inlet being disposed at a wing and body interface of the high speed airborne mobile platform. The Pitot inlet includes a duct structure having a face and a throat, positioned with the face located outside an exterior surface of a fuselage of the mobile platform, and such that the throat receives a first portion of a fuselage boundary layer adjacent to the fuselage and moving over the fuselage during flight, and feeds the first portion of the fuselage boundary layer to the cabin compressor. The Pilot further includes a boundary layer diverter for supporting the duct structure outside the fuselage by a predetermined height, such that the boundary layer diverter is able to prevent a second portion of the boundary layer immediately adjacent to the exterior surface of the fuselage from entering the throat. The duct structure of the Pitot inlet has an inner lip and an outer lip spaced apart from the inner lip, the inner lip being closer to the exterior surface of the fuselage; and a ratio of a thickness of the outer lip to a thickness of the inner lip is between about 2:1 to about 4:1. The predetermined height of the diverter, and the ratio of thickness of the outer lip to the inner lip, enables the Pitot inlet to provide a recovery factor of at least about 0.8 at the input of the cabin air compressor.

The Pitot inlet may include a throat aspect ratio of between about 5:1 to about 6:1.

The boundary layer diverter may include a height of about 1.0 inch (25.4 mm) to about 3.0 inch (76.20 mm).

The apparatus may be in flow communication with a cabin air compressor of the mobile platform.

In accordance with another aspect of the invention, there is provided an air inlet apparatus for use on a fuselage of a jet aircraft to provide intake air for a cabin air compressor of an environmental control subsystem of the aircraft. The apparatus includes a cabin air compressor for supplying air to an environmental control system. and a Pitot inlet in communication with the cabin air compressor. The Pitot inlet includes a duct structure having a throat and a face, the face positioned outside an exterior surface of the fuselage of the aircraft, and such that the throat receives a first portion of a fuselage boundary layer adjacent to the fuselage and moving over the fuselage during flight of the aircraft, the first portion of the fuselage boundary layer being fed to the cabin air compressor. The Pilot inlet further includes a boundary layer diverter disposed between a surface of the duct structure and the exterior surface of the fuselage for supporting the duct structure outside the fuselage by a height of between about 1.0 inch to about 3.0 inches, and that prevents a second portion of the boundary layer immediately adjacent to the exterior surface of the fuselage from entering the throat. The Pitot inlet includes a throat aspect ratio of between about 5:1 to about 6:1; and the Pitot inlet provides a minimum recovery factor of about 0.8 at a face of the cabin air compressor.

The duct structure inlet may include an inner lip and an outer lip spaced apart from the inner lip, the inner lip being closer to the exterior surface of the fuselage, and a ratio of a thickness of the outer lip to a thickness of the inner lip is between about 2:1 to about 4:1.

In accordance with another aspect of the invention, there is provided an aircraft. The aircraft includes a fuselage having an exterior surface, an environmental control system having a cabin air compressor housed within the fuselage and a Pitot inlet in communication with the cabin air compressor, the Pitot inlet being located at a wing and body interface of the aircraft. The Pitot inlet includes a duct structure having a face and a throat, and positioned with the face outside the exterior surface of the fuselage of the aircraft, and such that the duct structure receives a first portion of the boundary layer adjacent to the fuselage and moving over the fuselage during flight of the aircraft, the duct structure in communication with the environmental control system to feed the first portion of the boundary layer to the cabin air compressor. The Pilot inlet further includes a boundary layer diverter disposed between a surface of the duct structure and the exterior surface of the fuselage for supporting a portion of the duct structure outside the fuselage by a predetermined height, and that prevents a second portion of the boundary layer immediately adjacent to the exterior surface of the fuselage from entering the duct structure. The duct structure of the Pitot inlet includes an inner lip and an outer lip spaced apart from the inner lip, the inner lip being closer to the exterior surface of the fuselage, a ratio of a thickness of the outer lip to a thickness of the inner lip is between about 2:1 to about 4:1, the throat of the Pitot inlet includes a throat aspect ratio of between about 5:1 to about 6:1, and the Pitot inlet providing a minimum recovery factor of about 0.8 at a face of the cabin air compressor.

In accordance with anther aspect of the invention, there is provided a method for forming an inlet on an exterior surface of a fuselage of a jet aircraft for feeding air into a cabin air compressor of an environmental control system of the jet aircraft. The method involves forming a Pitot inlet having a throat that is disposed at a wing/body interface area of the fuselage, adjacent to the exterior surface of the fuselage but elevated from the exterior surface and placing the throat in communication with the cabin air compressor. The method further involves forming the Pitot inlet with an inner lip and an outer lip spaced apart from the inner lip, the inner lip being closer to the exterior surface of the fuselage and being spaced apart from the exterior surface of the fuselage a distance of at least about 1.0 inch to about 3.0 inches and further forming the inner and outer lips so that a thickness ratio of the outer lip to a thickness of the inner lip is between about 2:1 to about 4:1. The method further involves diverting a low energy portion of a boundary layer disposed adjacent to the exterior surface of the fuselage, and at an inlet face of the Pitot inlet, to prevent the low energy portion from entering the throat of the Pitot inlet, and–using the face of the Pitot inlet to receive a higher energy portion of the boundary layer and to feed the higher energy portion of the the boundary layer to the cabin air compressor of the environmental control system.

The method may involve forming the air inlet apparatus with a throat aspect ratio of between about **5**:**1** to about **6**:**1**.

Diverting a low energy portion of a boundary layer may involve using a diverter disposed between a duct structure of the Pitot inlet and the exterior surface of the fuselage, to support the duct structure.

The method may involve controlling at least one of a throat aspect ratio of the Pitot inlet, and the thickness ratio of the outer lip of the Pitot inlet to the inner lip of the Pitot inlet, such that the Pitot inlet provides a minimum recovery factor of about **0**.**8**.

Further areas of applicability will become apparent from the description provided herein. It should be understood that the description and specific examples are intended for purposes of illustration only and are not intended to limit the scope of the present disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

The drawings described herein are for illustration purposes only and are not intended to limit the scope of the present disclosure in any way.

Figure **1** is a perspective view of a portion of an exterior surface of an aircraft incorporating an air inlet apparatus in accordance with one embodiment of the present disclosure;

Figure **2**A is a front view of the apparatus of Figure **1**;

Figure **2**B is a top view of the apparatus;

Figure **2**C is an enlarged, cross-sectional view of the Pitot inlet in accordance with section line **2**C-**2**C in Figure **2**A;

Figure **3** is a side view of the apparatus of Figure **2**A;

Figure **4** is a schematic block diagram of a typical environmental control system used with the inlet apparatus, as employed on an aircraft;

Figure **5** is a cross sectional side view similar to Figure **2**C showing a boundary layer approaching the apparatus;

Figure **6** is a side schematic view of a tandem inlet apparatus in accordance with one embodiment of the present disclosure;

Figure **7** is a simplified diagram of a portion of a boundary layer being "swallowed" in the heat exchanger inlet, to thus form a thinner boundary layer at the face of the Pitot inlet of the apparatus;

Figures **8-11** are graphs obtained in a laboratory environment of boundary layer measurements taken forward and aft of the heat exchanger inlet, that illustrate the modification of the boundary layer induced by the heat exchanger inlet of the present disclosure;

Figure **12** is a plot illustrating the Pitot inlet sizing benefit resulting from the tandem inlet apparatus via a comparison of a baseline placement of the Pitot inlet without the benefit of the forwardly placed heat exchanger inlet, with the comparison being presented at an altitude of **43,000** feet on a hot day, at maximum flow; and

Figure **13** presents a comparison similar to that presented in Figure **12**, at an altitude of **39,000** feet, on a standard temperature day, at minimum flow.

DETAILED DESCRIPTION

The following description is merely exemplary in nature and is not intended to limit the present disclosure, application, or uses.

Referring to Figure **1**, an inlet apparatus **10** in accordance with one embodiment of the present disclosure is illustrated employed on a fuselage **14** of a mobile platform **12** at a fuselage/wing interface area adjacent to but below a wing **14**a. In this example the mobile platform **12** comprises an aircraft, although it will be appreciated that the inlet apparatus **10** could be employed on other forms of high speed mobile platforms such as other airborne platforms, for example on missiles or rockets, or even on high speed land vehicles such as trains, or on marine craft. It is anticipated, however, that the inlet apparatus **10** will find particular utility with commercial and military jet powered aircraft that employ an environmental control system making use of at least one cabin air compressor (CAC).

Referring to Figures **2**A, **2**B, **2**C, **3** and **5**, the inlet apparatus **10** includes a Pitot inlet **16** having an inlet duct structure **19** that is positioned and supported adjacent an exterior surface **18** of the fuselage **14** by a diverter **20**. The inlet duct structure **19** includes inlet face **22** that is formed by an inner lip **24** and an outer lip **26**. As shown in Figure **2**C, the inner lip **24** and outer lip **26** help to define an inlet duct **25** having a throat **23**. The throat **23** represents the minimum cross sectional area of the inlet duct **25**. The inlet duct **25** curves inwardly towards and through the fuselage **14** exterior surface **18** (Figure **2**C). The inlet duct **25** leads to an inlet face of a cabin air compressor (CAC) indicated by numerals **40**a and **42**a in Figure **4**, that is located within the fuselage **14**. The diverter **20** supports the inner lip **24** of the Pitot inlet **16** at a predetermined distance away from the exterior surface **18**, as designated by arrows **30** (Figure **2**C). In one embodiment, the distance represented by arrows **30** is between about **1.0** inch – **3.0** inch (**25.40** mm - **76.20** mm), and more preferably about **2.0** inches (**50.80** mm).

With further reference to Figure **2**A, the throat aspect ratio (width-to-height) of the Pitot inlet **16** is also a factor in the performance of the inlet, and particularly in obtaining an RF (recovery factor) of close to **1.0** with a minimum drag penalty. A minimum RF of about **0.8** at the inlet face (**40**a or **42**a in Figure **4**) of the cabin air compressor is desirable. However, a higher RF in the range of about **0.88** – **0.92** is strongly preferred at the throat **23** of the Pitot inlet **16** to account for inlet diffuser losses between the inlet throat **23** and the cabin air compressor (CAC) inlet face at maximum flow rate. This is because the cross sectional shape of the inlet duct **25** needs to transition from a rectangular cross sectional shape to a circular cross sectional shape, which causes the Pitot inlet **16** losses to tend to increase as the throat aspect ratio is increased. Accordingly, a throat aspect ratio of between about **5**:**1** to about **6**:**1** is desirable to achieve at least a minimum RF of about **0.8** at the inlet face of the CAC, while minimizing the drag of the Pitot inlet **16**.

Referring to Figures **2**A and **2**C, the thickness of the inner lip **24** of the Pitot inlet **16**, relative to the outer lip **26**, is also important in the performance of the inlet apparatus **10**. Preferably, the thickness of the inner inlet lip **24** should be as small as possible in order to prevent deterioration of RF performance at low mass flows (typically mass flow ratio between about **0.2** – **0.5**). Furthermore, when exposed to large amounts of spillage (i.e., airflow being forced outwardly away from the inlet lips **24** and **26**), the thinner inner lip **24** does not lead to curvature related flow acceleration to high Mach numbers, which would tend to "clog" the area around the diverter **20**. The thickness of the inner lip **24** is defined by arrows **32** and the thickness of the outer lip **26** is defined by arrows **34**. In one embodiment, an outer lip-to-inner lip thickness ratio in the range of about **2**:**1** – **4**:**1** works particularly well to balance drag and RF performance.

With brief reference to Figure **5**, the inlet apparatus **10** is illustrated in a schematic block diagram together with an environmental control system **36** employed on the aircraft **12**. The environmental control system (ECS) **36** in this example includes a heat exchanger ram air inlet **38** and a pair of cabin air compressors **40** and **42** that apply compressed air to an ACM (Air Cycle Machine) **44**. The cabin air compressors **40** and **42** have inlet faces **40**a and **42**a, respectively, that are each in communication with the inlet apparatus **10**. Hot compressed air from the ACM **44** is passed through a heat exchanger **46** to control the temperature of the air which is supplied by the ACM **44** to a cabin area **48** of the aircraft **12**. Components **40**, **42**, **44** and **46** comprise an air conditioning pack **50**. Fresh air from the air conditioning pack **50** is circulated within the cabin **48** and then exhausted through one or more outflow valves **52**. Ram air from the heat exchanger inlet **38** is used to cool the hot compressed air in the heat exchanger **46** and subsequently discharged through the modulated ram air exit **54**.

Referring now to Figure **5**, a description of operation of the inlet apparatus **10** will be provided. The inlet apparatus **10** is positioned within a boundary layer **56** as the boundary layer **56** moves past the inlet apparatus **10** during flight of the aircraft **12**, a low energy portion of the boundary layer **56** is diverted from entering the Pitot inlet **16** by the diverter **20**. The low energy portion of the boundary layer **56** is typically that portion which is within about **1.5** inch – **2.5** inch (**38.10** mm – **63.50** mm) from the outer surface **18** of the fuselage **14**, and more typically about **2.0** inches (**50.80** mm) from the outer surface **18**. The Pitot inlet **16** captures the higher momentum outer region of the boundary layer **56**. The overall height of the boundary layer **56** in this example is about **5.0** inches (**127** mm). Optionally, to prevent the ingestion of foreign object debris (FOD) during takeoff, taxiing and landing operations, a pivotable door **58**, shown in phantom, may be disposed forwardly of the inlet face **22** of the Pitot inlet **16**. The FOD door **58** can be actuated such that it shields the inlet face **22** during selected times of operation of the aircraft **12**.

The inlet apparatus **10** provides the additional benefit of delaying the onset of Helmholtz instability over what could be achieved with a flush mounted inlet. In modes of operation involving a single cabin air compressor, in which the mass flow ratio may drop to approximately **0.2** or slightly lower, a flush mounted inlet would typically require throat area modulation to avoid the onset of Helmholtz instability. Throat area modulation would decrease the RF obtained at the CAC inlet face as well as increase the cost and complexity of the inlet structure.

In the rare event of a dual CAC failure, the mass flow ratio of airflow through the Pitot inlet **16** would drop to nearly zero, and in this instance

Helmholtz instability would be likely unavoidable. However, to avoid Helmholtz instability in this scenario, the FOD door **58** could be deployed in flight. Such a deployment of the FOD door **58** in flight would shield the Pitot inlet **16** from the impact pressure of the approaching airflow and prevent large amplitude stationary pressure waves (i.e., Helmholtz instability) from developing in the Pitot inlet duct **25**.

Accordingly, it can be appreciated that the inlet apparatus **10** operates to provide a significantly increased RF needed to supply cabin air to a cabin air compressor, while minimizing the overall drag of the inlet apparatus **10**.

Referring to Figure **6**, a tandem inlet apparatus **100** is illustrated formed on the exterior surface **18** of the fuselage **14** of the aircraft **12**. The tandem inlet apparatus **100** makes use of a Pitot inlet **102** and a heat exchanger (Hx) inlet **104** that is positioned forwardly of the Pitot inlet **102**, and longitudinally aligned with the Pitot inlet **102** so as to be preferably directly in front of the inlet **102**. By "forwardly" it will be understood as being positioned upstream of the Pitot inlet **102**, relative to a boundary layer flow over the Pitot inlet **102**.

The Pitot inlet **102** includes an inlet structure **103** having a duct **114**, a throat **113**, a face **106** and a diverter **108**. The tandem inlet apparatus **100** may be placed at various locations on the fuselage of the aircraft **12**, but in one implementation is placed at the wing/body fairing area indicated in Figure **1**. Optionally, a deployable FOD shield **110** may be employed forwardly of the face **106** of the Pitot inlet **102** in a manner similar to FOD shield **58** described in connection with Figure **4**. In one implementation a modulatable door **112** is used to controllably block the airflow into the heat exchanger inlet **104**. Optionally, a modulated **2**-door type structure may be used to selectively block the heat exchanger inlet **104**.

In this implementation, the deployable FOD shield **110** also operates to prevent debris ingestion during ground operations and to delay the onset of Helmholtz instability within the duct **114** of the Pitot inlet **102** in the same manner as described in connection with FOD shield **58** in Figure **4**.

In operation, the tandem inlet apparatus **100** enables the approaching thick fuselage boundary layer **118** in Figure **7** to be partially or completely "swallowed" by the heat exchanger inlet **104**, thus forcing a new, much thinner boundary layer to develop from the lip **116** of the heat exchanger inlet **104**. Thus, the Pitot inlet **102**, which is placed aft of and in line with the heat exchanger inlet **104**, effectively sees a much "thinner" boundary layer at its inlet face **106**. This results in a much higher pressure recovery typically close to an RF = **1.0** at the inlet face **106** of the Pitot inlet **102**. This in turn allows a reduced size inlet throat **113** area to be used for the Pitot inlet **102**, as well as a reduced diverter **108** height, to achieve the desired RF performance at the inlet face (**40**a or **42**a) of the cabin air compressor (**40** or **42** in Figure **5**).

The placement of the heat exchanger inlet **104** and the Pitot inlet **102** works especially well at a design point condition of highest altitude, "hot" day and maximum cabin airflow, which is used for sizing each of the heat exchanger inlet **104** and the Pitot inlet **102**. At altitudes in excess of about **36,000** feet (**10,920** meters), a "hot" day is typically understood in the industry to be a temperature warmer than about -**70**°F and more typically between about -**43**°F – -**70**°F. Under these conditions, the heat exchanger inlet **104** typically operates wide open at the highest mass flow ratio, thereby "swallowing" the entire, or substantially the entire, approaching fuselage boundary layer, as indicated by the boundary layer diagram **120** in Figure **7**. Then the Pitot inlet **102** sees a much thinner boundary layer, as indicated by boundary layer diagram **122** in Figure **7**, at its inlet face **106**. The reduced height boundary layer **122** enables an RF of close to **1.0** to be achieved at the inlet throat **113**. This allows a reduction in the throat area ($Area_{throat}$) of the inlet throat **113**, thus enabling the desired RF performance to be achieved at the cabin air compressor (**40** or **42**) inlet face (**40**a or **42**a).

On "cold" days, typically less than about -**70**°F at altitudes in excess of about **36,000** feet, and lower altitude conditions (typically **10,000** to **20,000** feet; **3033**m - **6066**m) where the heat exchanger cooling airflow demand drops off, the heat exchanger inlet **104** preferably operates at a lower mass flow ratio. The mass flow ratio of the inlet is defined as the actual mass flow through the inlet divided by the mass flow that would pass through the full open throat area of the inlet in the free-stream. At low mass flow ratios, typically in the range of **0.1** to **0.5**, the modulated heat exchanger inlet **104** operates in partially open positions. However, the heat exchanger inlet **104** still "swallows in" the lower energy portion of the boundary layer **118** in Figure **7** that is formed closest to the exterior surface **18** of the fuselage **14**. As a result, the boundary layer approaching the Pitot inlet **102** thickens somewhat and the RF drops off at the inlet throat **113**. This is illustrated in Figure **8**. In Figure **8** the throat RF of the tandemly placed cabin air inlet **102** is plotted versus the mass flow ratio of the heat exchanger inlet **104**. On a cold day, the heat exchanger inlet **104** would operate at a low mass flow ratio in a partially open position. Therefore, the RF achieved at the Pitot inlet throat **113** would be lower. However, since the free-stream mass flux is higher on a cold day compared to that on a hot day, the mass flow ratio and Mach number at the inlet throat **113** of the Pitot inlet **102** are lower on a cold day. This would reduce the internal losses in the Pitot inlet duct **114**. Therefore, the required RF at the cabin air compressor inlet face (**40**a or **42**a in Figure **5**) can still be met with a lower pressure recovery at the Pitot inlet throat **113** on a cold day.

Referring now to Figures **9-11**, data representing various boundary layer measurements made in a laboratory environment, forward and aft of the modulated heat exchanger inlet **104** are illustrated for a range of heat exchanger inlet openings and mass flows. Figure **9** illustrates the boundary layer velocity profiles aft of the heat exchanger inlet **104** with the heat exchanger inlet **104** **100**% open. Figure **10** illustrates the boundary layer velocity profiles with the heat exchanger inlet **104** approximately **70**% open, while Figure **11** illustrates the boundary layer velocity profiles with the heat exchanger inlet **104** approximately **50**% open. In each plot, the boundary layer velocity profiles are shown for several values of mass flow through the heat exchanger inlet **104**. The abscissa in these plots is the ratio (u/u_{inf}) of local velocity (u) in the boundary layer and the velocity at the edge of the boundary layer (u_{inf}). The ordinate is distance (y) in inches from the exterior surface **18** on which the inlets **102** and **104** are installed. On a cold day, the heat exchanger inlet **104** would operate at a low mass flow ratio in a partially open position. Therefore, the RF achieved at the Pitot inlet throat **113** would be lower. The model scale for the test that produced the data represented in Figures **9-11** was a scale of one half. The dashed curve **124** in Figures **9-11** represents the boundary layer profile just ahead of the heat exchanger inlet ramp **126** in Figures **6** and **7**, while the data points making up curve **128** in each of Figures **9-11** indicate the change in the boundary layer velocity profile aft of the heat exchanger inlet **104** (i.e., which is viewed as being approximately at the inlet face **106** of the Pitot inlet **102**). Note that in each of graphs **9-11**, the boundary layer velocity profile represented by curve **128**, aft of the heat exchanger inlet **116**, is much fuller (i.e., the boundary layer is much thinner) compared to the boundary layer velocity profile ahead of the heat exchanger inlet **104**, as represented by curves **124**. This illustrates that a higher RF is obtained at the inlet face **106** of the Pilot inlet **102** as a result of the heat exchanger inlet **104** effectively "swallowing" a substantial portion of the boundary layer **124**.

Figures **12** and **13** illustrate plots that show the Pitot inlet **102** sizing benefit resulting from the tandem arrangement of the heat exchanger inlet **104** and the Pitot inlet **102**. Referring initially to Figure **12**, for the baseline placement of the Pitot inlet **102** in a five inch thick fuselage boundary layer, without the benefit of the boundary layer being swallowed by the heat exchanger inlet **104**, the required inlet throat area is approximately **33** inch^2 with a diverter **108** height (d_d) of about **2.0** inches. This results in an inlet mass flow ratio of about **0.78**, throat pressure recovery (RFth) = **0.897**, and an inlet drag of about **2.174** cts/AP at the sizing point of **43,000** feet, on a hot day and with maximum flow (cts/AP being the total drag in counts per aircraft produced by both two Pitot type cabin air inlets **102**, one on each side of the aircraft. The throat area of the tandemly placed Pitot inlet **102** is approximately **28** inch^2 with a diverter **108** height (d_d) of about **0.5** inch (**12.7** mm), which yields an inlet mass flow ratio of **0.92**, throat pressure recovery RF_{throat} = **0.984**, and an inlet drag of **2.085**cts/AP at the same sizing point. The throat mass flow ratio of the tandem Pitot inlet **102** is therefore higher than that of the baseline Pitot inlet, which will result in higher inlet duct **114** pressure losses. However, the throat RF of the tandem Pitot inlet **102** is significantly higher, which is expected to compensate for the higher duct pressure losses and still meet the minimum desired RF requirement (i.e., about **0.8**) at the cabin air compressor inlet face.

Referring to Figure **13**, at the drag evaluation point of **39,000** feet (**11,830** m), ISA "Standard Day" (i.e., a temperature of about **-70**°F) and minimum flow, the tandemly placed Pitot inlet **102** operates at a higher mass flow ratio and throat RF as compared to the baseline Pitot inlet. At this condition the mass flow ratio for the tandem Pitot inlet **102**, as well as the baseline Pitot inlet, is quite low. Therefore, the duct **114** pressure losses are small as well, and achieving the required RF performance at the cabin air compressor inlet face is not a problem for either placement. A principal benefit of the tandemly placed inlets **104** and **102** is highlighted in the drag at the performance evaluation point. The Pitot inlet **102** drag is reduced by about **0.25**cts/AP for the tandem placement as compared to the baseline arrangement shown in Figure **13**.

Thus, the tandem inlet apparatus **100** enables the desired level of RF performance to be achieved with a smaller area throat for the Pitot inlet **102**, and a shorter diverter **108**, because of the ability of the forwardly placed heat exchanger inlet **104** to swallow a good portion of the boundary layer. The benefits realized in the performance of the Pitot inlet are present even when the heat exchanger inlet **104** is partially closed.

While various embodiments have been described, those skilled in the art will recognize modifications or variations which might be made without departing from the present disclosure. The examples illustrate the various embodiments and are not intended to limit the present disclosure. Therefore, the description and claims should be interpreted liberally with only such limitation as is necessary in view of the pertinent prior art.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. An air inlet apparatus for use in supplying air to a cabin compressor of an environmental control system of a high speed airborne mobile platform, the apparatus comprising:

    a cabin compressor for supplying air to an environmental control system;

    a Pitot inlet in communication with an input of the cabin compressor, the Pitot inlet being disposed at a wing and body interface of the high speed airborne mobile platform, the Pitot inlet including:

        a duct structure having a face and a throat, positioned with the face located outside an exterior surface of a fuselage of the mobile platform, and such that the throat receives a first portion of a fuselage boundary layer adjacent to said fuselage and moving over said fuselage during flight, and feeds the first portion of the fuselage boundary layer to the cabin compressor; and

        a boundary layer diverter for supporting the duct structure outside the fuselage by a predetermined height, such that the boundary layer diverter is able to prevent a second portion of the boundary layer immediately adjacent to said exterior surface of said fuselage from entering said throat;

said duct structure of said Pitot inlet having an inner lip and an outer lip spaced apart from said inner lip, said inner lip being closer to said exterior surface of said fuselage; and

a ratio of a thickness of said outer lip to a thickness of said inner lip is between about 2:1 to about 4:1;

said predetermined height of said diverter, and said ratio of thickness of said outer lip to said inner lip, enabling said Pitot inlet to provide a recovery factor of at least about 0.8 at said input of said cabin air compressor.

2. The apparatus of claim 1, wherein said Pitot inlet comprises a throat aspect ratio of between about 5:1 to about 6:1.

3. The apparatus of claim 1, wherein said boundary layer diverter comprises a height of about 1.0 inch (25.4 mm) to about 3.0 inch (76.20 mm).

4. The apparatus of claim 1, wherein said apparatus is in flow communication with a cabin air compressor of the mobile platform.

5. An air inlet apparatus for use on a fuselage of a jet aircraft to provide intake air for a cabin air compressor of an environmental control subsystem of said aircraft, the apparatus comprising:

a cabin air compressor for supplying air to an environmental control system;

a Pitot inlet in communication with the cabin air compressor, the Pitot inlet including:

a duct structure having a throat and a face, the face positioned outside an exterior surface of said fuselage of the aircraft, and such that the throat receives a first portion of a fuselage boundary layer adjacent to said fuselage and moving over said fuselage during flight of the aircraft, the first portion of the fuselage boundary layer being fed to the cabin air compressor;

a boundary layer diverter disposed between a surface of the duct structure and the exterior surface of the fuselage for supporting the duct structure outside the fuselage by a height of between about 1.0 inch to about 3.0 inches, and that prevents a second portion of the boundary layer immediately adjacent to said exterior surface of said fuselage from entering said throat;

wherein said Pitot inlet comprises a throat aspect ratio of between about 5:1 to about 6:1; and

wherein said Pitot inlet provides a minimum recovery factor of about 0.8 at a face of the cabin air compressor.

6. The apparatus of claim 5, wherein:

said duct structure inlet comprises an inner lip and an outer lip spaced apart from said inner lip, said inner lip being closer to said exterior surface of said fuselage; and

a ratio of a thickness of said outer lip to a thickness of said inner lip is between about 2:1 to about 4:1.

7. An aircraft comprising:

a fuselage having an exterior surface;

an environmental control system having a cabin air compressor housed within the fuselage;

a Pitot inlet in communication with the cabin air compressor, the Pitot inlet being located at a wing and body interface of the aircraft, the Pitot inlet comprising:

a duct structure having a face and a throat, and positioned with said face outside said exterior surface of said fuselage of the aircraft, and such that the duct structure receives a first portion of the boundary layer adjacent to said fuselage and moving over said fuselage during flight of the aircraft, the duct structure in communication with the environmental control system to feed the first portion of the boundary layer to the cabin air compressor; and

a boundary layer diverter disposed between a surface of the duct structure and the exterior surface of the fuselage for supporting a portion of the duct structure outside the fuselage by a predetermined height, and that prevents a second portion of the boundary layer immediately adjacent to said exterior surface of said fuselage from entering said duct structure;

said duct structure of said Pitot inlet comprises an inner lip and an outer lip spaced apart from said inner lip, said inner lip being closer to said exterior surface of said fuselage;
a ratio of a thickness of said outer lip to a thickness of said inner lip is between about **2**:**1** to about **4**:**1**;

said throat of said Pitot inlet includes a throat aspect ratio of between about **5**:**1** to about **6**:**1**; and

the Pitot inlet providing a minimum recovery factor of about **0**.**8** at a face of the cabin air compressor.

8. A method for forming an inlet on an exterior surface of a fuselage of a jet aircraft for feeding air into a cabin air compressor of an environmental control system of the jet aircraft, the method comprising:

forming a Pitot inlet having a throat that is disposed at a wing/body interface area of the fuselage, adjacent to said exterior surface of said fuselage but elevated from said exterior surface;

placing the throat in communication with the cabin air compressor;
forming said Pitot inlet with an inner lip and an outer lip spaced apart from said inner lip, said inner lip being closer to said exterior surface of said fuselage and being spaced apart from the exterior surface of the fuselage a distance of at least about **1**.**0** inch to about **3.0** inches;

further forming said inner and outer lips so that a thickness ratio of said outer lip to a thickness of said inner lip is between about **2**:**1** to about **4**:**1**;

diverting a low energy portion of a boundary layer disposed adjacent to said exterior surface of said fuselage, and at an inlet face of said Pitot inlet, to prevent said low energy portion from entering said throat of said Pitot inlet; and

using said face of said Pitot inlet to receive a higher energy portion of said boundary layer and to feed the higher energy portion of the said boundary layer to the cabin air compressor of the environmental control system.

9. The method of claim 8, further comprising forming said air inlet apparatus with a throat aspect ratio of between about 5:1 to about 6:1.

10. The method of claim 8, wherein diverting a low energy portion of a boundary layer comprises using a diverter disposed between a duct structure of said Pitot inlet and said exterior surface of said fuselage, to support said duct structure.

11. The method of claim 8, further comprising controlling at least one of:

a throat aspect ratio of the Pitot inlet; and

the thickness ratio of the outer lip of the Pitot inlet to the inner lip of the Pitot inlet, such that the Pitot inlet provides a minimum recovery factor of about 0.8.

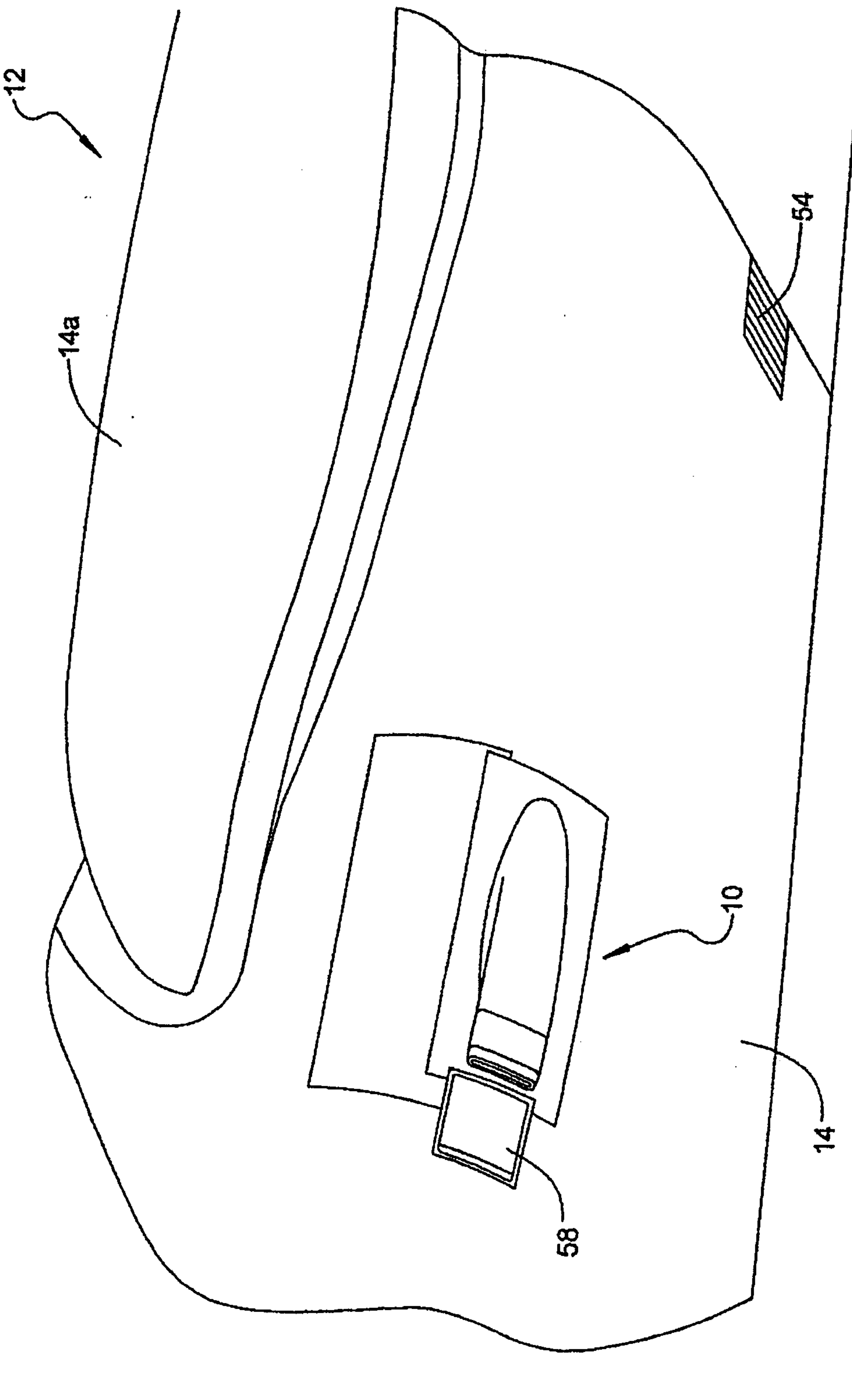
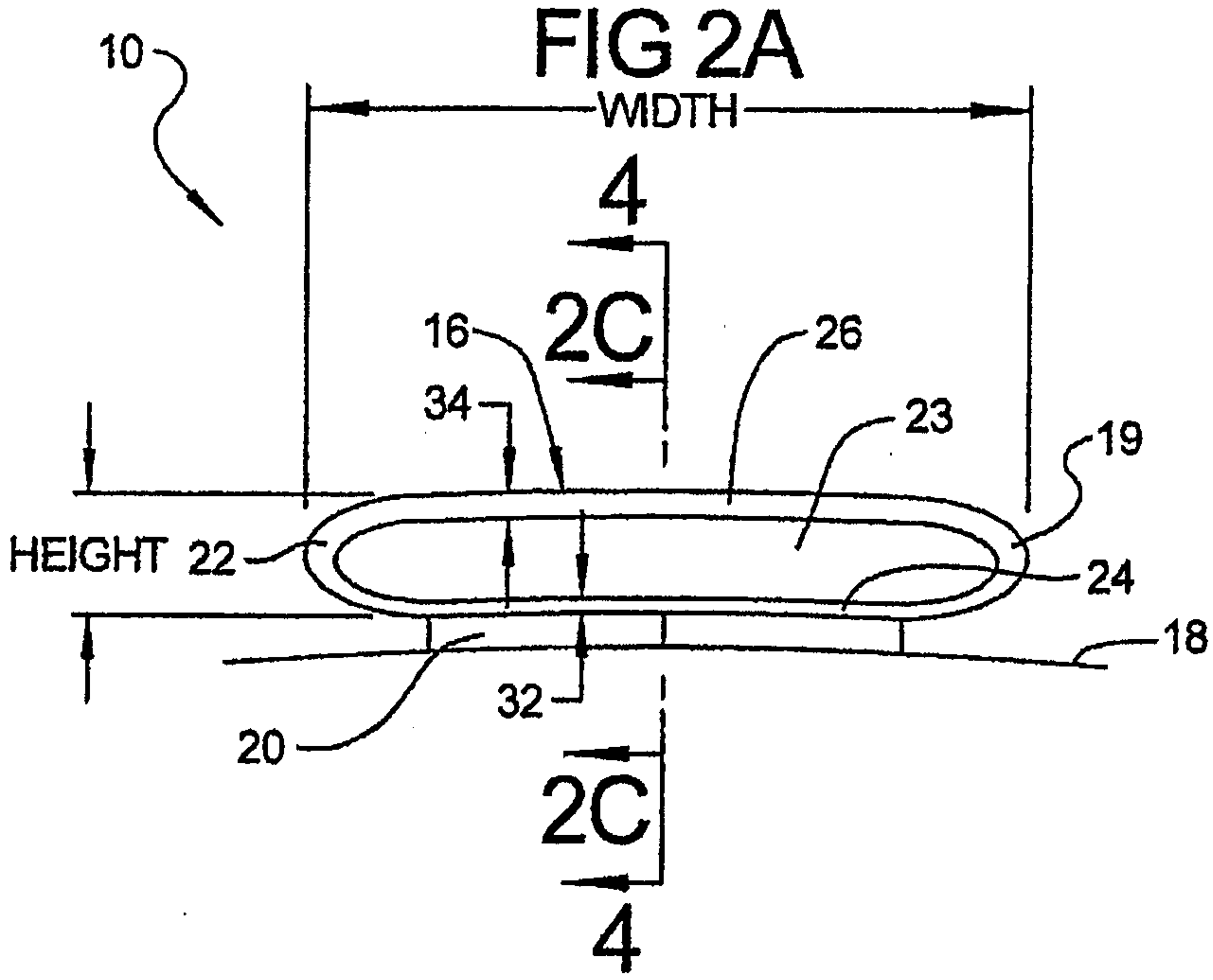


FIG 1

FIG 2A



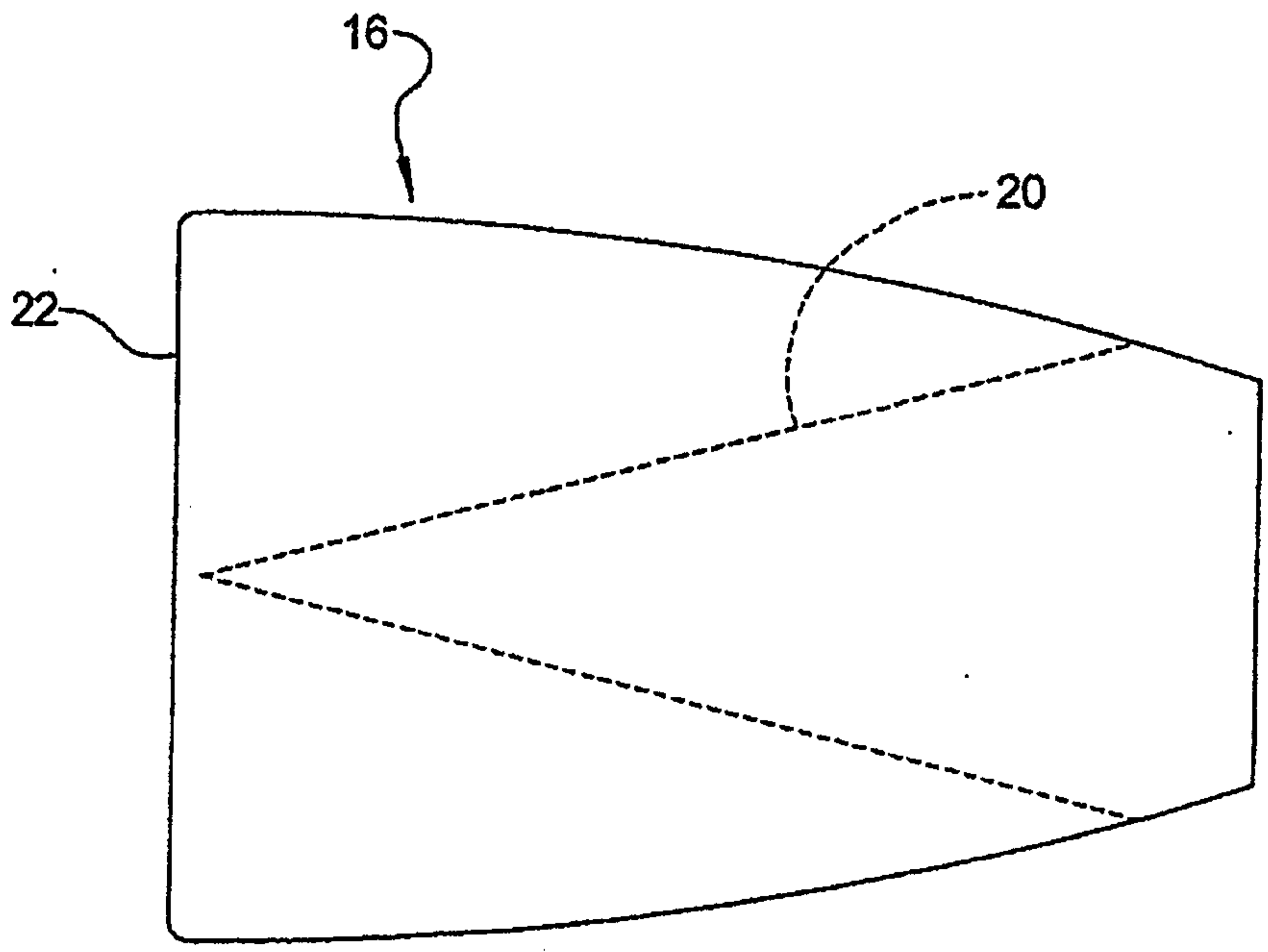


FIG 2B

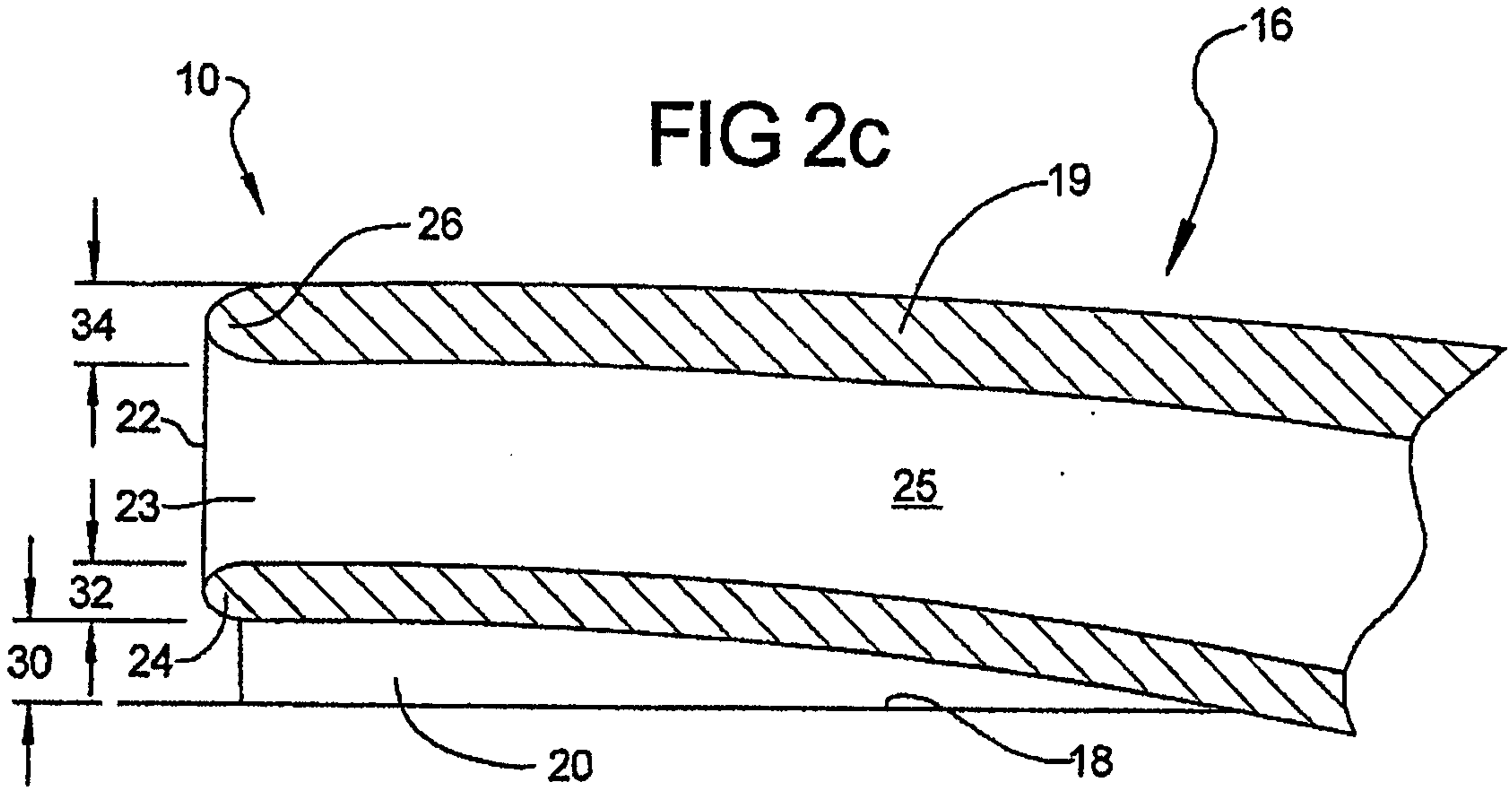


FIG 2c

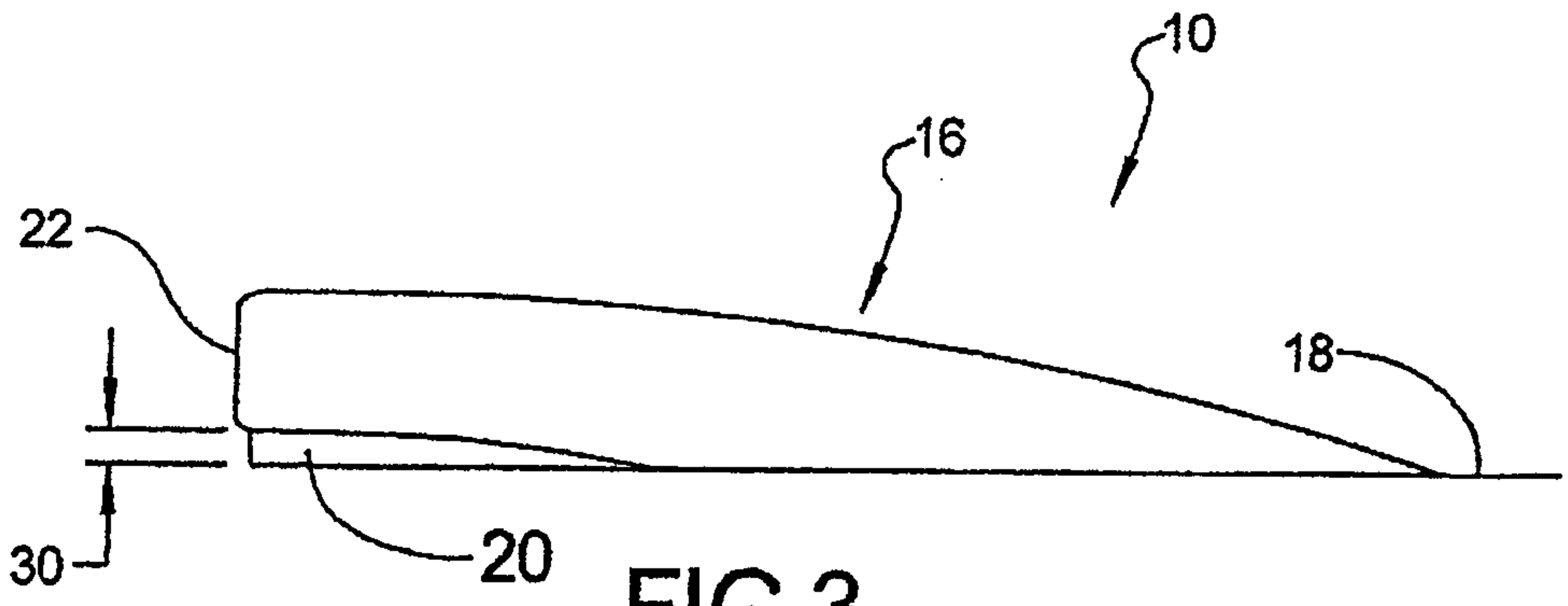


FIG 3

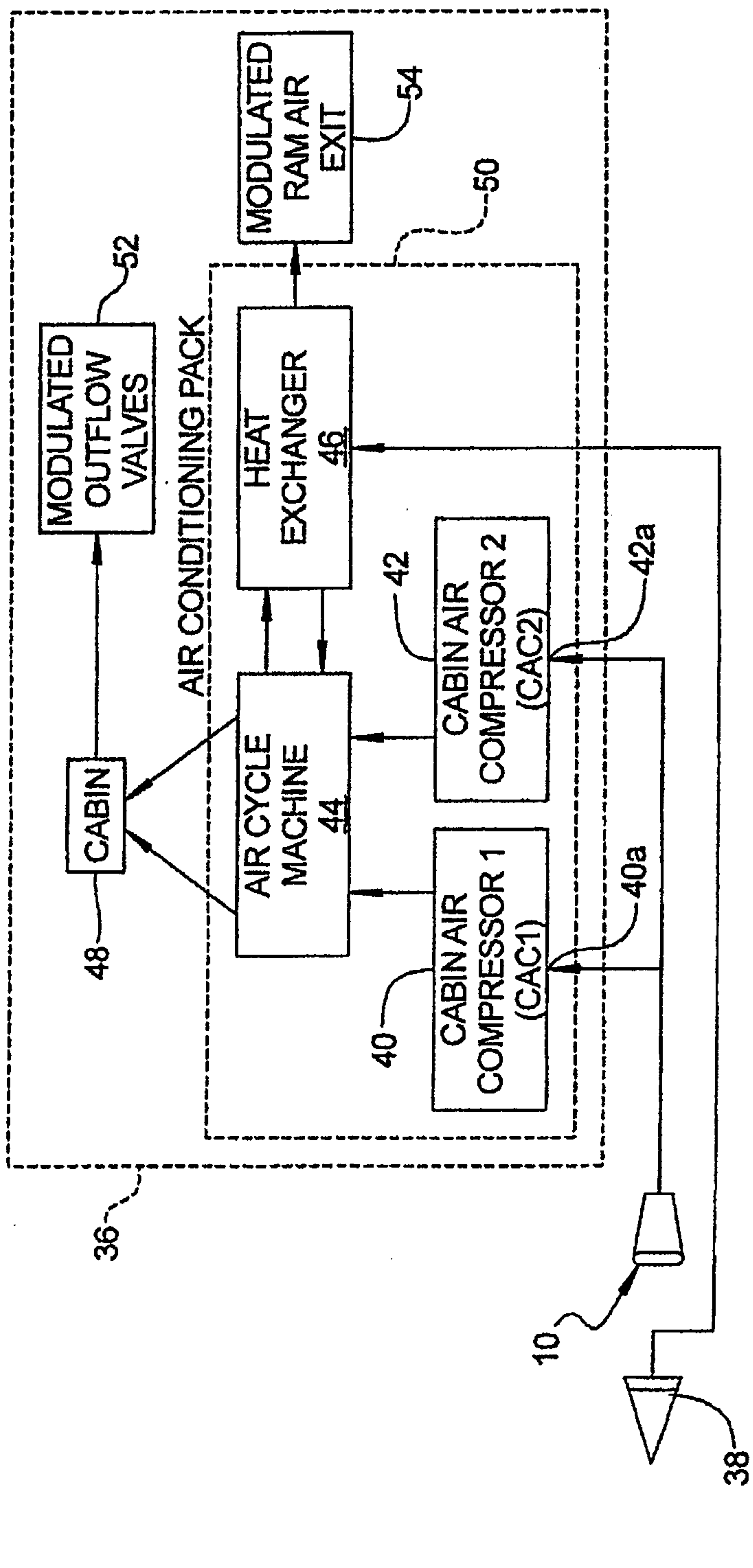

MODULATED OUTFLOW VALVES
52
MODULATED RAM AIR EXIT
54
50
AIR CONDITIONING PACK
HEAT EXCHANGER 46
CABIN
48
AIR CYCLE MACHINE 44
CABIN AIR COMPRESSOR 2 (CAC2)
42
42a
CABIN AIR COMPRESSOR 1 (CAC1)
40
40a
36
10
38

FIG 4

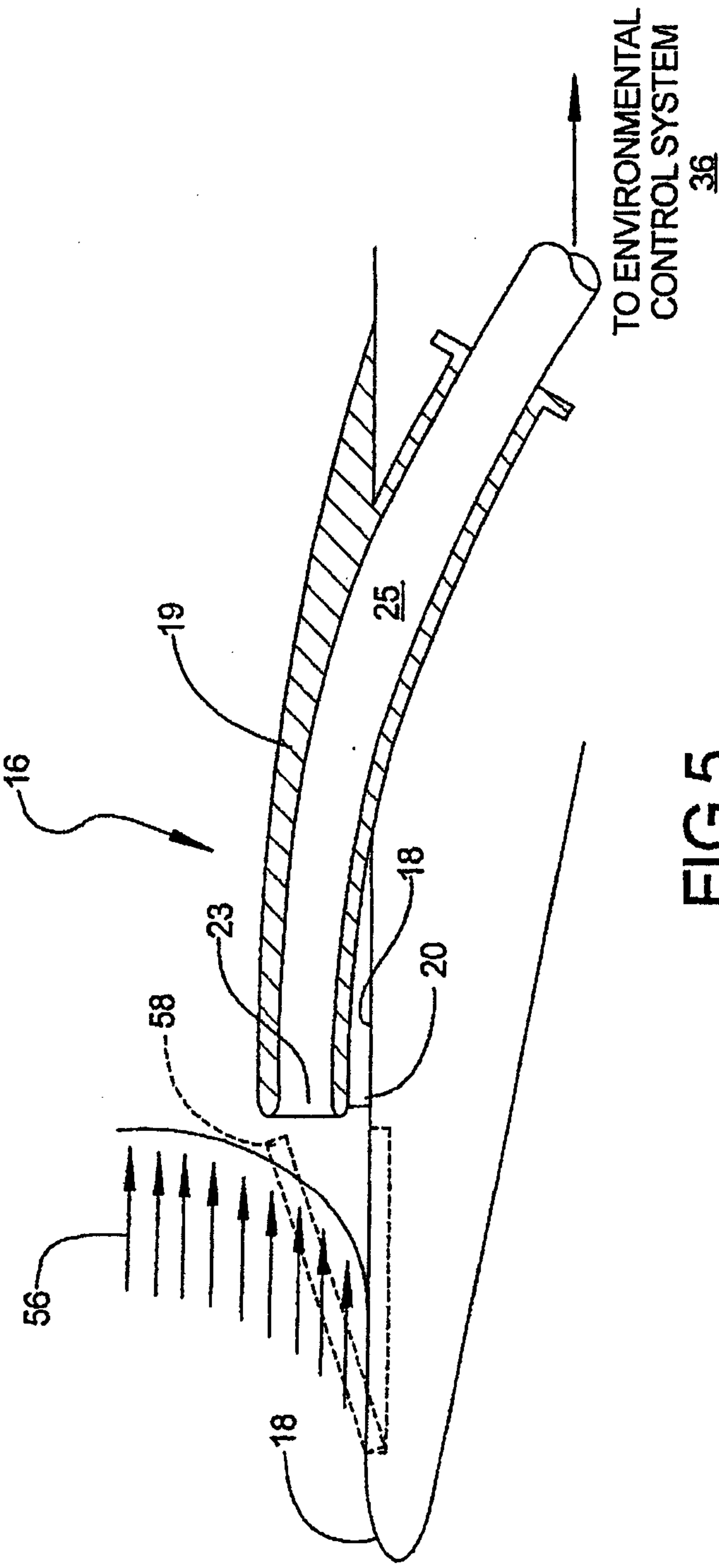


FIG 5

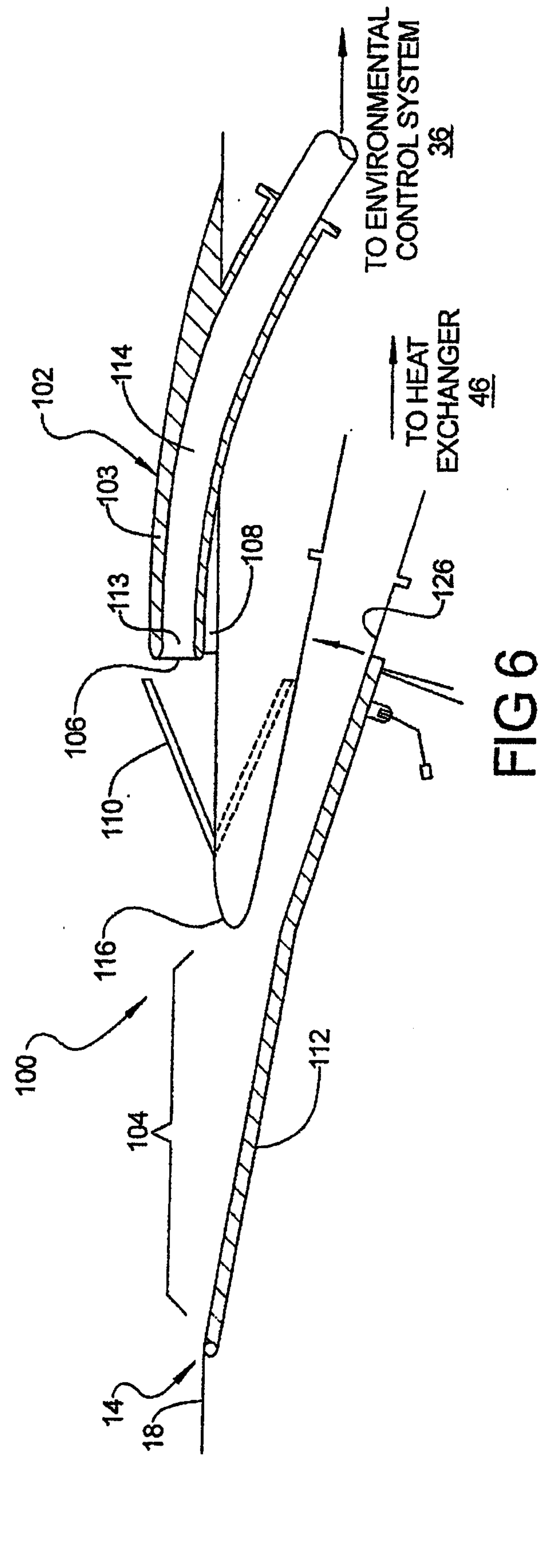

TO ENVIRONMENTAL CONTROL SYSTEM
36
TO HEAT EXCHANGER
46
102
114
103
113
108
106
126
110
116
100
112
104
14
18

FIG 6

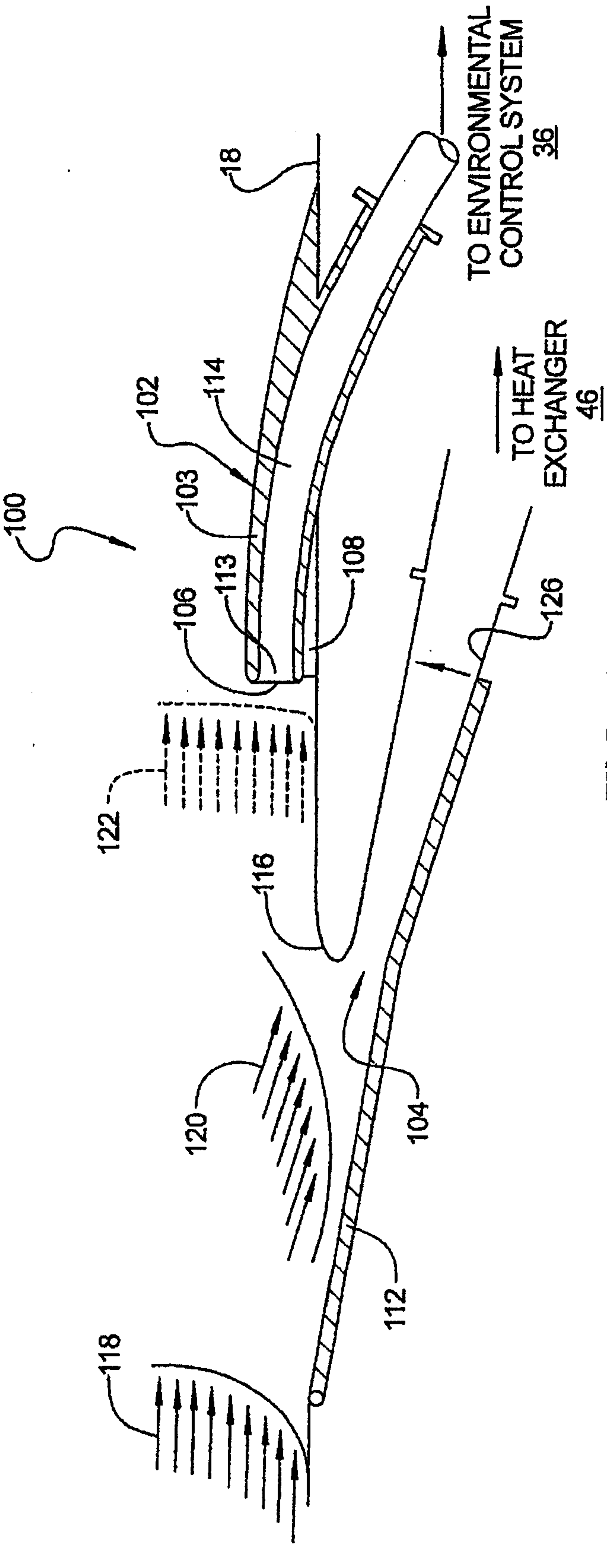

TO ENVIRONMENTAL CONTROL SYSTEM 36
TO HEAT EXCHANGER 46
18
114
102
103
100
113
106
108
126
122
116
120
104
112
118

FIG 7

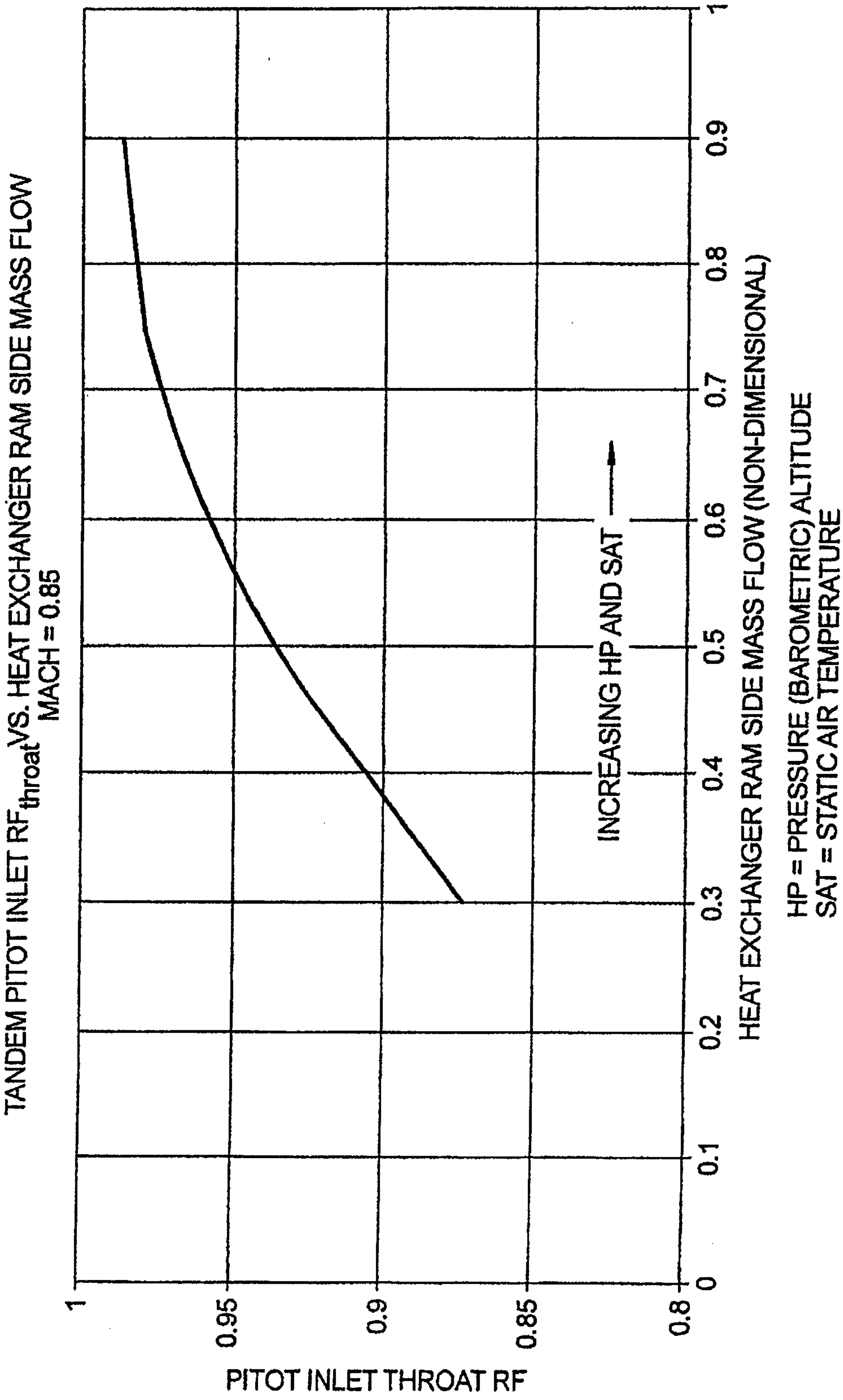

TANDEM PITOT INLET RF_{throat} VS. HEAT EXCHANGER RAM SIDE MASS FLOW
MACH = 0.85
PITOT INLET THROAT RF
1
0.95
0.9
0.85
0.8
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
INCREASING HP AND SAT
HEAT EXCHANGER RAM SIDE MASS FLOW (NON-DIMENSIONAL)
HP = PRESSURE (BAROMETRIC) ALTITUDE
SAT = STATIC AIR TEMPERATURE

FIG 8

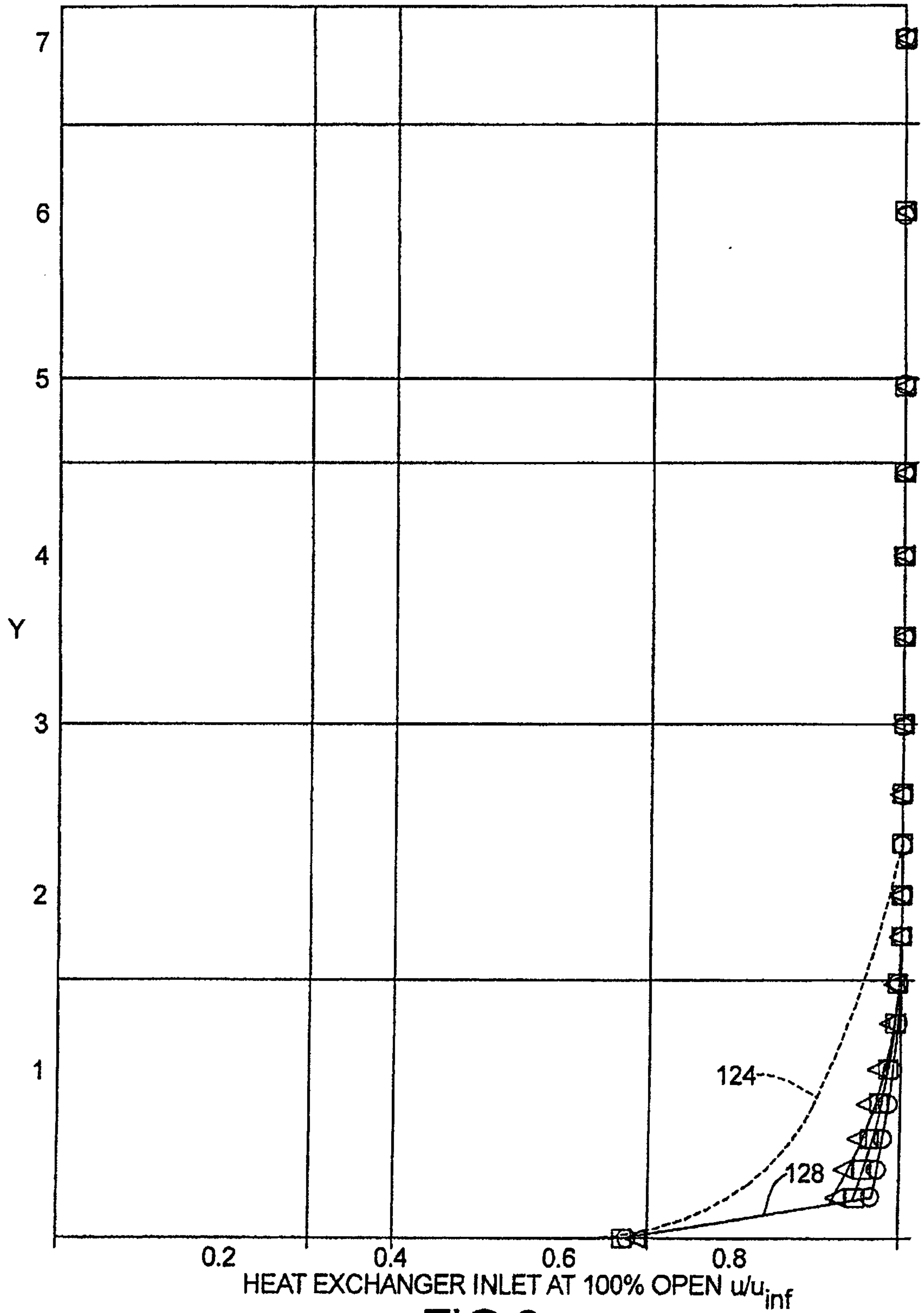

7
6
5
4
Y
3
2
1
124
128
0.2
0.4
0.6
0.8
HEAT EXCHANGER INLET AT 100% OPEN u/u_inf

FIG 9

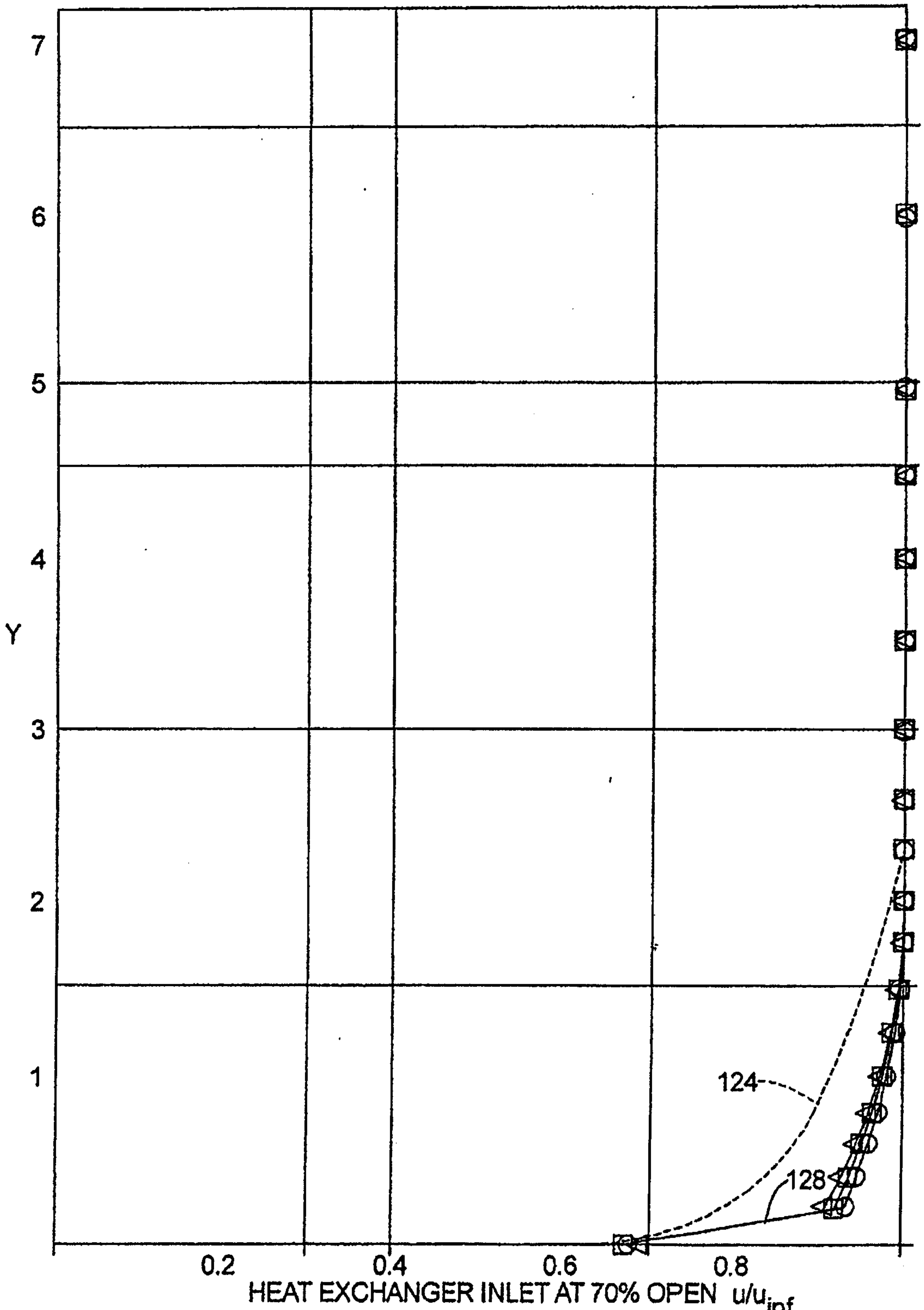

7
6
5
4
Y
3
2
1
124
128
0.2
0.4
0.6
0.8
HEAT EXCHANGER INLET AT 70% OPEN u/u
inf

FIG 10

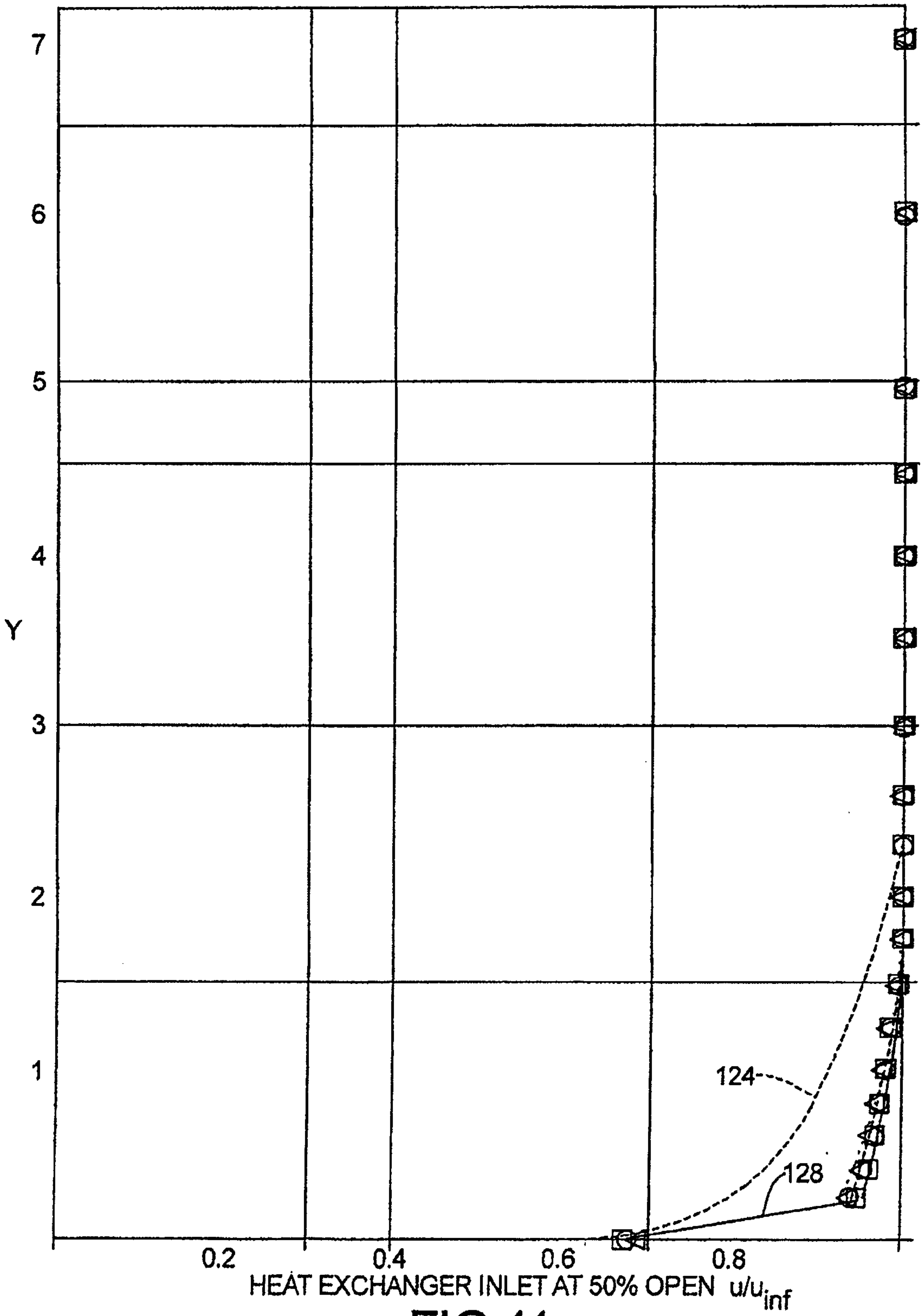
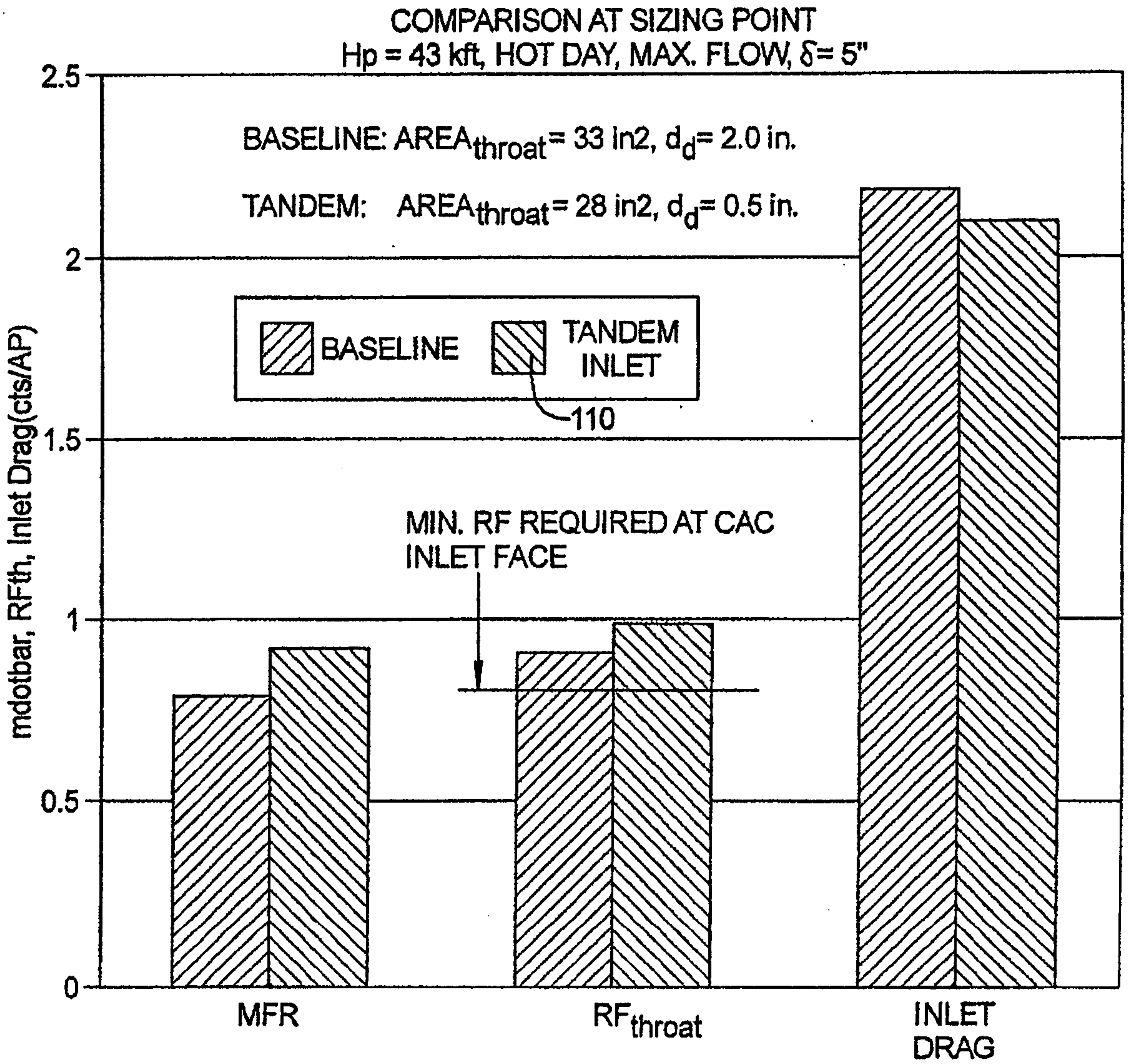
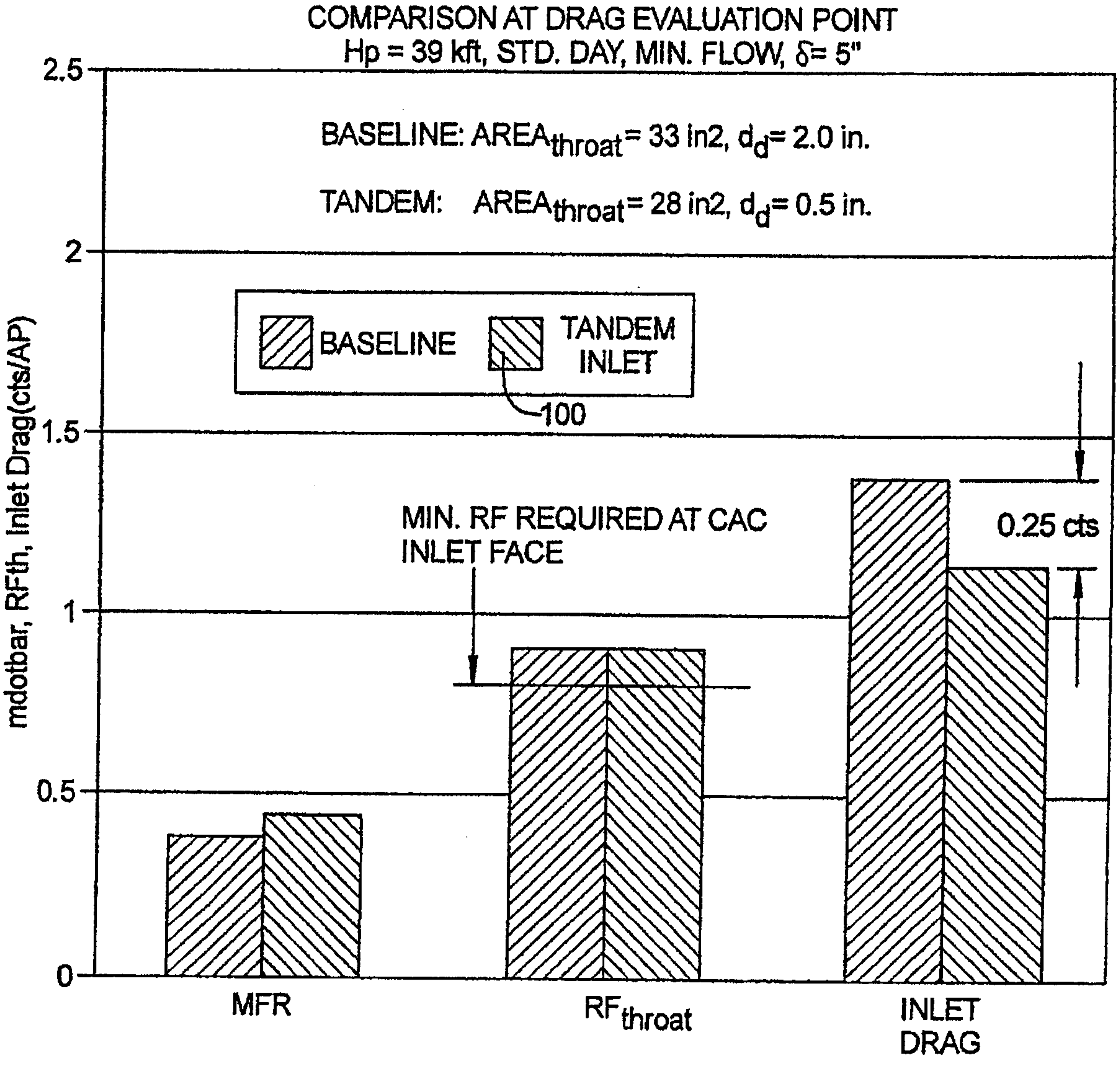

7
6
5
4
Y
3
2
1
124
128
0.2
0.4
0.6
0.8
HEAT EXCHANGER INLET AT 50% OPEN u/u_{inf}

FIG 11



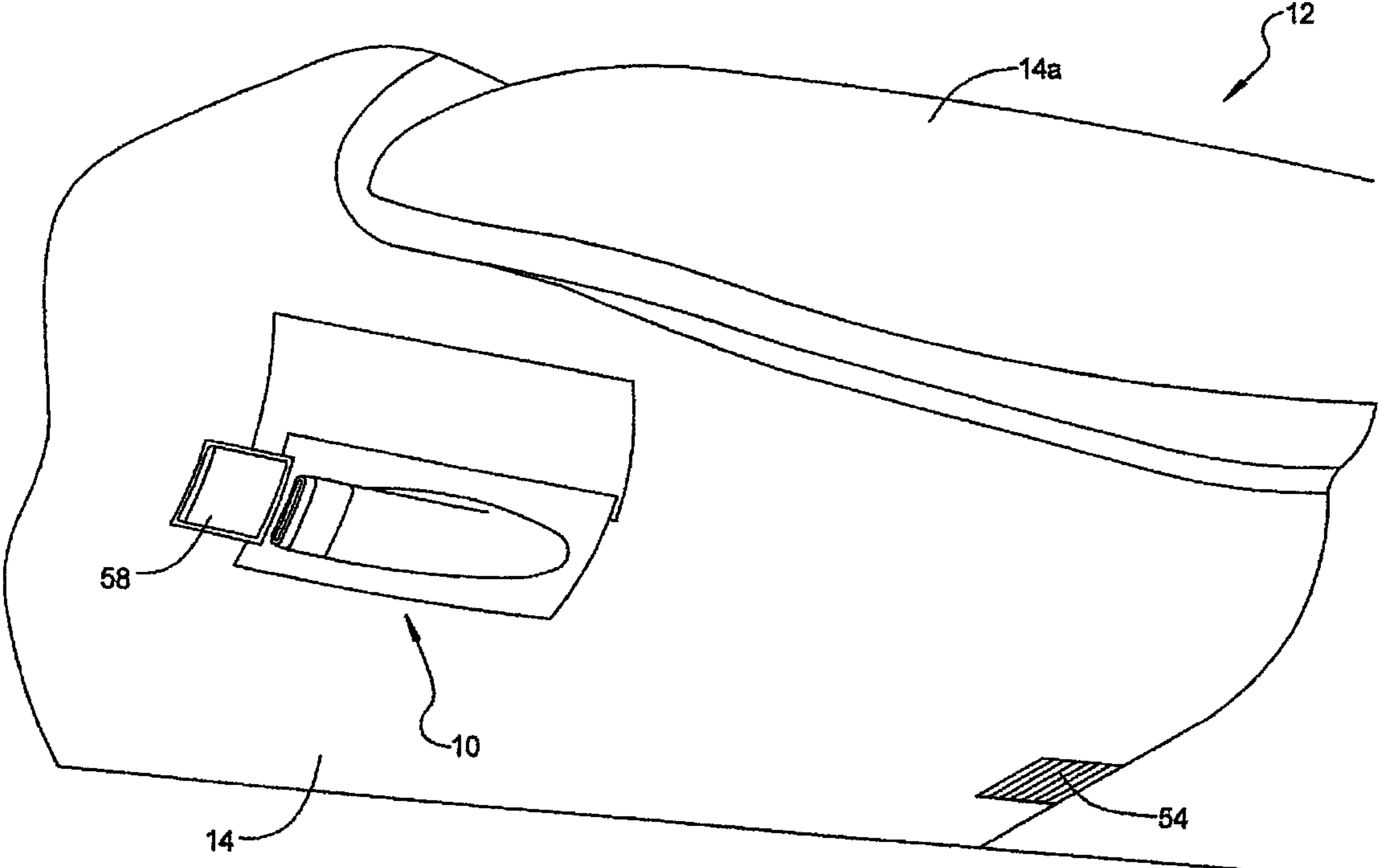
mdotbar = NON-DIMENSIONALIZED MASS FLOW THROUGH THE INLET
cts/AP = DRAG IN COUNTS PER AIRCRAFT (I.E. TOTAL DRAG OF BOTH RAM INLETS ON THE AIRCRAFT)

FIG 12



mdotbar = NON-DIMENSIONALIZED MASS FLOW THROUGH THE INLET
cts/AP = DRAG IN COUNTS PER AIRCRAFT (I.E. TOTAL DRAG OF BOTH RAM INLETS ON THE AIRCRAFT)

FIG 13


12
14a
58
10
14
54