Nov. 15, 1960 J. A. CHIERA ET AL 2,959,919

GAS IMPINGEMENT STARTER NOZZLE FOR TURBINES

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Fig 2

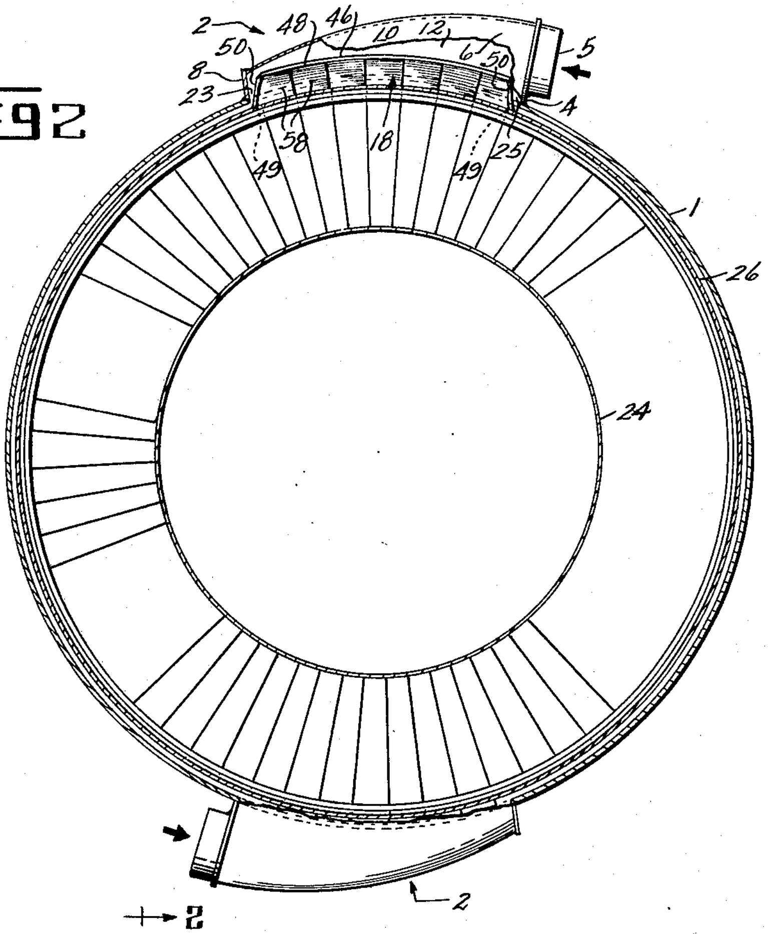
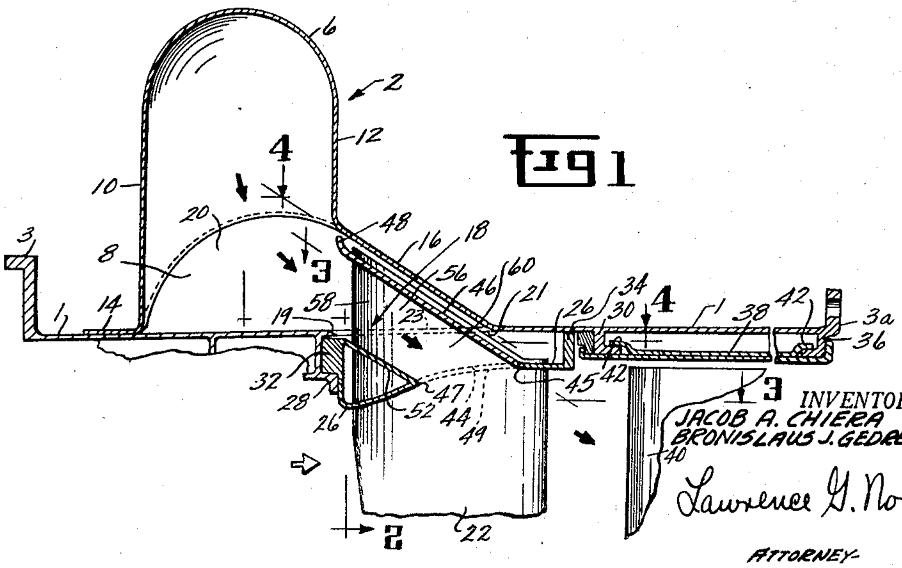


Fig 1



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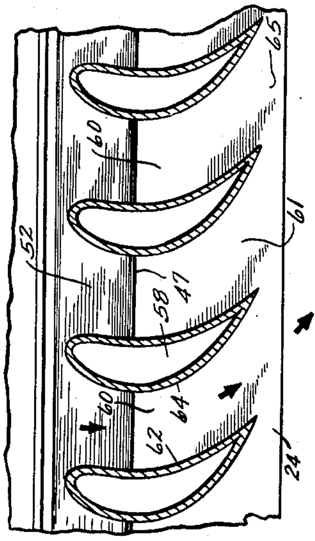
3 Sheets-Sheet 2



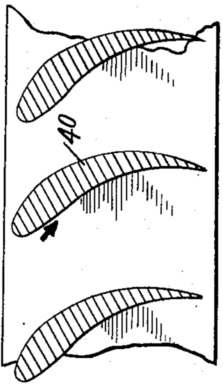


Fig. 3

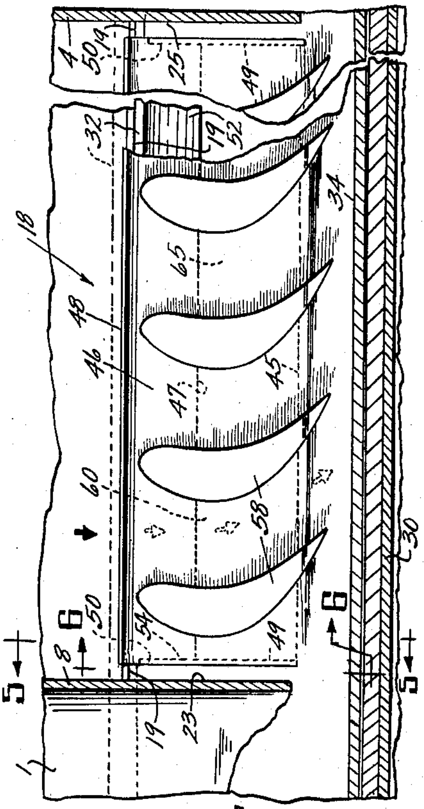


Fig. 4

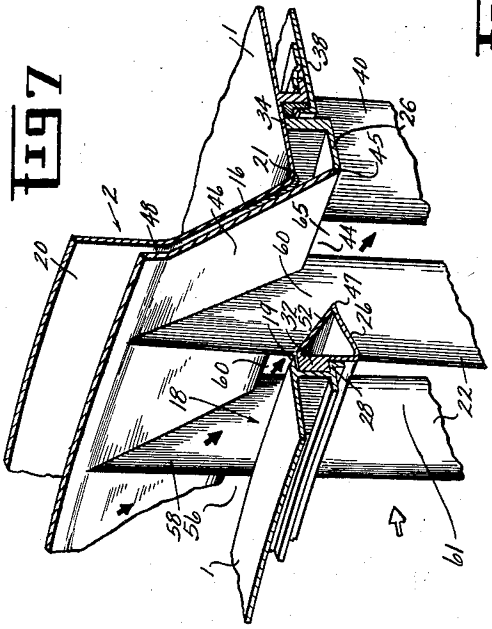


Fig. 7

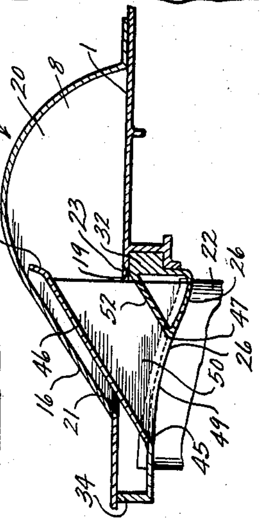


Fig. 5

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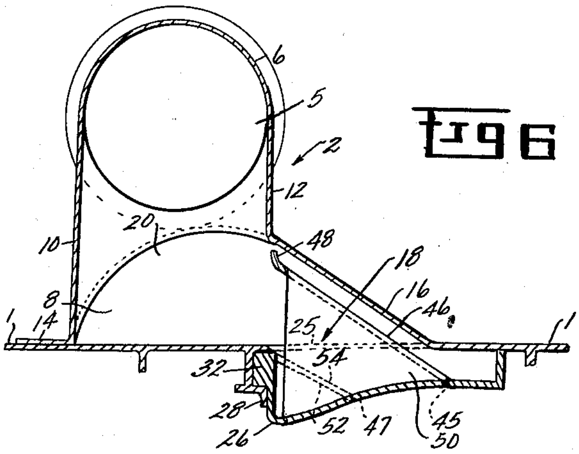

Fig 6

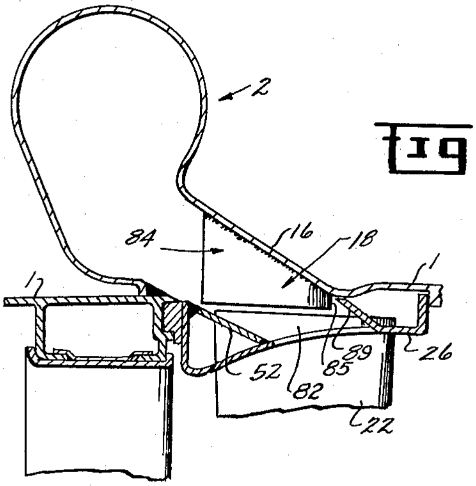

Fig 8

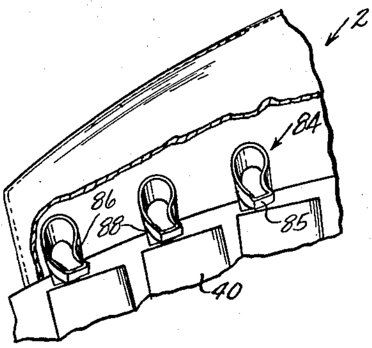

Fig 9

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United States Patent Office

2,959,919

Patented Nov. 15, 1960

2,959,919

GAS IMPINGEMENT STARTER NOZZLE FOR TURBINES

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Filed Jan. 2, 1958, Ser. No. 706,743

4 Claims. (Cl. 60—39.14)

The present invention relates to a mechanism for starting a gas turbine engine, particularly a small turbo-propeller engine of the type described in U.S. patent application Serial No. 548,987, filed by Gerald William Lawson November 25, 1955. More particularly, the invention relates to a gas impingement starter in which a gas under pressure from an external source, e.g. compressed air, is discharged through a nozzle and impinged against the turbine buckets of the gas turbine to thereby initiate rotation of the turbine. Such a starter is referred to thereinafter as a gas impingement starter and the nozzle is referred to as a gas impingement starter nozzle.

A gas impingement starter construction has been proposed which utilizes high pressure air stored in cartridges. The high pressure air is discharged against the turbine buckets through a number of small apertures punched either in the outer turbine nozzle diaphragm or in the turbine shroud.

Such high pressure air cartridges, and other sources of high pressure gas, are expensive and not ordinarily available as standard airport equipment. Consequently, it is an object of the present invention to provide a gas impingement starter which efficiently utilizes low pressure gas which is readily available from standard ground cart type compressors. The low pressure gas is discharged through a plurality of gas impingement starter nozzles against the turbine rotor.

It has been found that with the use of a low pressure gas a relatively large total cross-sectional nozzle area is required to provide adequate rotational thrust. However, a large number of nozzles of small cross-sectional size has been found to be undesirable because they result in increased aerodynamic losses, they have a deleterious effect on normal turbine operation, they increase the cost of manufacture, and it is difficult to pass sufficient low pressure gas therethrough to achieve adequate rotational thrust. Consequently, it is another object of the present invention to provide a gas impingement starter in which a relatively large total nozzle cross-sectional area is provided with a minimum number of gas impingement nozzles.

This can be achieved by providing each of the nozzles with a relatively large cross-sectional area. However, an increase in individual nozzle cross-sectional area results in a decrease in the useful velocity developed by the nozzle and available for conversion into rotational thrust. Consequently, it is necessary to reduce dissipation of such reduced velocity to a minimum. Therefore, it is another object of the present invention to provide a gas impingement starter nozzle in which dissipation of useful velocity

is reduced to thereby permit the use of relatively large nozzle cross-sectional areas.

The use of apertures in the cartridge starter construction referred to above is inefficient, results in substantial aerodynamic losses and deleteriously affects normal turbine operation. In effect, the apertures comprise nozzles of a design which varies substantially from the kind of nozzle design with which the turbine buckets are designed to operate efficiently. Consequently, a large part of the useful velocity is dissipated. Useful velocity is also dissipated due to changes in pattern of the gas flow after the gas is discharged from the apertures and before it is impinged against the turbine buckets. Consequently, it is another object of the present invention to provide a gas impingement starter nozzle design more closely approximating the kind of nozzle design with which the turbine buckets are designed to operate most efficiently; it is another object to provide a gas impingement starter in which dissipation of useful velocity, due to aerodynamic mismatching of the gas impingement starter nozzle and turbine buckets and due to changes in pattern of the gas flow after it is discharged from the nozzle, is reduced to a minimum; it is another object to provide a gas impingement starter in which aerodynamic losses are substantially reduced and which does not detrimentally effect normal turbine operation; and it is another object to provide a gas impingement starter in which a gas under pressure is discharged through a gas impingement starter nozzle against the turbine buckets at an angle of incidence approximating that provided by the turbine nozzles.

Another object is to provide such a starter, which is simple and light in construction and is inexpensive to manufacture, which does not substantially weaken the structural strength of the turbine assembly, and which can be easily incorporated into conventional turbine assemblies without extensive modifications in aerodynamic design.

Briefly stated, in accordance with one aspect of the invention, a gas impingement starter nozzle is provided having a pair of walls, which lie in planes inclined in a direction having a tangential and an axial component, and a pair of walls, which lie in planes inclined in a direction having a radial component and an axial component. The nozzle is located radially from the turbine nozzles and the inclination of the tangentially inclined walls approximates the exit angle of the turbine nozzles. More specifically a gas impingement starter nozzle is provided comprising aerodynamic, radial extensions of a pair of turbine nozzle partitions.

Since the turbine nozzle partitions are designed to provide optimum rotational thrust with minimum aerodynamic losses, the aerodynamic, radial extensions thereof, which have the same design, achieve optimum starting efficiency in most engine designs. This is due in a large part to the fact that they provide an optimum angle of incidence.

The air impingement nozzles discharge the gases into the turbine nozzle passages at a point aft of the leading edges of the nozzle partitions. However, since the contours of the turbine nozzle partitions and those of the air impingement starter nozzles are the same, the pattern of gas flow is not appreciably changed after the gas is ejected from the nozzle throats and before it is impinged on the turbine buckets. Consequently, dissipation of useful velocity is avoided.

By utilizing the radial extensions of the turbine nozzle partitions a maximum cross-sectional area is obtained per turbine nozzle, thereby permitting a large total nozzle cross-sectional area with a minimum number of gas impingement nozzles. The increased efficiency brought about by the air impingement nozzle design permits the use of smaller useful velocities and hence larger individual cross-sectional nozzle areas.

The radially inclined walls restrict the cross-sectional area of the nozzle and direct the gases radially into the spaces between the nozzle partitions, the radial inclination of such walls being selected to impart to the discharged gases a minimum radial component with a minimum number of nozzles.

The above objects and explanation of the invention will be more apparent when read in the light of the accompanying drawings, in which the parts are designated specifically but are intended to be regarded as generically as the prior art will permit and in which:

Fig. 1 is a section in elevation of a part of the gas turbine section of a small gas turbo-propeller engine of the type described in the above mentioned application and which embodies an embodiment of the present invention;

Fig. 2 is a section taken along the line 2—2 of Fig. 1 transversely through the engine;

Fig. 3 is a section taken along the line 3—3 of Fig. 1;

Fig. 4 is a section taken along the line 4—4 of Fig. 1;

Fig. 5 is a section taken along the line 5—5 of Fig. 4;

Fig. 6 is a section taken along the line 6—6 of Fig. 4;

Fig. 7 is a view similar to Fig. 1 but in perspective.

Fig. 8 is a view similar to Fig. 1 of another embodiment of the invention, in which the aerodynamic extensions of the nozzle partitions forming a part of the air impingement nozzles are separated from such partitions;

Fig. 9 is a perspective view of a plurality of the separated partition extensions of Fig. 8 looking from an aft direction and with parts cut away.

Referring to the figures, **1** is a section of the gas turbine casing of an engine of the type described and shown in the above-mentioned application. Casing section **1** is attached to a forward section of the engine casing by means of flange **3** (Fig. 1) and to an aft section of the engine casing by means of flange **3*a***. Casing section **1** has a pair of circumferentially elongated housings **2** located on opposite sides thereof, each housing comprising an end wall **4**, having an opening **5** therein, a top tapered wall **6** extending in a circumferential direction, a rear wall **8**, a forward side wall **10** and an aft side wall **12**. Forward side wall **10** extends into flange **14**, which is attached to casing **1**, as shown. Aft side wall **12** is inclined in an aft direction at **16** and then extends integrally into casing shell **1**, as shown. The circumferential direction measured from front wall **4** to rear wall **8** of each of the housings is opposite from the direction of rotation of the turbine.

Each housing is located over a circumferentially elongated slot **18** in the casing **1**. Each slot is defined by a forward bevelled edge **19**, an aft edge **21**, formed by the juncture of inclined wall **16** with casing **1**, as shown in Figs. 1 and 7, and side edges **23** and **25** formed respectively by the juncture of the aft portion of rear wall **8** with casing **1** and the juncture of the aft portion of front wall **5** with casing **1**. Slot **18** provides communication between the manifold chamber **20** formed by the housing and the interior of the turbine casing **1**. Actually, the slot is located under the inclined wall **16**, as shown.

A plurality of second stage turbine nozzle partitions **22** are mounted in an inner annular diaphragm or band **24** (see Fig. 2) and an outer diaphragm or band **26**, the latter band being in turn mounted in casing **1** by means of annular casing rabbets **28** and **30** (see Figs. 1 and 7) and cooperating annular outer band rabbets **32** and **34**. Casing rabbet **30** also cooperates with casing rabbet **36** to support the turbine shroud **38** of the second stage turbine rotor **40** through shroud rabbets **42**.

The portion of ring **26** located approximately under each slot **18** has a circumferentially elongated slot **44** therein which partially overlaps, but is slightly offset in an aft direction from slot **18**, as shown in Fig. 1.

An inclined wall **46** extends from the aft edge **45** of the slot **44** forwardly and radially outwardly over the slot **44**, through the slot **18**, into the housing **2** and along the inclined wall **16** of the housing. Inclined wall **46** is substantially parallel with and disposed radially inwardly of wall **16** as shown. Wall **46** joints band **26** at the aft edge **45** of slot **44**. Wall **46** has a radially outwardly extending lip **48** and extends over the circumferential length of slot **44**, as shown. The circumferential ends of wall **46** extend radially inwardly at **50** (see Figs. 2, 4, 5 and 6) to the circumferential edges **49** of the slot **44** to which they are joined, as shown, to form end walls **50**.

Another inclined wall **52** extends from the forward edge **47** of the slot **44**, forwardly and radially outwardly to the rabbet **32** to which it is joined, as shown. Wall **52** is substantially parallel to wall **46**. The circumferential edges **54** (see Fig. 6) of wall **52** abut against the end walls **50**.

Inclined walls **46** and **52** and end walls **50** form a circumferentially elongated hopper-like chamber or chute **56** providing communication between manifold chamber **20** of the housing and the interior of outer band **26**.

Each of the seven nozzle partitions **22** mounted in the slotted portion of the outer band has an extension **58** extending radially outwardly through the outer band **26** and slot **44**, through notches in wall **52** and through apertures in wall **46**, as shown. Part of such extension extends through slot **18** in the casing and into the housing, as shown in Figs. 1 and 7. Extensions **58** divide the chamber **56** into a number of air impingement nozzles or nozzle passages **60** defined by a contoured pressure surface **62** (see Fig. 3) and a contoured suction surface **64** of adjacent extensions **58** and the parts of the inclined walls **46** and **52** located between such adjacent extensions. Each air impingement nozzle passage provides communication between manifold chamber **20** and the main turbine nozzle passage **61** located between the main part of the adjacent nozzle partitions from which such adjacent extensions extend. The throat **65** of such air impingement nozzle is formed by the forward and aft edges **45** and **47** of slot **44** and the portions of surfaces **62** and **64** aligned therewith.

To start the engine compressed air from a conventional ground cart type compressor and at a low pressure, e.g. 40 p.s.i., is introduced at about 110 pounds per minute through opening **5** into manifold chamber **20**, as shown by the arrows in Figs. 1 and 2, and from there it flows through the air impingement nozzle passages **60** and throats **65**, as shown by the arrows in Figs. 1, 3, 4 and 7. It is discharged from throats **65** in the form of jets into the main nozzle passages **61** and against the turbine buckets **40** (see the arrows in Figs. 3 and 7) to thereby cause the turbine rotor to rotate, which operates the engine compressor and fuel pump to introduce fuel and compressed air into the burners where they are ignited.

Walls **62** and **64** of the air impingement nozzles impart to the compressed air a turning movement corresponding to that imparted by the turbine nozzle partitions to exhaust gases during normal turbine operation, and direct the compressed air in a direction having a tangential component (right-hand direction as viewed in Figs. 3 and 4) and an axial component (vertical direction in the plane of the paper as viewed in Figs. 3 and 4). The airfoil contours of the pressure and suction surfaces of the nozzle partitions are designed to achieve maximum rotational thrust with minimum aerodynamic losses. Since the walls **62** and **64** of the air impingement nozzles have the same contours, and hence have the same turning and exit angles and discharge the gas against the turbine buckets at the same angle of incidence, optimum starting efficiency is obtained. Furthermore, the flow path of the jets of compressed air after they emerge from the air impingement nozzles and before they are impinged against the turbine buckets is not appreciably changed in pattern and direction and hence a minimum of useful velocity is dissipated.

The purpose of the inclined walls **46** and **52** is to restrict the cross-sectional area of the air impingement nozzles and to direct the compressed air radially into the turbine nozzle passages at the same time that the surfaces **62** and **64** turn it in a tangential direction. Actually, walls **46** and **52** direct the gas in a direction having an axial and a radial component. It is desirable that the radial component be kept at a minimum because the force exerted thereby is wasted. However, a decrease in the radial component results in a decrease in the cross-sectional area of the air impingement nozzle throat. A minimum total cross-sectional area is required to produce sufficient thrust to start the engine so that if the cross-sectional area of each throat is decreased, the number of air impingement nozzles must be increased with the result that weight, cost of manufacture, aerodynamic losses and detrimental effect on turbine operation are increased. In practice, the incline of walls **46** and **52** is selected to provide an acceptable radial component with a minimum number of air impingement nozzles. The acceptable angle of inclination of the walls **46** and **52** to the turbine axis, which determines the magnitude of the radial component, varies according to the turbine design.

The air jet is introduced into the turbine nozzles aft of the leading edges thereof. It is desirable to introduce them close to the trailing edges to avoid radial dissipation of useful velocity after they emerge from the air impingement nozzle throats.

Because of the increased efficiency made possible by the gas impingement nozzle design of the present invention, adequate rotational thrust can be developed with relatively low pressures and a small number of relatively large nozzle cross-sectional areas, thereby eliminating the necessity for a large number of nozzles of smaller cross-sectional areas and permitting the nozzle partition extensions to be used as walls of the air impingement nozzles. The optimum cross-sectional area of each air impingement nozzle will vary according to turbine design.

The walls **46** and **52** compensate for the decrease in structural strength due to slots **44**.

All or part of extensions **58** can be separated from the turbine nozzle partitions from which they extend. Such an arrangement is shown in Figs. 8 and 9 in which the extensions comprise separate stub blades **84** which are mounted on wall **16** and extend radially inwardly therefrom. They can just as well be mounted on the outer band **26**, or a flange which is integral with or mounted in, the casing. They have the same contours as the nozzle partitions **22** except that a small part of the trailing edges thereof are cut away at **85** to facilitate assembly. Consequently, each stub blade constitutes a stub of a nozzle partition. They are radially aligned with the nozzle partitions **22** so that their pressure surfaces **86** are aligned with the pressure surfaces of the nozzle partitions **22** and their suction surfaces **88** are aligned with the suction surfaces of the nozzle partitions **22**. However, each stub blade **84** is offset slightly forwardly of its main nozzle partition **22**, as shown. The stub blades form part of the gas impingement starter nozzles. Nozzle partitions **22** extend radially outwardly from diaphragm **26** at **82** only a short distance, as shown in Fig. 8. These slight integral extensions **82** also form part of the gas impingement starter nozzles.

The radially inclined wall **89** corresponds to wall **46** in Fig. 1 but is shorter. It is aligned with the inclined wall **16** of the housing as shown so that the two walls together form a radially inclined wall of the chute and gas impingement nozzles.

Thus, one wall of each nozzle assembly comprises the pressure surface of an integral extension **82** of a nozzle partition **22** and its aligned stub blade pressure surface **86** and the other oppositely facing wall comprises the suction surface of an integral extension **82** of an adjacent nozzle partition and its aligned adjacent stub blade suction surface **88**. One radially inclined wall is formed by wall **52** as in Fig. 1 and the other is formed by wall **89** and wall **16**.

Although the stub blades **84** are separate from partitions **22**, aerodynamically they are radial extensions thereof. The term "extensions" as referred to herein is used in its aerodynamic sense to include both integral extensions of the type shown in Fig. 1 and separate extensions of the type shown in Fig. 8.

The radially inner edges of the stub blades should be close to the radially outer edges of integral extensions **82** and the edge of wall **89** should contact the edge of wall **16** to avoid loss of pressure.

The integral extensions **82** can be eliminated in which case stub blades **84** are extended further inwardly.

Where the extensions are separate from the nozzle partitions, the surfaces thereof, which define the walls of the impingement nozzles, need not have the exact contours as the turbine nozzle partitions, although it is preferred that they be airfoil surfaces and correspond to the surfaces of a conventional turbine nozzle partition. However, if efficiency is willing to be sacrificed they need not be curvilinear so long as they are inclined in a direction having a tangential and an axial component. A tangential component is important in order that the jets be discharged against the turbine buckets at an acceptable angle of incidence, preferably at the same angle of incidence as that provided by the turbine nozzles. In such case the tangential angle of inclination is substantially equal to the exit angle of the turbine nozzle partitions.

It has been stated that the air impingement starter nozzles of the present invention operate efficiently with low pressure gas provided by conventional ground cart type compressors. Such compressors usually produce air at a pressure of between about 30 and 80 pounds per square inch. However, the invention is not limited to the use of such pressures.

The construction of the present invention is simple and inexpensive to manufacture. It requires in addition to conventional turbine parts only a pair of housings of simple construction, a pair of slots in the outer band, a pair of slots in the casing, a pair of inclined walls for each slot in the outer band and a number of elongated nozzle partitions.

While the particular embodiments of the present invention have been illustrated and described, it will be obvious to those skilled in the art that various changes and modifications may be made without departing from the invention. It is intended to cover in the appended claims all such changes and modifications that come within the true scope and spirit of the invention.

We claim:

1. A turbine assembly comprising a turbine casing, a plurality of nozzle partitions, an outer nozzle diaphragm, means for mounting said partitions in said diaphragm, means for mounting said diaphragm in said casing, said diaphragm having a slot therein, a pair of radially inclined walls extending radially outwardly and forwardly from said diaphragm to form a chute, the throat of which is defined by said slot, said nozzle partitions having aerodynamic extensions extending radially through said chute to divide said chute into nozzle spaces defined by adjacent surfaces of adjacent extensions and said walls, and means for directing a flow of gas under pressure into said nozzle spaces.

2. A turbine assembly according to claim 1, said casing having a housing defining a gas manifold, said casing having an opening therein providing communication between said manifold and the interior of said chute.

3. A turbine assembly according to claim 1, in which said aerodynamic extensions comprise stub blades mounted in said chute, each of said stub blades radially spaced from and aligned with one of said partitions.

4. A turbine assembly comprising a plurality of nozzle partitions mounted in a nozzle diaphragm, said diaphragm having a circumferentially elongated slot therein, each of the aft and forward edges of said slot extending into a wall which simultaneously extends radially outwardly and forwardly to form an inclined chute having a throat which is defined by said slot, a plurality of said partitions having radial extensions which extend through said diaphragm, said slot and said chute, to divide said chute into a plurality of gas impingement starter nozzle spaces and said slot into a plurality of gas impingement starter nozzle throats.

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