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TURBINE

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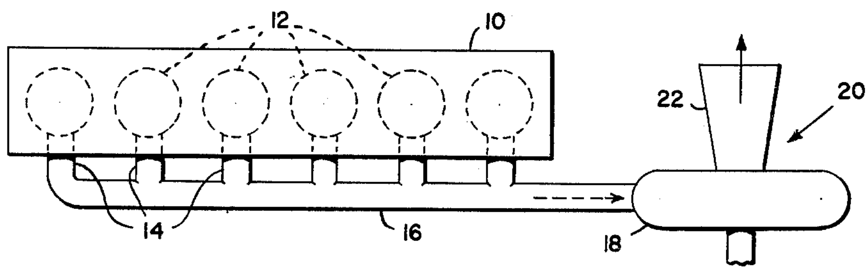

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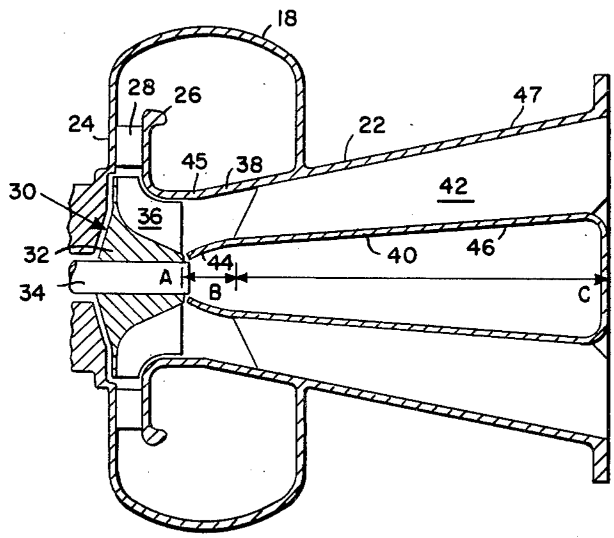

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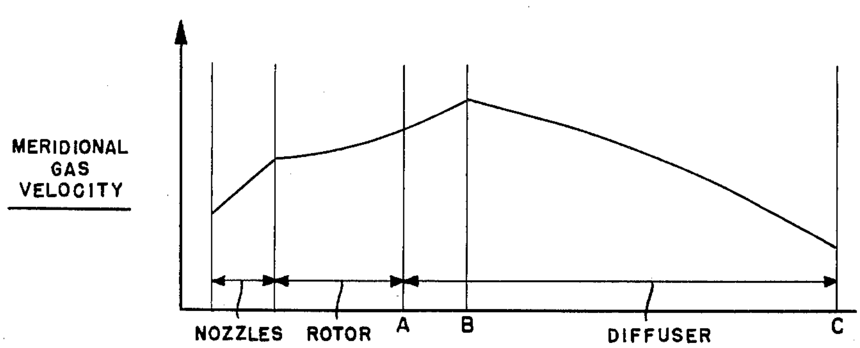

F I G. 3.

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TURBINE

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This invention relates to gas turbines to be driven by the exhaust gases from an internal combustion engine.

Numerous flow smoothing devices have been designed to reduce the magnitude of pulsations in gases discharged from internal combustion engines prior to their delivery into turbine rotors. Although such flow smoothing devices have been successful in substantially reducing the objectionable pulsations, residual pulsations still generally remain in the gases delivered to the turbine.

Before considering the aspects of the present invention, mention may be made of the fact that it is conventional to provide diffusers for the gases which flow from the turbine rotor passages. The diffusers recover to a considerable extent the residual kinetic energy of the gases leaving the turbine rotors, converting this energy into pressure energy, and since the diffusers discharge to the atmosphere, the pressures at their entrances are subatmospheric, which means that the pressure drop through the turbine rotor is increased.

Turbines which are to receive engine exhaust gases must be designed on a vectorial flow basis assuming an average value of steady flow. Design is theoretically such that for such flow the gases will enter the turbine blading at a proper relative angle, depending on the particular design, and will, in particular, leave the rotor with a minimum of spin. Since the pulsations represent changes of velocity, and the rotor speed is essentially constant, it will be evident that the achieved vectorial flow conditions depart from the theoretical in cyclical fashion, and this necessarily results in loss of efficiency. Particularly detrimental to operation appear to be the disturbances which occur at the exits from turbine wheels and entrances to their accompanying diffusers. The pulsations at the diffuser entrances build up turbulent flow and since the discharge velocities are subsonic the disturbances are reflected back into the rotor passages producing departures from the theoretically proper flow conditions.

The general object of the present invention is to minimize the disturbances in a diffuser. It has been found that if on leaving the turbine wheel the flow is accelerated prior to the deceleration involved in the ordinary diffuser action the turbulence referred to is very substantially lessened so that the deceleration takes place smoothly with efficient energy transformation in the diffuser and without the reflection of the disturbances back into the turbine passages, so that flows through these passages are optimized.

While the invention may be used in conjunction with pulsation-suppressing means preceding the turbine rotor, and then serves to minimize the effects of residual pulsations, it is found that even without the latter it greatly improves the turbine operation.

The foregoing general object as well as others more particularly relating to the details of construction will become more fully apparent from the following description read in conjunction with the accompanying drawings in which:

FIGURE 1 is a schematic diagram of an internal combustion engine and a turbine provided in accordance with the invention;

FIGURE 2 is an axial sectional view of a turbine embodying the principles of the present invention; and

FIGURE 3 is a graph indicating the meridional velocity of the gas as it flows through successive portions of the turbine.

Referring first to FIGURE 1, an internal combustion engine **10** has a plurality of cylinders **12** each of which is connected through an individual exhaust conduit **14** to the main exhaust manifold **16**. Engine **10**, irrespective of its type will produce pulsations in the exhaust gases due to the sequential firing of its individual cylinders.

Exhaust manifold **16** is connected to the inlet chamber **18** of turbine **20** which, for purposes of the present description is illustrated as being of the centripetal mixed flow type having a peripheral inlet and a central, axial outlet delivering gases to a diffuser section **22** which discharges to atmosphere. Between the engine and the turbine, or forming a part of the turbine, there may be a pulsation-suppressing means of known type, but this is not shown since the invention is useful even without it. It is to be understood that the present invention is not limited to centripetal turbines, but rather, may be employed with axial flow turbines as well.

As shown in FIGURE 2, the turbine casing includes an outer portion **24** and an inner portion **26** which support a plurality of peripherally arranged vanes **28** forming a plurality of inlet nozzles as guide passages through the invention is applicable to turbines the rotors of which receive vortex flow from an annular gas space without the use of guide vanes.

The turbine includes a conventional centripetal rotor **30** having a hub **32** secured to a shaft **34** suitably journalled in bearings (not illustrated) and providing the mechanical output, for example to drive an engine-charge compressor. Hub **32** rigidly supports the rotor blades **36** the particular shapes of which are of types well known in the art.

Immediately downstream of rotor **30**, the turbine is provided with the above mentioned diffuser section **22** which includes an outer annular wall **38** and an inner annular wall **40** between which there extend a plurality of spin suppressing vanes **42**, although it is to be understood that vanes **42** may be eliminated so as to provide a vaneless diffuser.

In what would be a generally similar but conventional diffuser arrangement, the cross-sections orthogonal to flow between the annular walls **46** and **47** would increase from the region of discharge of the rotor to the point of discharge of gases into the atmosphere. This type of arrangement resulted in progressive decrease of velocity and consequently the transformation of kinetic energy into pressure. Considering such an arrangement ideally, there would be achieved a pressure rise to atmospheric pressure which, if efficient would provide a minimum back pressure on the turbine passages and, theoretically, maximum turbine efficiency.

However, when pulsating flow is involved, in such an arrangement turbulence is produced primarily at the diffuser entrance at which point there is maximum disturbance of the vectorial flow pattern. Not only does such turbulence lessen the effective action of the diffuser, but, apparently, because the rotor discharge velocities are subsonic, the effects of this turbulence are propagated backwardly opposite the direction of flow and into the rotor passages where their disturbing effects are even more serious.

In accordance with the present invention the diffuser arrangement provides, initially, an acceleration of the gas flow after which the conventional diffuser action takes place with decrease of flow velocity. In accordance with the invention, therefore, one or both of the portions **44** and **45** of the walls **40** and **38** are shaped (primarily **44** as illustrated) to provide an initial progressive decrease of the cross-sectional area orthogonal to the flow. This decrease of cross-sectional area continues to a throat of minimum cross-sectional area beyond which the cross-sectional areas orthogonal to the flow progressively increase to provide the conventional diffuser action involving decrease of flow velocity. The portions of the walls providing for this are indicated at 46 and 47, and their divergence from the standpoint of the cross-sectional area may be provided primarily by one or the other or jointly by both. It may be noted that the particular axial sections presented are of no significance so long as curvatures are sufficiently gradual to produce smooth flow conditions. The variations of orthogonal areas are, alone, of significance. In fact the arrangement need not by symmetrical about the rotor axis and, depending upon external configuration desired, the diffuser may be in the form of a generally radially extending annulus about, or approximately about the rotational axis, flow being primarily or at least terminating in a generally radial direction. Vaneless diffusers of this type are well known and the walls may be substantially parallel since the increase in cross-sectional area orthogonal to flow is provided by increase of radius in the flow direction.

If it were not for other considerations, the arrangement just described would be less desirable than that heretofore used in that the minimum pressure point would be substantially beyond the turbine discharge with the pressure at the discharge above this minimum. The effect would then be a greater back pressure on the turbine passages than might otherwise be secured.

But considering the aspects of minimizing the detrimental results of turbulence, the arrangement just described increases the efficiency of the turbine. What occurs appears essentially to be this:

The vectorial flow disturbances now occur in a region in which acceleration of flow is occurring. By reason of this acceleration, the flow pattern is rapidly smoothed out so that at the throat of the diffuser arrangement there is quite smooth flow which has little, if any, tendency to set up turbulence. The vectorial deviations of flow are relatively minor (though if directed into a region of deceleration they will set up turbulence) and of themselves do not create a disturbing situation which is propagated backwardly into the turbine passages.

The suppression of turbulence more than compensates for the fact that the back pressure on the turbine is somewhat higher than it theoretically need be.

Reference may now be made to FIGURE 3 which illustrates the merodional velocities of the gas at various

portions of the turbine. It will be noted that the velocity increases through the nozzle passages as well as through the rotor passages as is conventional in reaction turbines. The velocity of the gas is further accelerated as it passes through the accelerator portion A–B of the diffuser and thereafter decreases as the kinetic energy is recovered as pressure in the divergent portion B–C of the diffuser.

From the foregoing description it will be readily apparent that numerous modifications may be made without departing from the scope of the invention as defined in the following claims.

What is claimed is:

1. In combination with an internal combustion engine delivering pulsating exhaust gas, a turbine having a single inlet chamber and a bladed rotor, means for directing gas from said engine to said inlet chamber, means directing the gas from said inlet chamber to said rotor throughout the circumference thereof to drive the latter with the gases being discharged therefrom at a subsonic velocity, means defining a vaneless and continuous annular discharge passage immediately adjacent the rotor discharge for receiving gas discharged from the rotor directly at said subsonic velocity and having cross-sectional areas orthogonal to flow which progressively decrease to form a convergent section for accelerating the flow of the gases passing through the discharge passage in both angular and axial directions, and means defining a divergent section following said convergent section and having cross-sectional areas orthogonal to the flow which progressively increase to provide diffuser action and deceleration of flow.

2. The combination according to claim 1 wherein said diverging section has a plurality of vanes extending longitudinally from the entrance thereof to reduce spinning of the gases passing therethrough.

References Cited by the Examiner

UNITED STATES PATENTS

2,730,861	1/1956	Buchi	60—13
2,810,545	10/1957	Buchi	253—65 X

FOREIGN PATENTS

724,553	8/1942	Germany.

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