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LOW NOISE GENERATION FAN

Filed June 13, 1968

FIG. 1

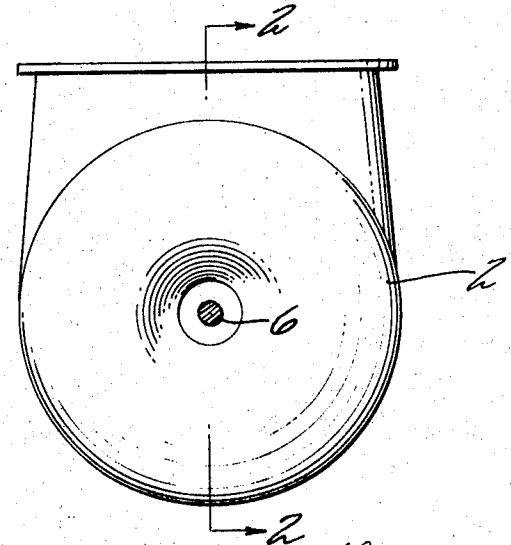
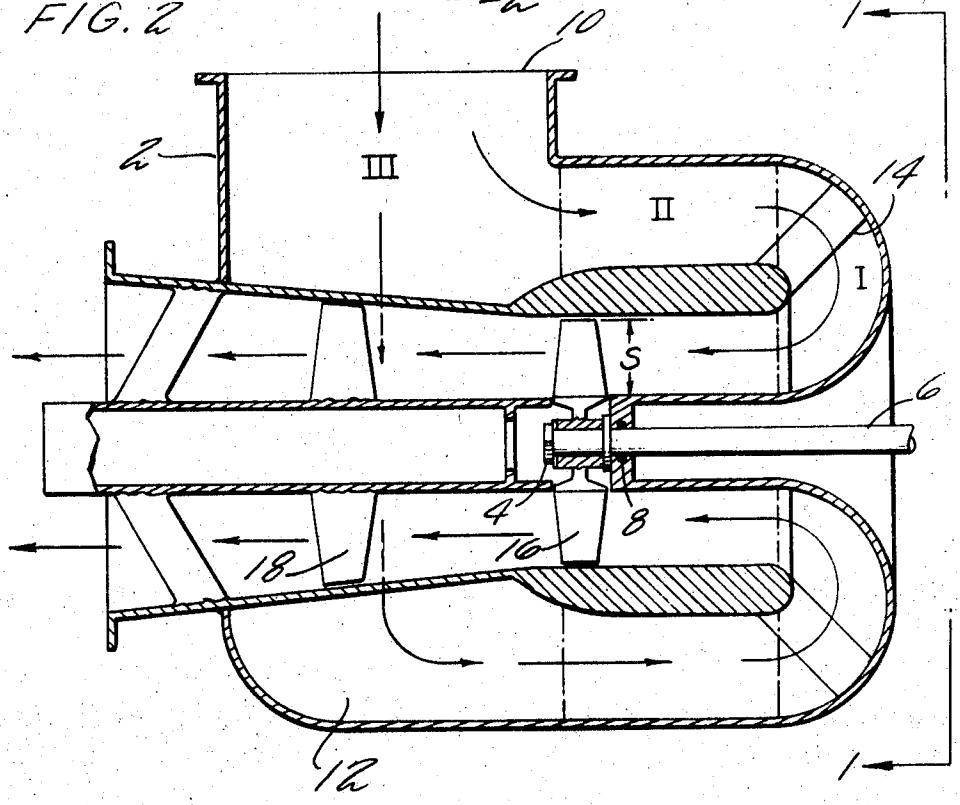


FIG. 2



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LOW NOISE GENERATION FAN

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ABSTRACT OF THE DISCLOSURE

A configuration for attenuating fan noise created by flow disturbances is provided by an inlet passage in the fan housing having an area discontinuity therein.

BACKGROUND OF THE INVENTION

Field of the invention

This invention relates to the attenuation of noise and particularly to the attenuation of fan noise.

Description of the prior art

The nature of axial flow compressor noise is described in U.S. Patent No. 3,194,487 and in an article by S. M. Levin entitled "Aircraft Noise—Can it be Cut?" appearing in Space Aeronautics Magazine, August 1966, pages 65 to 75. These references disclose that in an axial flow compressor, the greater the spacing between the inlet vanes and the rotor, and the greater the spacing between the rotor and the exit vanes, the greater the noise attenuation; this is so because the increased distance between the vanes and the rotating blades allows more dissipation of turbulent upstream wakes before impinging on pressure fields around the downstream blades and vanes. The above-mentioned references also disclose that fan noise generation is also a function of the relative number of blades to vanes. As the above-mentioned references point out, by using a large number of vanes relative to blades the noise generation of a fan can be further reduced. It is also known that area changes in a duct cause discontinuities in the flow path. At the discontinuity, a backward travelling sound wave is generated. The backward travelling sound wave subtracts energy from the forward travelling sound wave and thus reduces the forward travelling sound wave noise level. See Kinsler and Frey, Fundamentals of Acoustics. 2d ed., New York: John Wiley & Sons, Inc., 1962.

In the prior fan art it had not been thought prudent to introduce area discontinuity into the inlet of a fan because of the supposition that the pressure drop through the inlet would increase to such an extent that fan performance would fall below acceptable levels. Therefore, it was thought that the only manner in which to achieve noise attenuation in a fan was to space the rotor a relatively great distance from the inlet guide vanes, to space the exit vanes a relatively great distance from the rotor, and to utilize a large number of vanes as compared to the number of blades on the rotor. However, I have found that the principle of area discontinuity can be adapted to attenuate fan noise by introducing discontinuities into the inlet duct of a fan, thereby considerably reducing the noise generation of the fan, without substantially increasing the pressure drop across the inlet and, therefore, without adversely affecting fan performance.

SUMMARY OF THE INVENTION

The object of the present invention is to provide increased fan noise attenuation without substantially increasing the pressure drop of the fan inlet or adversely affecting fan performance.

In accordance with the present invention, a fan which has greater noise attenuation than those known in the prior art is provided by an inlet duct which has area discontinuity therein, the area of said inlet duct either increasing or decreasing as the flow proceeds downstream towards impingement on the fan blades.

The inlet discontinuity attenuates noise in accordance with the following equation:

Noise transmission loss (attenuation)=

$$10 \log_{10} \left[1+\frac{1}{4}\left(m-\frac{1}{m}\right)^2 \sin^2 kL\right] db.$$

where

m=area change ratio
$k=2\pi/\tau$
τ=wave length of sound
L=distance from one area change to the next

Since the noise field in a fan environment is random, $\sin^2 kL=1$. Therefore, for a fan the equation may be expressed as

$$10 \log_{10} \left[1+\frac{1}{4}\left(m-\frac{1}{m}\right)^2\right] db.$$

The area changes may be either gradual or step changes although it is believed that step changes may degrade fan performance somewhat more than gradual changes. Advantages will be realized using my invention with one area change in the fan inlet although it may be desirable to utilize more than one area change (discontinuity) to achieve the desired amount of noise attenuation. On the other hand too many area discontinuities may degrade fan performance. Therefore, in practice the optimum number of discontinuities will depend upon the particular fan, whether of the high efficiency type, etc., and the sizes of the areas and changes thereof will be determined in a trade-off with the desired fan performance.

The foregoing and other objects, features and advantages of the present invention will become more apparent in light of the following detailed description of a preferred embodiment thereof as illustrated in the accompanying drawings.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a front elevation view of a fan.

FIG. 2 is a sectional view taken along line 2—2 of FIG. 1 schematically showing a fan having an inlet with discontinuities therein in accordance with the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIG. 2, there is shown a preferred embodiment of my invention. A fan housing **2** surrounds a fan rotor **4** which is disposed on a shaft **6** rotatably mounted in bearing **8**. The shaft is driven by motor means (not shown). A radial inlet **10** is provided for bringing the gas into the fan. Gas enters the radial inlet **10** and then flows into an annular chamber **12** and thence to the rotor **4** in a direction indicated by the arrows. Inlet guide vanes **14** are disposed upstream of the fan rotor **4** to straighten the flow of gas prior to its impinging on the fan blades **16**. The inlet guide vanes **14** are preferably spaced from the rotor a distance S equal to or greater than the height of the rotor blades. Likewise, exit vanes **18** are disposed downstream of the rotor **4** a distance of at least S therefrom. The above-described spacing allows the harmonics of blade passage frequency to decay in the duct both upstream and downstream of the rotor blades. As mentioned previously, it is desirable to utilize a large number of rotor blades, and I have found that the optimum

number of vanes to blades is determined by the following equation:

$$V=2nB+1$$

where

V=the number of inlet guide vanes and the number of exit vanes;
B=the number of rotor blades; and
n=harmonic order=1, 2, 3 . . . ∞.

It has been found that a configuration in accordance with the above equation gives the greatest decay of the harmonics of blade passage frequency.

My invention comprises area discontinuity in the fan inlet in combination with the above-mentioned noise attenuation features. For purposes of this description of the best mode of carrying out my invention two inlet area changes are shown. Or in other words, there are three separate inlet regions in the fan inlet upstream of the rotor 4. At each area discontinuity (i.e., between regions I and II and between regions II and III) a backward travelling sound wave is generated. The fractional portion of forward wave energy distributed to generate the backward travelling wave results in an energy loss, and, therefore, a decibel reduction in the continuing forward wave.

While I have shown three distinct area regions, it will be obvious to one skilled in the art that one area discontinuity will achieve noise attenuation. Furthermore, while the area change in the fan inlet duct has been shown as decreasing from the inlet to the fan rotor, it is obvious that my invention will also work successfully when the area change in the fan inlet duct increases from the inlet to the fan rotor. Therefore, it should be understood that various changes and omissions in the form and detail of the preferred embodiment my be made therein without departing from the spirit and scope of the invention which is to be limited only as set forth in the following claims:

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A configuration for attenuating fan noise created by flow disturbances caused by fan vanes and fan rotor blades comprising a fan housing having an inlet passage with inlet guide vanes disposed therein, a fan rotor disposed downstream of the inlet guide vanes and spaced therefrom a distance of at least the height of the fan rotor blade, and exit vanes disposed downstream of the fan rotor and spaced therefrom a distance of at least the height of the fan rotor blade, and said inlet passage in the housing having an area discontinuity therein.

2. A configuration for attenuating fan noise as recited in claim 1, wherein said inlet passage area discontinuity is such that the area of said inlet passage decreases from the inlet of the inlet passage towards the fan rotor.

3. A configuration for attenuating fan noise as recited in claim 1, wherein said inlet passage area discontinuity is such that the area of said inlet passage increases from the inlet of the inlet passage towards the fan rotor.

4. A configuration for attenuating fan noise as recited in claim 1, wherein said inlet passage area discontinuity is a step change in area.

5. A configuration for attenuating fan noise as recited in claim 1, wherein said inlet passage area discontinuity is a gradual change in area.

6. A configuration for attenuating fan noise created by flow disturbances caused by fan vanes and fan rotor blades comprising a fan housing having an inlet passage with inlet guide vanes disposed therein, a fan rotor disposed downstream of inlet guide vanes and spaced therefrom a distance of at least the height of the fan rotor blade, and exit vanes disposed downstream of the fan rotor and spaced therefrom a distance of at least the height of the fan rotor blade, and wherein the relationship of the number of inlet guide vanes and exit vanes to the number of fan rotor blades satisfies the equation

$$V=2nB+1$$

where

V=the number of inlet guide vanes and exit vanes,
B=the number of fan rotor blades, and
n=harmonic order=1, 2, 3 . . . ∞, and said inlet passage in the housing having an area discontinuity therein for the attenuation of fan noise according to the equation.

$$10\log_{10}\left[1+\frac{1}{4}\left(m-\frac{1}{m}\right)^2\right]$$

where m=the area change ratio within said inlet passage.

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HENRY F. RADUAZO, Primary Examiner

U.S. Cl. X.R.

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