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SEARCH ROOM

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Aug. 25, 1959 E. L. GRINDLE ET AL 2,900,817
VIBRATING REED VIBROMETER
Filed March 2, 1955

FIG_1_

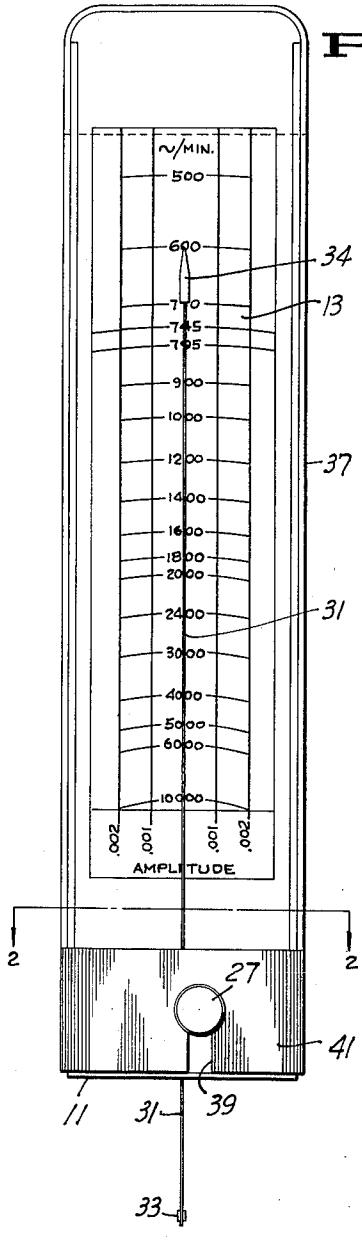



FIG_2_

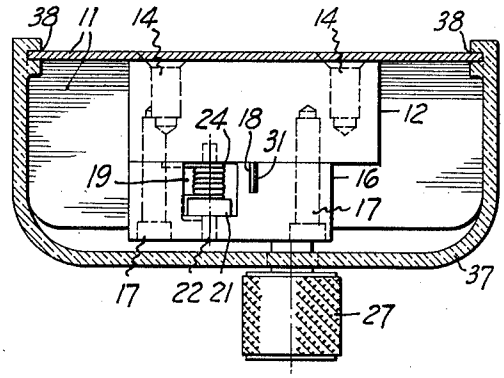
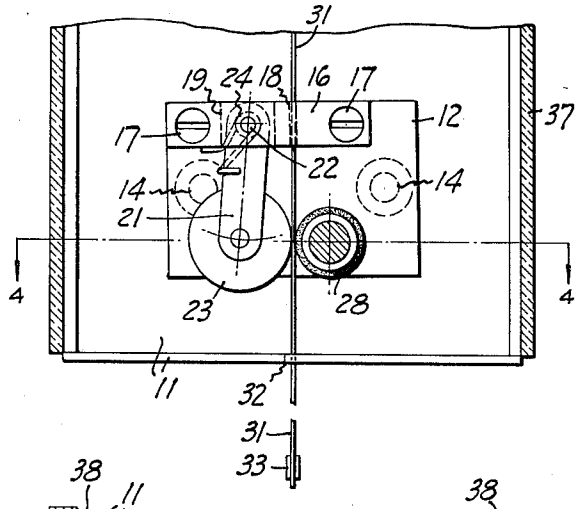



FIG_3_



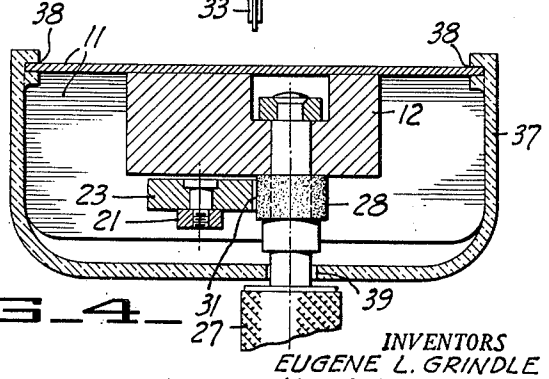




FIG_4_

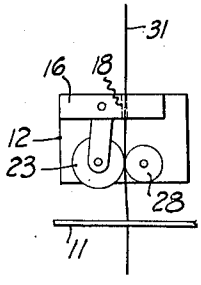



FIG_5_

INVENTORS
EUGENE L. GRINDLE
JAMES L. SAVAGE
BY
Fleher and Swain
ATTORNEYS

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# VIBRATING REED VIBROMETER

Eugene L. Grindle, San Mateo, and James L. Savage, Redwood City, Calif., assignors to Deterjet Corporation, San Mateo, Calif., a corporation of California

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4 Claims. (Cl. 73—70.2)

This invention relates to vibrometers and particularly to vibrometers of the vibrating reed type. The invention further relates to apparatus for detecting excessive propeller vibration and apparatus for phasing propellers of multi-engine aircraft.

Conventional vibrometers have been found to be expensive and not suited for particular applications such as used in aircraft. In general, it is an object of the present invention to provide a new and improved vibrometer which is particularly suited for such use.

Another object of the invention is to provide a vibrometer of the above character in which a solid metal-to-metal contact is provided at the fulcrum point of the vibrating reed.

A further object of the invention is to provide a new and improved vibrometer of the above character in which the vibrating reed is continually urged in one direction at the fulcrum point.

A further object of the invention is to provide a new and improved vibrometer of the above character with a scale for measuring frequency of vibration and amplitude of vibration.

A further object of the invention is to provide a method for detecting excessive propeller vibration with a vibrometer.

A further object of the invention is to provide a method for phasing propellers of multi-engine aircraft with a vibrometer.

Additional objects and features of the invention will appear from the following description in which the preferred embodiment has been set forth in detail in conjunction with the accompanying drawing.

Referring to the drawing:

Figure 1 is an elevational view of a vibrometer incorporating the present invention;

Figure 2 is an enlarged cross-sectional view taken along the line 2—2 of Figure 1;

Figure 3 is a partial enlarged elevational view of our vibrometer with the cover removed;

Figure 4 is a cross-sectional view taken along the line 4—4 of Figure 3; and

Figure 5 is a view similar to Figure 3 with misalignment of the reed exaggerated.

The embodiment of our device as shown in the drawing consists of an L-shaped mounting plate **11** which forms a support for mounting block **12** and graduated scale **13**. Mounting block **12** may be secured to plate **11** by any suitable means such as screws **14**.

A fulcrum block **16** is attached to the upper portion of mounting block **12** as by screws **17** and is provided with an elongate slot **18** and a U-shaped slot **19**. One end of the depending arm **21** extends into slot **19** and is pivotally carried by a pin **22** that extends between the fulcrum block **16** and the mounting block **12**. A roller **23** is rotatably mounted on the other end of depending arm **21**. The lower end of the arm **21** and the roller **23** are continuously urged to the right as viewed in Figure 3



by a spring **24** that is mounted on rod **22** for a purpose hereinafter described.

A thumb screw **27** is rotatably mounted in block **12** adjacent roller **23** and is provided with a rubber roller **28**. A vibrating reed **31** is frictionally carried between rollers **23** and **28** and passes through elongate slot **18** in fulcrum block **16** and through a slot **32** in the lower portion of L-shaped mounting plate **11**. Slots **18** and **32** are aligned vertically but thumb screw **27** and roller **28** have been offset slightly to the left (exaggerated in Figure 5) as viewed in Figure 3. This causes bending of reed **31** about roller **28** and urges the reed against the lower left side of slot **18** and the upper right side of slot **18** as viewed in Figure 3. Bending of the reed causes the portion of the reed above block **16** to be swung to the right as viewed in Figure 3 from the vertical centerline formed by slots **18** and **32**. This is overcome by shifting block **12** slightly counterclockwise as viewed in Figure 3 until the upper portion of reed **31** rests on the aforementioned vertical centerline. The force exerted by the roller **28** on the reed **31** is greater than the greatest force introduced into the reed by vibration of the reed and hence the reed will always remain in engagement with the upper right side of the slot **18**.

Spring **24** and roller **23** increase the friction between roller **28** and reed **31** and assure positive slip-free adjustment of the reed length without damping vibrations.

A stop **33** has been placed on the bottom portion of reed **31** and is slightly larger than slot **32** to thereby prevent drawing that end of the reed through the same. The other end of the reed has been provided with a tip **34** as a visual aid to facilitate the reading of scale **13** and which also serves as a stop to prevent that end of the reed from being drawn through slot **18**.

The scale **13** has been calibrated vertically in cycles per minute and horizontally in amplitude of vibration in thousands of an inch double amplitude of vibration.

A cover **37** has been provided to protect the working parts. It may be of any suitable transparent material such as plastic and is provided with a pair of grooves **38** which are adapted to engage the side edges of the L-shaped mounting plate **11**. The lower portion of cover **37** is provided with a slot **39** to allow cover **37** to accommodate thumb screw **27**. The lower portion **41** of the cover may be coated with suitable opaque material to conceal the mechanism for varying the length of the reed.

The operation of the device may now be briefly described as follows: Assuming that it is desired to obtain the vibration frequency and amplitude of vibration of a piece of equipment, particularly where rotating elements are being used such as in an airplane, the base of the vibrometer is placed on a rigid portion of the apparatus that is not shock mounted. The vibrator is then tuned by extending or retracting the free end of the reed by rotating thumb screw **27** until the reed vibrates at maximum amplitude. As is well known to those skilled in the art, the natural frequency of vibration of the reed is dependent on its length. Therefore, with a proper scale, the vibration frequency of the reed may be read directly upon the scale at the free tip of the reed. For example, as shown in Figure 1, if the reed is vibrating at maximum amplitude at the length shown, it is vibrating at the frequency of 600 cycles per minute.

After the frequency of vibration has been ascertained, the amplitude of vibration may be determined from the vertical lines on the scale **13**.

In measuring low frequencies, the reed occasionally may be excited by some frequency higher than that corresponding to the reed length. When this happens, a node will appear between the fulcrum and the free end of the reed. To obtain a true reading, the reed should be

shortened until the end vibrates freely with a maximum amplitude free of nodes.

It is apparent that our device is suitable for obtaining the frequency of vibration and the amplitude of vibration of various types of equipment, particularly those utilizing rotating parts. The mechanism we have shown for advancing and retracting the reed adds to the accuracy of our device. As shown in Figure 3, the reed **31** passes through the slot **18** and is continuously urged against the upper right side of the slot as viewed in Figure 3 to provide a metal-to-metal contact for the fulcrum point of the reed. This mechanism serves to maintain the fulcrum point of the reed at one particular point regardless of the length of the reed extending above the fulcrum block **16**.

We have also provided a scale in which the frequency of vibration and amplitude of vibration can be read at the same time.

Our device is particularly suitable for use in a method for detecting excessive propeller vibration. It is well known that rotating components on an airplane will vibrate at frequencies in relation to their basic rotating frequencies. An engine turning at 2,000 r.p.m. may vibrate once per revolution, in which case the source of vibration would probably be the crank shaft. It may vibrate once every two revolutions, in which case the the source of vibration would probably be a cylinder. A propeller will usually vibrate once per propeller revolution or a portion of the crank shaft speed directly dependent upon the gear reduction ratio. However, it is common to find vibration frequencies at propeller speed times the number of blades. This is caused by air "slugs" from each blade. The source of vibration can be isolated by the method hereinafter set forth by identifying the vibration frequency with a rotating component of a directly related frequency.

The vibrometer is mounted on any suitable portion of the aircraft which is not shock mounted and preferably in the cockpit within easy reach of a crew member. The reed of the vibrometer is then tuned until it vibrates at the maximum amplitude. If the amplitude of vibration or deflection exceeds a predetermined value such as two thousandths of an inch double amplitude, corrective action may be required on the aircraft. The vibration frequency is then identified with the speed of some aircraft component frequency by multiplying the engine speed by one of the following:

(*a*) Crankshaft ..... 1.00
(*b*) Power impulses or cylinder reciprocations ..... .50
(*c*) Propeller—by the gear reduction relation between crankshaft and propeller, e.g. ..... .375

As soon as the aircraft frequency component has been determined, the particular engine that is causing the trouble is isolated by advancing the r.p.m. on one engine at a time while holding the others at the vibrating frequency. When the increase in speed of a particular engine results in a noticeable reduced amplitude, that engine is at fault.

Our vibrometer has also been found to be particularly useful in a method that we have devised for phasing propellers of multi-engine aircraft for minimum vibration. It is well known that on multi-engine aircraft it is desirable to adjust all engines to the same speed after the cruising altitude has been assumed. When two or more propellers are operating at different speeds, vibration and throbbing noises may be set up. Various types of engine synchronizers have been developed by which the pilot, by operating the propeller controls, causes the propellers to rotate at exactly the same speed. However, it has been found that although the propellers are rotating in synchronism, considerable vibration may still be imparted to the plane.

By our method, it is possible to reduce the vibration level in the plane to an almost imperceptible minimum.



We do not, however, eliminate the actual vibration of any particular propeller, but only the additive effects of all the propellers transmitted to the fuselage.

The method consists of positioning the blades of each propeller in relation to the other propellers so that the unbalanced effect of one propeller is opposed or cancelled by the unbalanced effect of the other propellers. Modern multi-engine aircraft are provided with switch means including a propeller synchronization selector switch to cause operation of the automatic synchronizing means to bring the propellers into synchronization or to allow manual synchronization.

Assuming that cruising power has been established and that the propellers have been synchronized by the automatic synchronizing means hereinbefore described, the vibrometer is tuned to maximum amplitude at propeller frequency. The propeller synchronization selector switch is placed in manual. The number 2 propeller toggle switch is actuated in one direction and then the other direction to obtain a very slow rotation of number 2 propeller in relation to the other propellers. The propeller toggle switch serves to vary the pitch of the propeller and hence the propeller speed at a particular power input.

As the number 2 propeller is rotated through 360° with respect to the other propellers, the vibrometer reed will begin to increase or decrease in amplitude. When the vibrometer reed has reached a minimum amplitude, the synchronization selector switch is moved to the automatic or synchronized position. The number 2 propeller will now be locked in a new relationship with the other three propellers.

The same procedure is then followed with the other propellers until the propellers are phased to give minimum propeller vibration to the aircraft.

From the foregoing, it is apparent that we have provided a new and novel method for detecting excessive propeller vibration and for phasing propellers of multi-engine aircraft for a minimum vibration. In addition, we have provided a vibrometer which is particularly suited for use in these methods.

We claim:

1. In a vibrometer of the vibrating reed type, a mounting formed with a pair of aligned slots therein, a reed slidably mounted in said slots, and roller means frictionally engaging a portion of the reed between the slots, the roller means being so positioned that the point of contact between the reed and the roller means is out of alignment with said slots to cause said reed to be urged against one side of said slot to provide a fulcrum for said reed.

2. A vibrometer as in claim 1 together with means for increasing the friction between said roller means and said reed, said means including a roller engaging the reed on the side opposite the side engaged by the roller means.

3. A vibrometer as in claim 2 together with means provided at each end of said reed to prevent the ends of said reed from passing through said slots.

4. A vibrometer as in claim 2 together with a scale connected to said mounting block adjacent the free end of said reed, the scale being calibrated in frequency of vibration and amplitude of vibration to permit simultaneous reading of frequency of vibration and amplitude of vibration.

**References Cited** in the file of this patent

UNITED STATES PATENTS

| | | |
|---|---|---|
| 2,306,391 | Keinath | Dec. 29, 1942 |
| 2,352,219 | Olesen | June 27, 1944 |
| 2,361,990 | Brown | Nov. 7, 1944 |
| 2,428,671 | Kent et al. | Oct. 7, 1947 |
| 2,496,295 | Langer | Feb. 7, 1950 |
| 2,511,694 | Burkhardt | June 13, 1950 |
| 2,514,153 | Dickerson | July 4, 1950 |
| 2,604,781 | Bechtold et al. | July 29, 1952 |
| 2,711,647 | Ongaro et al. | June 28, 1955 |