April 26, 1960 — E. P. WARNKEN — 2,934,317

PRESTRESSED COMPRESSOR BLADE

Filed May 5, 1954 — 2 Sheets-Sheet 1

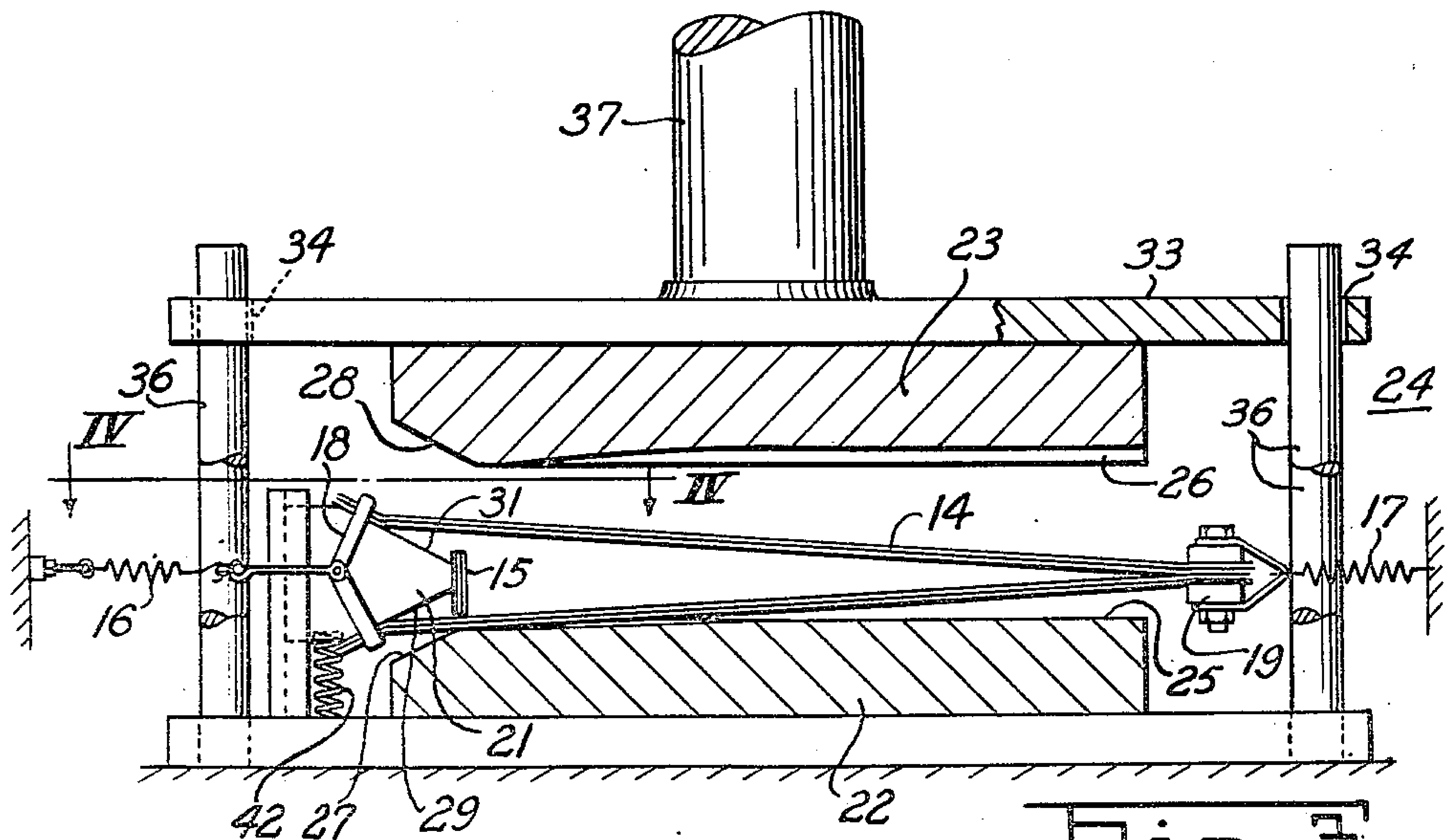

Fig. 3.

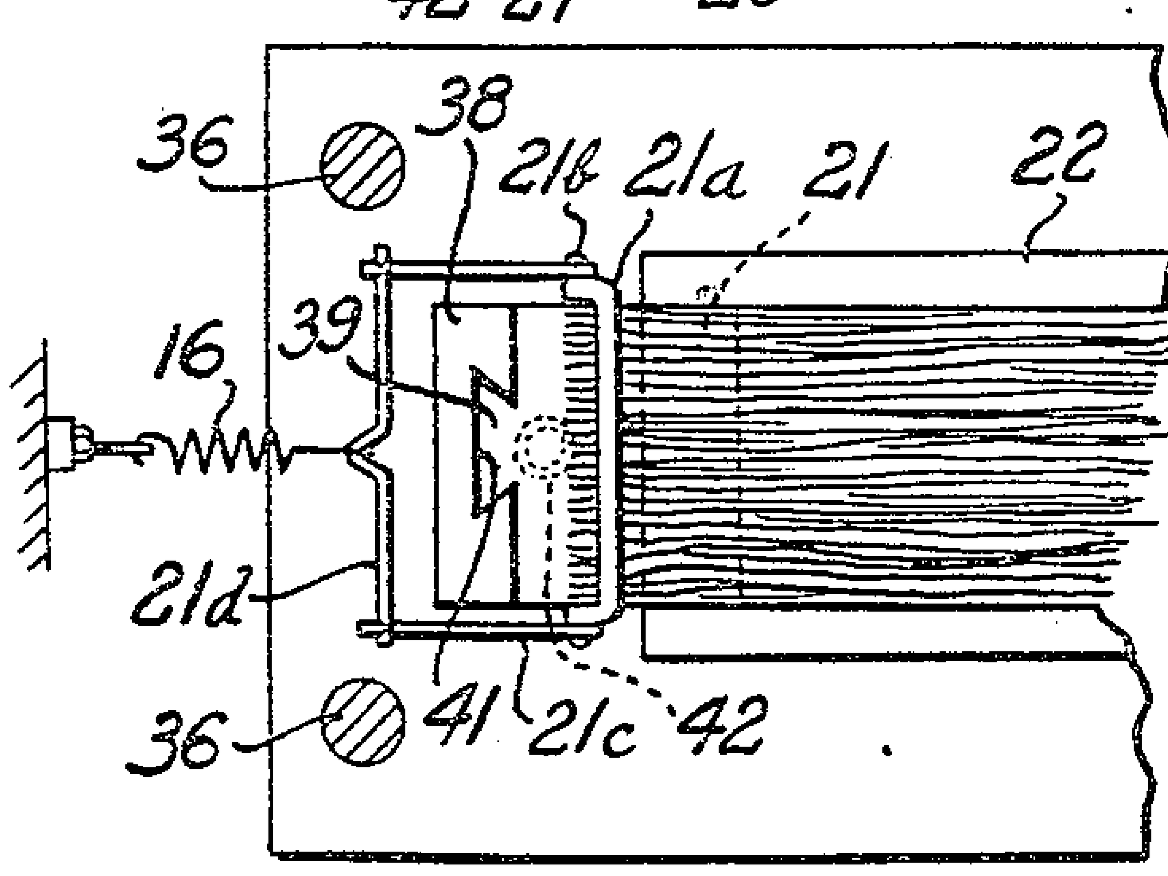

Fig. 4.

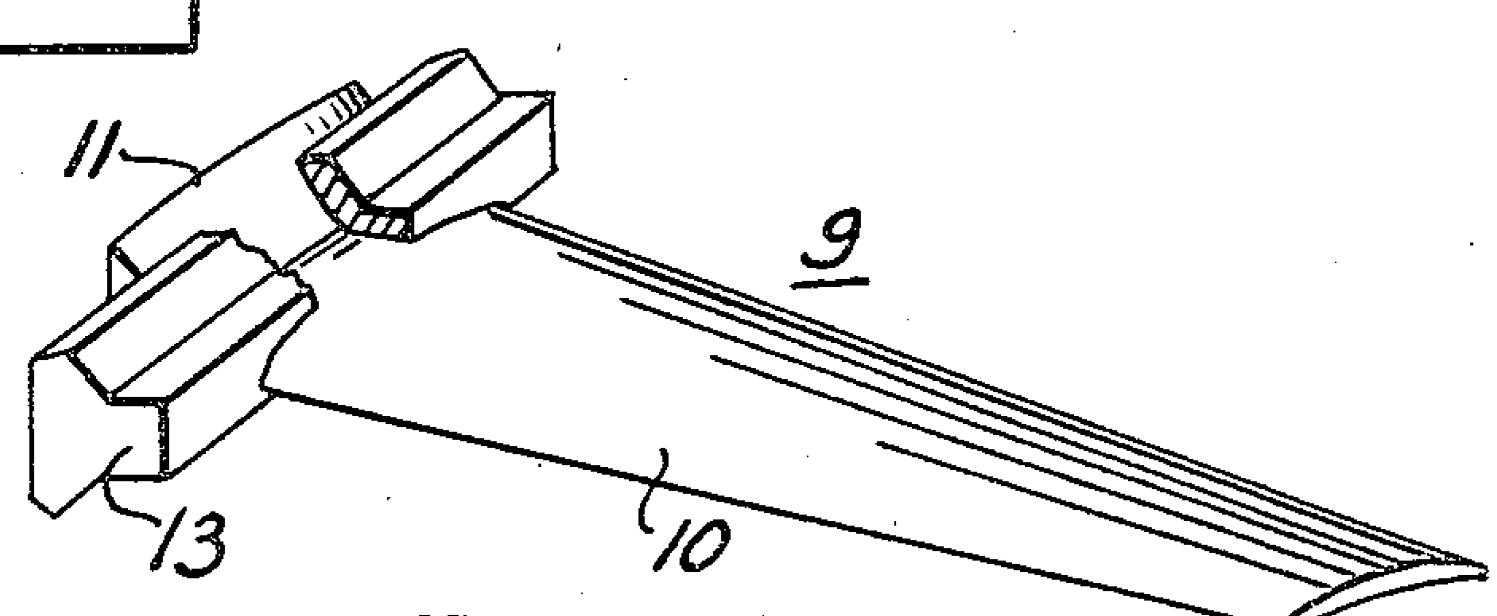

Fig. 1.

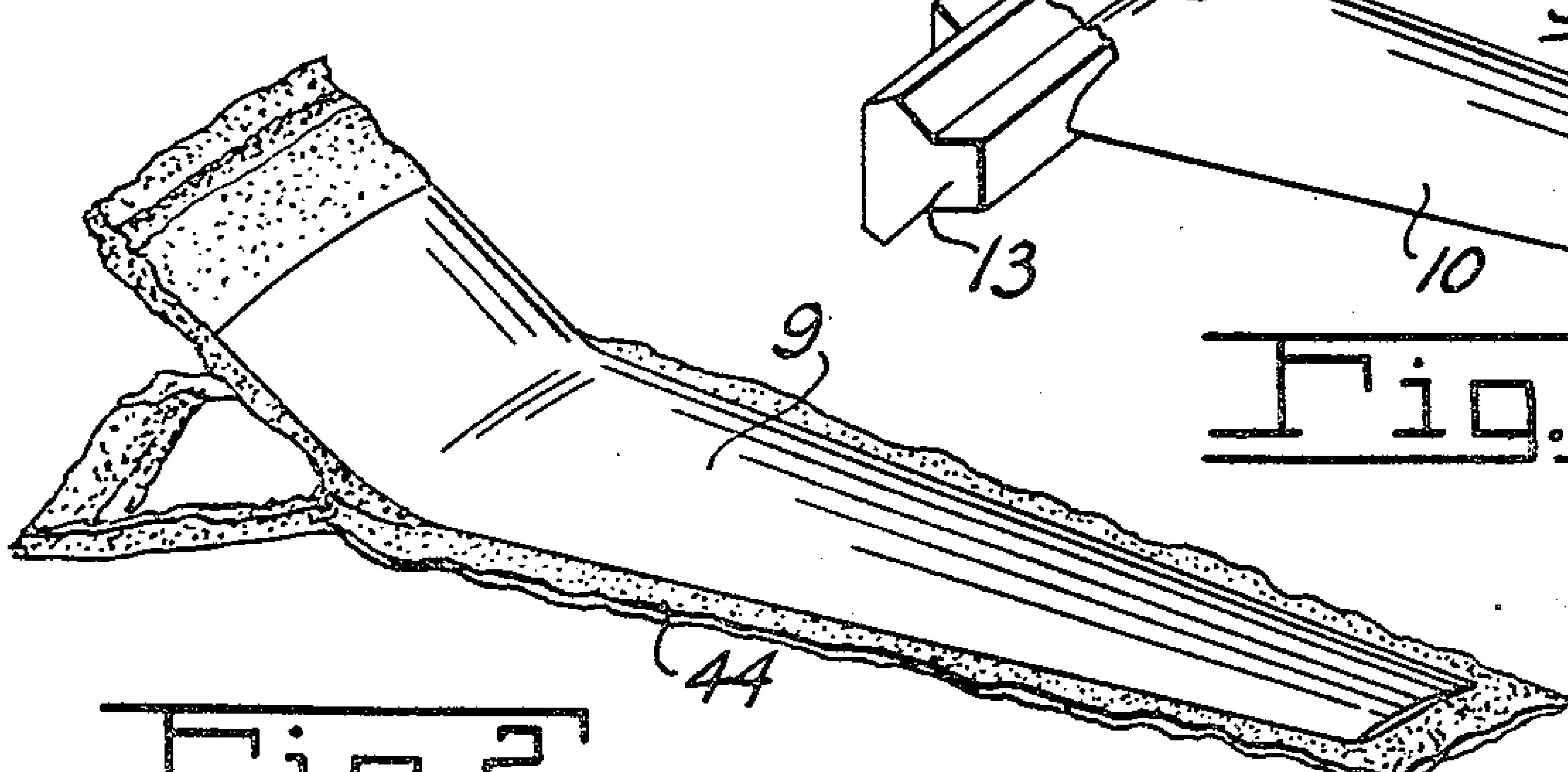

Fig. 2.

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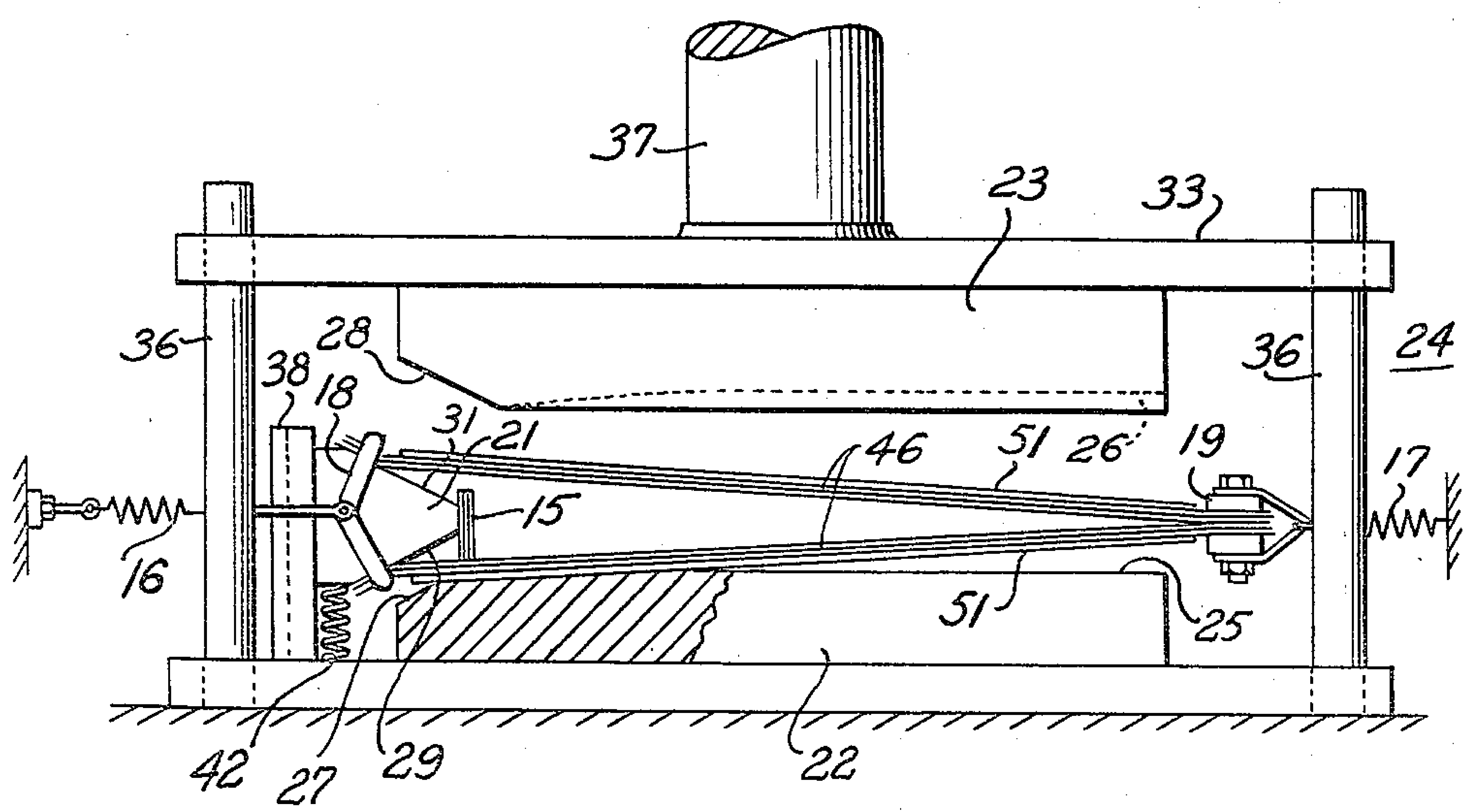

Fig. 5.

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PRESTRESSED COMPRESSOR BLADE

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Application May 5, 1954, Serial No. 427,739

5 Claims. (Cl. 253—77)

This invention relates to turbine compressor blades. The blades of this invention represent an improvement over the blades shown in my co-pending application, Serial Number 314,698 filed October 14, 1952.

An object of this invention is to provide a prestressed resin-impregnated laminated rotor blade having a main molded impeller or vane portion and a thickened portion at one end thereof by means of which the blade may be mounted in place on the rotor of an air compressor or the like.

A further object of this invention is to provide a blade having laminations extending lengthwise of the blade, which laminations are prestressed in tension to a sufficient degree to stress the resin of the blade in compression after molding is completed and the prestress is released, so that, when the blade is in use in a compressor the resin is maintained in compression.

A further object of this invention is to provide a blade having laminations which extend lengthwise thereof, the laminations being divided at one end of the blade into a V-shape to provide for thickening of that end of the blade.

The above and other objects and features of the invention will in part be apparent and will in part be obvious to those having ordinary skill in the art to which the invention pertains, from the following detailed description, and the drawing, in which:

Figure 1 is a perspective view showing a compressor blade constructed in accordance with an embodiment of this invention with a root-holding member being shown mounted on the blade, a portion of the root-holding member being broken away for clarity;

Fig. 2 is a perspective view of the blade in the form assumed when removed from a mold and before excess material and flash are trimmed therefrom;

Fig. 3 is a view partly in side elevation and partly in section, showing a machine for molding the blade, laminations being shown in place and prestressed prior to the molding of the laminations;

Fig. 4 is a view in section taken along line IV—IV in Fig. 3; and

Fig. 5 is a fragmentary view partly in side elevation and partly in section showing the molding machine with another set of laminations in place with part of the laminations being prestressed.

In Figure 1 of the drawing, a rotor blade **9** for an axial flow air compressor is shown. Blade **9** includes an impeller section **10** and a thickened end or root portion **11** on which is mounted a member **13** by means of which the blade may be mounted on and secured to the rotor of the air compressor.

The impeller section **10** and the root portion **11** are formed from a plurality of superimposed layers of glass fabric or glass fibre rovings **14** (see Fig. 3), or the like, which are impregnated with a thermosetting resin. At the root end of the blade, the layers are separated by a cross piece **15** composed of a plurality of superimposed

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layers of glass fabric impregnated with the same thermosetting resin as layers **14**.

Elongated layers **14** are held in a prestressed or tensioned condition by tension springs **16** and **17** and by suitable clamps **18** and **19** attached to the springs. As shown in Fig. 3, the clamp **19** grips the right hand ends of the layers **14**. The left hand ends of the layers **14** extend along the sides of a floating die member **21** and are clamped against the sides of the die member **21** by the clamp **18**. As shown in Figs. 3 and 4, the clamp **18** includes two U-shaped members **21*a*** hinged together by pivots **21*b***. Links **21*c*** connect the pivots **21*b*** to a cross member **21*d*** to which one end of spring **16** is attached so that the spring causes the U-shaped members **21*a*** to firmly grip the left hand ends of the elongated layers **14**.

The elongated layers or laminations **14** and the cross piece **15** are molded between dies **22** and **23** of a molding machine indicated generally at **24** in Fig. 3. The lower die **22** is stationary while the upper die **23** is movable. The dies **22** and **23** have co-operating opposed molding faces **25** and **26** which mold the impeller section of the blade to an airfoil configuration. As shown, the left hand ends of the dies **22** and **23** terminate in diverging faces **27** and **28** which are opposed to and co-operate with faces **29** and **31** of the floating die member **21**.

The upper die **23** is mounted on a plate or platen **33** having openings **34** in the corners thereof. The openings **34** receive pins **36** which guide the upper die. The upper die and the platen **33** are mounted on an hydraulic plunger **37**, and the plunger **37** may be urged downwardly by any appropriate mechanism, not shown, to bring the upper die toward the lower die.

The floating die member **21** is mounted to move up and down along a post **38** which guides the floating die. The post **38** and the floating die **21** are connected together by a dove tail **39** and a dove tail slot **41**, as shown in Fig. 4, so that the floating member can move up and down along the post. A compression spring **42** (Fig. 3) normally holds the floating die member spaced above the stationary die **21** when not in use.

Before the mold is closed, the tension of the springs is so adjusted as to provide a tensile load on the fibres of the blade, such that, when the blade is completed and in use, the centrifugal load will not sufficiently dissipate the prestress compression to cause failure of the resin of the blade by exceeding its tensile strength. The prestress compression preferably is so adjusted that the centrifugal load is less than the initial tension imposed on the fibres. Therefore, the resin of the blade will be held in compression during use. For a blade four (4) inches long and having a cross-sectional area of one-quarter (¼) of a square inch for use in a rotor having a tip diameter of thirty-five (35) inches and a rotational rate of eight thousand (8,000) r.p.m., the prestress tensile load may be approximately one thousand fifty (1050) pounds.

When the blade is removed from the molding machine of Fig. 3, it is in the condition indicated in Fig. 2 in which condition it includes an edging of excess material or flash **44** extending outwardly from the blade **9**. This flash is trimmed off to form the finished blade of Fig. 1.

In Fig. 5, the molding machine **24** is shown with elongated prestressed core laminations **46**, which are held by the clamps **18** and **19**, and facing laminations **51** on the upper and lower sides of the prestressed laminations. The facing laminations are preferably resin-impregnated glass fabric laminations, while the core laminations may be resin-impregnated fabric or resin-impregnated rovings of glass fibers. The facing laminations terminate short of the clamp so that, when the laminations are molded into a blade, the facing laminations are not prestressed. When the blade formed from the laminations shown in

Fig. 5 is completed and removed from the molding machine, the prestress is released, and the facing laminations are stressed and maintained in compression, and the resin of the blade is also stressed in compression.

The blades described above and illustrated in the drawing are subject to structural modification without departing from the spirit and scope of the appendec claims.

Having described my invention, what I claim as new and desire to secure by Letters Patent, is:

1. A rotary blade of airfoil configuration which comprises a plurality of elongated laminations of glass fibre material arranged one on top of the other in flatwise relation, said laminations including a multitude of glass fibres extending lengthwise of the blade, said laminations being resin-impregnated and stressed in tension lengthwise of the blade, and surface laminations of resin-impregnated glass fibre material on opposite faces of the tensioned laminations, the laminations being molded to airfoil shape, the resin and the surface laminations being stressed in compression.

2. A rotary blade of airfoil configuration which comprises a plurality of elongated substantially flat laminations of glass fibre material arranged one on top of the other, said laminations including a multitude of glass fibres extending lengthwise of the blade, said laminations being resin-impregnated and stressed in tension lengthwise of the blade, surface laminations of glass fibre material on opposite faces of the tensioned laminations, the laminations being molded to airfoil shape, the resin and the surface laminations being stressed in compression, the laminations being divided into two portions adjacent one end of the blade, said portions diverging at an acute angle, and a resin-impregnated cross piece disposed between said diverging portions, whereby said end of the blade is substantially thicker than the remainder of the blade.

3. A blade in accordance with claim 2, characterized by the fact that the prestress load of the tensioned laminations is at least equal to the load in the blade when rotated at speeds encountered in use, whereby the resin and facing laminations are stressed in compression during use.

4. A method of forming an airfoil blade which comprises stressing in tension a pair of elongated resin-impregnated laminations lengthwise thereof with said laminations having adjacent end portions and diverging end portions, placing a resin-impregnated cross-piece between the diverging end portions, molding the elongated laminations between dies to airfoil shape while stressed in tension, and molding the diverging end portions to blade root shape.

5. A method of forming an airfoil blade which comprises stressing in tension a pair of elongated resin-impregnated laminations lengthwise thereof with said laminations having adjacent end portions and diverging end portions, disposing slack elongated resin-impregnated surface laminations on opposite outer faces of the tensioned laminations, placing a resin-impregnated cross-piece between the diverging end portions, molding the elongated laminations between dies to airfoil shape while the tensioned laminations are stressed in tension, and molding the diverging end portions to blade root shape.

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