

PATENT SPECIFICATION

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(54) VARIABLE CAPACITOR

(71) We, N.V. PHILIPS' GLOEILAMPEN-FABRIEKEN, a limited liability Company, organised and established under the laws of the Kingdom of the Netherlands, of 5 Emmasingel 29, Eindhoven, the Netherlands, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in 10 and by the following statement:—

The invention relates to a variable capacitor, comprising a stator and a rotor which are clamped and arranged, respectively, between an upper plate and a lower plate each 15 of a synthetic material suitable for ultrasonic welding, the upper plate and the lower plate being maintained parallel at a fixed distance from each other by spacer columns, pair of which are coaxially situated relative 20 to each other and extend transversely of the plane of the plates, each spacer column of a pair being formed to be integral with a respective one of the plates, one column in each of at least two of the pairs spacer 25 columns having an at least partly tubular construction for connection of the upper plate to the lower plate.

In a capacitor of the described kind, which is known from British Patent Specification 1,132,552, all spacer columns between the upper plate and the lower plate 30 are tubular columns wherethrough draw bolts are inserted which are screwed into a separate metal supporting plate situated below the lower plate. The threaded holes in the supporting plate required for screwing 35 down the bolts must be exactly situated relative to each other, whilst the fixing bolts themselves should also be extremely accurately manufactured. The draw bolts 40 (four in the most commonly used construction) as well as the additional commonly used construction as well as the additional supporting plate give rise to a 45 comparatively expensive construction which

can be manufactured in bulk only by highly specialized skilled workers.

It is to be noted that from German Patent Application 1,439,581 laid open to public inspection a variable capacitor is known in 50 which a spacer column of hot formable synthetic material is connected to a stator plate by hot upsetting. The spacer column is also connected, in a manner not shown, to a lower plate of synthetic material. A 55 capacitor of this kind has a drawback in that the hot upsetting of the column causes a collar to be formed around the column, said collar being elastically or plastically readily deformable by the stator stack of the 60 capacitor which is subject to a compression load. Consequently, said collar starts to bend, so that the press-on force between the stator plates is no longer sufficient to ensure suitable electrical contact. 65

Finally, it is to be noted that from British Patent Specification 1,225,628 a connection is known between a hollow rod of synthetic material and a plate of synthetic material which extends transversely thereof. The 70 connection is realized by ultrasonic deformation of an end of the rod which projects through a hole in the plate by means of sonotrodes of different shape. When use is made of this method of ultrasonic connection, the hollow rod of synthetic material 75 is subjected to compression forces which may cause kinking when used in variable capacitors.

It is the object of the invention to provide 80 for a capacitor which is cheap in mass manufacture and wherein a sufficient press-on force between the stator plates is ensured. Accordingly, the invention is characterized in that, for said at least two 85 pairs, a spacer of column integral with one of the plates is inserted with clearance into the tubular part its associated spacer column integral with the other plate, an ultrasonic welded joint being present between the inner 90

surface of the tubular column and the outer surface of the other column inserted therein, said joint being so made and being situated at such a distance from the end of the tubular column remote from its associated plate that part of the tubular column is subject to a compression force, whilst a part of the other column projecting into the tubular column is subject to a tensile force.

10 An embodiment of the invention will now be described in detail with reference to the accompanying drawings, of which:—

Fig. 1 is a side elevation of a preferred embodiment of a capacitor in accordance with the invention.

Fig. 2 is a bottom view of the capacitor shown in Fig. 1.

Fig. 3 is a cross-sectional view of a first pair of spacer columns of a capacitor as shown in any of the other Figures,

Fig. 4 is a cross-sectional view of a second pair of spacer column of a capacitor as shown in any of the other Figures, and

Figure 5 is a detailed view of the area where the ultrasonic connection between the upper plate and a spacer column is formed.

The capacitor shown in Fig. 1 is a capacitor of the so-termed multiple type, comprising a number of stator stacks 1, 3 and 5, and a number of rotor stacks 7, 9 and 11. Each of the stacks 1 and 7, 3 and 9, 5 and 11 forms a variable capacitor. The rotor stacks 7, 9, and 11 are secured on a rotor shaft 13 which is journaled near one end in an upper plate 15, whilst it is journaled in a lower plate 17 near its other end. The rotor stacks 7, 9 and 11 are located between two supporting rings 8 and 10 which are located between a nut 12 and a shaft shoulder 14. Upon rotation of the rotor shaft 13, the rotor stacks 7, 9 and 11 are simultaneously rotated relative to the associated stator stacks 1, 3 and 5. The rotor shaft 13 can be rotated by means of a toothed control knob 19 which is provided near the end which is journaled in the lower plate 17. The stator stacks and the rotor stacks may be assembled in the usual manner from metal plates which are maintained at a distance from each other by metal spacer rings, each time a rigidly arranged dielectric foil being present between two rotor and stator plates in a stack which are situated directly opposite each other. The stator and/or rotor plates may alternatively be provided, however, with a dielectric layer such as paraxylene. The loose dielectric foils can then be dispensed with. The stator plates are maintained at a distance from each other by metal space rings. For example, the four stator plates of the stator stack 1 are maintained at a distance from each other by the spacer rings 21, 23 and 25.

65 The upper plate 15 as well as the lower

plate 17 which is parallel thereto comprises four spacer columns which extend transversely of the plane of the plates, only two columns being visible in Fig. 1. Only the columns 27 and 29 of the four spacer columns associated with the upper plate 15 are visible, whilst of the four spacer columns associated with the lower plate 17 only the columns 31 and 33 are visible. The columns 27 and 29 comprise continuous, stepped, circle-cylindrical cavities 35 and 37 and thus a tubular construction. The columns 31 and 33 of the lower plate 17 are solid and project through the tubular columns 27 and 29 by way of an end 39 and 41, respectively. The figures 3, 4 and 5 show a more detailed cross-sectional view of the columns 27 and 31 and the columns 29 and 33, respectively, for the sake of clarity. The stator stacks 3 and 5 are clamped, with insertion of spacer rings, between an end face 43 of the tubular column 27 and a shoulder 45 of the solid column 31. The stator stack 1 is similarly clamped between an end face 47 to the tubular column 29 and a shoulder 49 of the solid column 33. As is clearly shown in Fig. 2 each stator stack is each time clamped between two pairs of spacer columns which are symmetrically situated relative to the centre of the capacitor.

Each of the four tubular columns comprises a comparatively narrow circle-cylindrical portion which has a diameter which is substantially equal to the diameter of the solid columns at the area of the ultrasonic connection to be formed. For example, the tubular columns shown in the Figures 3, 4 and 5 comprises the comparatively narrow portions 51 and 53. The solid columns are preferably constructed to be slightly conical, with an inclination of 1:100. The diameter of the cylindrical solid columns 31 and 33 is chosen so that at the area of the reference numerals 55 and 57 a sliding fit is present or an annular opening having a width of no more than approximately 0.05 mm. The lower plate 17 and the (four) solid columns which are integral therewith are preferably made of the same synthetic material as the upper plate 15. The plates 15 and 17 are preferably injection moulded. For example, the following synthetic materials can be used for the plates 15 and 17:

- polystyrene
- styrene acrylonitrile
- polycarbonate
- acrylonitrile butadiene styrene (ABS)
- polyacetal
- polymethyl-metalacrylate
- polyamides
- polypropylene
- polyvinyl chloride (PVC)
- polyphenylene oxide (PPD)
- polysulphone

Said synthetic materials are preferably filled with fibre glass in order to counteract creepage.

The capacitor shown in Fig. 1 is assembled by arranging the capacitor with the upper plate 15 on an anvil 59 and by subsequently supplying ultrasonic energy for some time to the capacitor frame by means of an ultrasonic welding electrode 61 (sonotrode) which is pressed against the lower plate 17. The sonotrode 61 is coupled to a known ultrasonic welding apparatus. The press-on force of the sonotrode 61 is preferably between 40 and 45 P.S.I. The welding time amounts to approximately 0.07 s and the holding time amounts to 0.2 s for the capacitor shown in Fig. 1. During the welding time of 0.07 s a lateral oscillation occurs in the solid columns 31 and 33 which has an amplitude which is slightly higher than or equal to said 0.05 mm at the areas 55 and 57. Consequently, it is only at the areas 55 and 57 that such high mechanical friction occurs between the solid and the tubular columns that an ultrasonic (annular) connection is formed. Approximately 0.2 s after the welding, the ultrasonic weld has cooled so far that adequate mechanical strength is obtained in the weld to allow removal of the capacitor from the welding equipment. The part of the solid columns of the completed capacitor which is situated above the shoulder 45 and 47 is subject to a tensile force, whilst the tubular columns are subject to a compression force. The compression force in the tubular columns ensures an adequate, permanent press-on force of the stator stacks 1, 3 and 5. Because intimate mechanical contact between the tubular and the solid columns occurs only at the areas 55 and 57 during welding, it is ensured that an ultrasonic connection is formed only at these areas. It is of essential importance that the location of the ultrasonic connection is well-defined in order to ensure that the press-on force of all end faces of the tubular columns on the stator stacks is adequate and equally large. The anvil 59 may be provided with four bores 64, but also with two bores 64 which are arranged diagonally opposite each other. In the former case all four ultrasonic connections are realized in one welding cycle, and it is advisable to arrange the anvil to be tiltable. In the latter case one pair of diagonally oppositely situated ultrasonic connections are realized in each of two welding cycles.

Simultaneously with the stator stacks, external connections 63 and 65 are clamped, said connections being guided in sleeves 67 and 69 injection moulded to the lower plate 17. Supports 71 and 73 are also injection moulded to the lower plate 17, shoulders 75

and 77 of said supports bearing on a printed wiring board. The supports 71 and 73 comprise cylindrical protrusions 79 and 81 which fit in holes of a printed wiring board. The protrusions 79 and 81 prevent movement of the capacitor during soldering and straining of the soldered connections between the connections 63 and 75 and the conductors on a printed wiring board after soldering when the capacitor is jolted. The control knob 19 is accessible through a hole in the printed wiring board and has a length such that the flow pattern in the flow soldering bath is not disturbed during flow soldering.

Finally, it is to be noted that in order to obtain a defined position of the ultrasonic connections, it is also possible to construct the solid spacer columns to be circular-cylindrical and to provide the upper plate with columns which have a partly conical bore or not. Comparatively abrupt reductions in the open space between tubular columns and solid columns can also be used.

WHAT WE CLAIM IS:—

1. A variable capacitor, comprising a stator and a rotor which are clamped and arranged, respectively, between an upper plate and a lower plate each of a synthetic material suitable for ultrasonic welding, the upper plate and the lower plate being maintained parallel at a fixed distance from each other by spacer columns, pairs of which are coaxially situated relative to each other and extend transversely of the plane of the plates, each spaced columns of a pair being formed to be integral with a respective one of the plates, one column in each of at least two of the pairs of spacer columns having an at least partly tubular construction for connection of the upper plate to the lower plate, characterized in that, for said at least two pairs, a spacer column integral with one of the plates is inserted with clearance into the tubular part of its associated spacer column integral with the other plate, an ultrasonic welded joint being present between the inner surface of the tubular column and the outer surface of the other column inserted therein, said joint being so made and being situated at such a distance from the end of the tubular column remote from its associated plate that part of the tubular column is subject to a compression force, whilst a part of the other column projecting into the tubular column is subject to a tensile force.

2. A capacitor as claimed in Claim 1, characterized in that the clearance between the tubular column and the column inserted therein is smaller at the area of the ultrasonic joint than elsewhere in the tubular column.

3. A capacitor as claimed in Claim 1, characterized in that the outer diameter of an inserted spacer column gradually de-



Said synthetic materials are preferably filled with fibre glass in order to counteract creepage.

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Simultaneously with the stator stacks, external connections 63 and 65 are clamped, said connections being guided in sleeves 67 and 69 injection moulded to the lower plate 17. Supports 71 and 73 are also injection moulded to the lower plate 17, shoulders 75

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WHAT WE CLAIM IS:—

1. A variable capacitor, comprising a stator and a rotor which are clamped and arranged, respectively, between an upper plate and a lower plate each of a synthetic material suitable for ultrasonic welding, the upper plate and the lower plate being maintained parallel at a fixed distance from each other by spacer columns, pairs of which are coaxially situated relative to each other and extend transversely of the plane of the plates, each spaced columns of a pair being formed to be integral with a respective one of the plates, one column in each of at least two of the pairs of spacer columns having an at least partly tubular construction for connection of the upper plate to the lower plate, characterized in that, for said at least two pairs, a spacer column integral with one of the plates is inserted with clearance into the tubular part of its associated spacer column integral with the other plate, an ultrasonic welded joint being present between the inner surface of the tubular column and the outer surface of the other column inserted therein, said joint being so made and being situated at such a distance from the end of the tubular column remote from its associated plate that part of the tubular column is subject to a compression force, whilst a part of the other column projecting into the tubular column is subject to a tensile force.

2. A capacitor as claimed in Claim 1, characterized in that the clearance between the tubular column and the column inserted therein is smaller at the area of the ultrasonic joint than elsewhere in the tubular column.

3. A capacitor as claimed in Claim 1, characterized in that the outer diameter of an inserted spacer column gradually de-



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creases, at least near the ultrasonic joint, to a value which, at the area of the ultrasonic joint, substantially equals the inner diameter of the tubular spacer columns into which it is inserted.

4. A capacitor as claimed in Claim 1 or 2, characterized in that the stator comprises a number of metal plates which are separated from each other by spacer rings and which are clamped between said end of a tubular spacer column and a shoulder of the spacer column inserted into this column.

5. A capacitor as claimed in Claim 1,

characterized in that the upper and the 15 lower plate and also the spacer columns which are integral therewith are made of polycarbonate with a fibre glass filling.

6. A variable capacitor substantially as hereinbefore described with reference to 20 the accompanying drawings.

R. J. BOXALL,
Chartered Patent Agent,
Berkshire House,
168-173 High Holborn,
London WC1V 7AQ.
Agent for the Applicants.

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