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PROCESS AND A DEVICE FOR
IMPREGNATING CONDENSERS

Filed Nov. 13, 1939

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2 Sheets-Sheet 1

Fig. 1

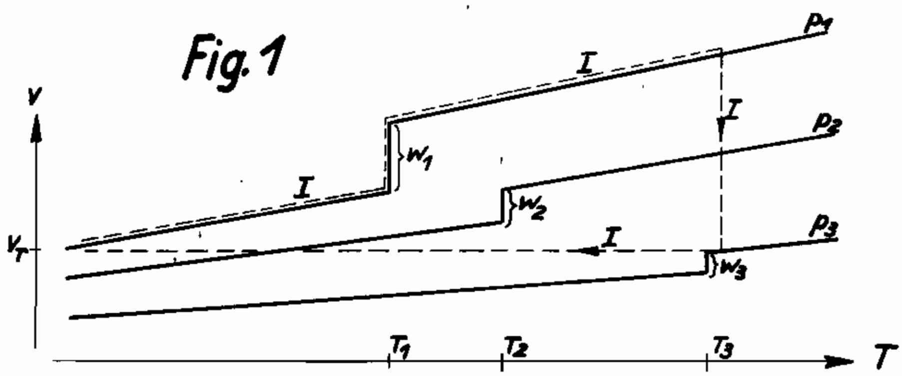

Fig. 2

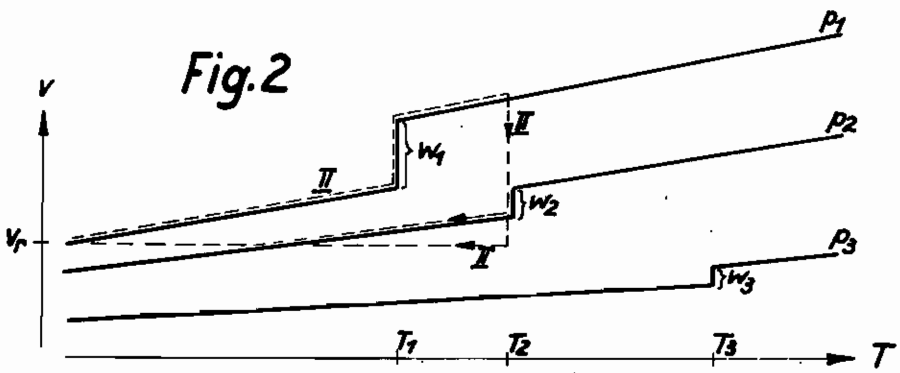

Fig. 3

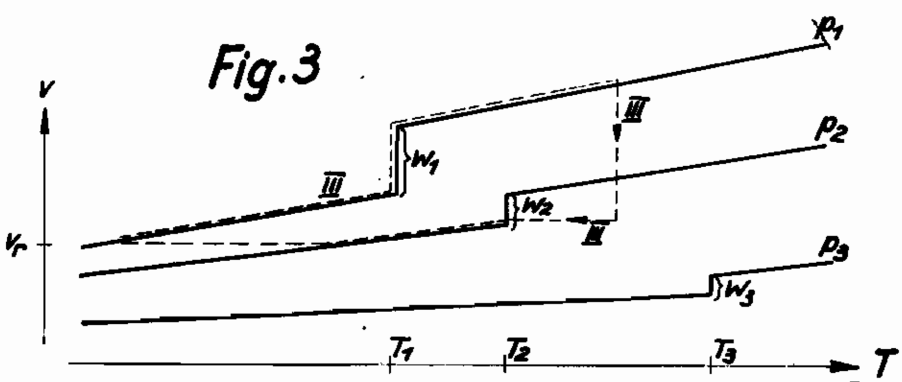

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Fig. 4

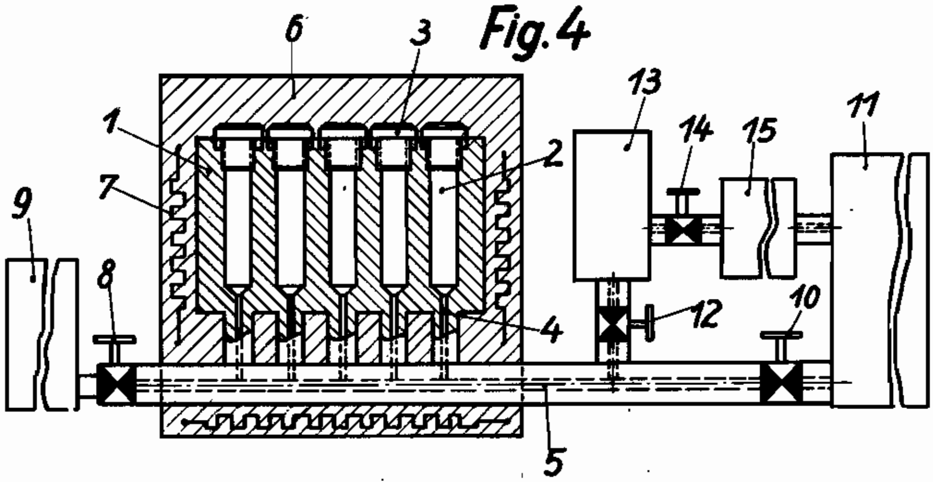


Fig. 5

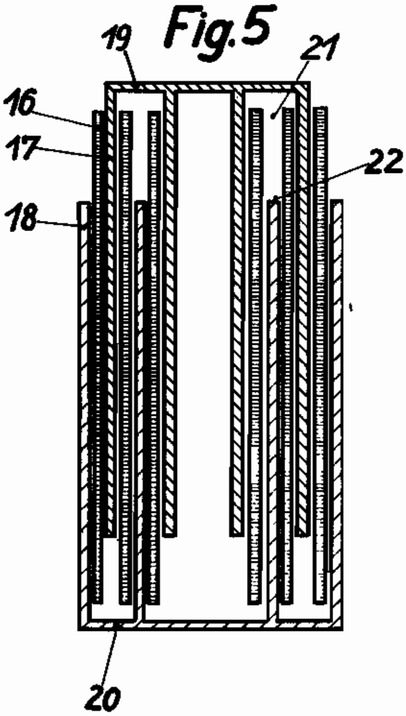


Fig. 5a

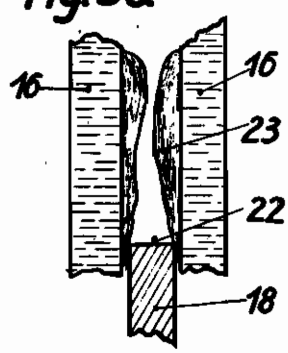
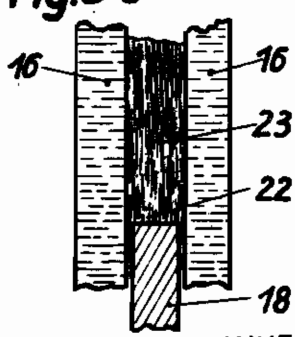


Fig. 5b



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ALIEN PROPERTY CUSTODIAN

PROCESS AND A DEVICE FOR IMPREGNATING CONDENSERS

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The present invention relates to a process and a device for impregnating condensers with impregnating agents which are solid at ordinary temperature, as for example paraffine, ozocerite, vaseline and similar substances.

As is known, fixed condensers and the like are usually impregnated in such a manner that the condenser rolls, which for instance exist of metal foils with interposed impregnable insulating sheets after being dried in vacuum at an elevated temperature are flooded with the molten impregnating means.

The present impregnating processes show the disadvantage that the electric properties of the finished condensers deteriorate very much owing to the volume contraction which takes place together with the solidification of the impregnating agents, especially after long storage. This is besides other reasons mainly caused by the fact that owing to the volume contraction during solidification near the ends of the finished roll the solid impregnating agent shows series of small cracks. The water coming from the air which slowly penetrates into these cracks causes deterioration of the electric properties of the condenser. With certain kinds of rolling, as for instance the rolling of noninductive condensers, the influence of the cracks can be especially troublesome. Till now it has been tried to improve the disadvantage of decreasing the dielectric strength by making the insulating coils considerably larger than the metal foils.

The present invention intends to abolish the appearance of disturbing cracks by suppressing the volume contraction of the impregnating agent. This contraction takes place during solidification. When impregnating condensers with impregnating agents which are solid at room temperature, according to the present invention, the impregnating agent is at first, starting at room temperature, liquefied in a cyclic process and in presence of the condenser submitted to such high temperatures and such high pressures that the volume of the impregnating agent, whether totally liquid or partly liquid and partly solid, is reduced to the volume which the impregnating agent takes at room temperature and at atmospheric pressure.

The process according to the invention is explained in the following with the isobars for the liquid and solid state of a pure impregnating agent in a diagrammatic drawing. It is to be understood that according to the invention impregnating agents consisting of mixtures can be used.

Curve p_1 shows the isobar of a certain amount of an impregnating agent in solid and liquid state under atmospheric pressure. The volume of this amount at room temperature is called v_r. The curves p_2 and p_3 show the isobars of the same amount at considerably increased pressures p_2 and p_3, respectively. The changes in volume which take place at the melting temperatures T_1, T_2 and T_3 are called w_1, w_2, w_3. They decrease, as can be seen in the drawing. with increasing pressures. The process for impregnating of condensers can be realised according to the invention in many different kinds of cyclic processes which suit the constants of the used impregnating agents.

In curve I of Fig. 1 merely one way of conducting the cyclic process is shown. The impregnating agent is heated at atmospheric pressure to a temperature which is higher than the melting point and higher than the temperature T_3. At constant temperature the pressure is raised from p_1 to p_3, the impregnating agent remaining liquid and assuming a volume which is equal to its volume at room temperature. After that it is cooled to ordinary temperature at constant volume.

By reducing the impregnating agent to the desired volume (v_r) in a liquid state, as described above, the solidification occurring at the following cooling as well as the further reducing down to ordinary temperature takes place without any change in volume, which could be disturbing by the formation of troublesome cracks.

In the above described performance of the process according to the invention generally comparatively high pressures and corresponding high temperatures have to be used. Therefore, in a preferred method of performing the cyclic process according to the invention, the impregnating agent which has to be treated is exhibited at a temperature above its melting point (at 760 tor) to such a pressure that it solidifies and then it is cooled at the same or at a higher pressure isobarically to its volume at ordinary temperature.

Such a cyclic process is shown in Fig. 2, curve II, of the accompanying drawing.

The impregnating agent is heated at the pressure p_1, which may differ from the atmospheric pressure, to the melting temperature T_2 corresponding to the isobar p_2, then exhibited to the pressure p_2 what makes it solidify, and is cooled to such a degree, for instance isobarically, until it assumes the desired volume (v_r).

The above described method has the effect that owing to the pressure p_2 being far above atmospheric pressure, the contraction of volume (w_2) connected with solidification is considerably smaller than the contraction of volume (w_1) at the melting point (at 760 tor). The contraction connected with the isobaric cooling of the solid material at the pressure p_2 has to be kept sufficiently small by choosing sufficiently high pressure in order to prevent troublesome cracks. Furthermore, the formation of undesired cracks at the ends of the condenser roll according to the contraction of volume during solidification cannot occur in the cooling of the impregnating agent in the solid state.

It is also advantageous to submit the impregnating material, which is to be treated, at a temperature above the melting point (at 760 tor) to a pressure at which the impregnating agent is still liquid, whereupon it is solidified by cooling at constant volume and reduced to the volume which it assumes at ordinary temperature. In Fig. 3, curve III, is shown, for instance, one way of conducting this kind of cyclic process.

The impregnating agent is heated at the pressure p_1 which may be equal or different from atmospheric pressure to a temperature higher than the temperature T_2. It is then submitted to a pressure higher than the melting pressure p_2 corresponding to T_2, remaining liquid. It is cooled isochorically to the temperature T_2, whereby the impregnating agent solidifies. Then it is whether cooled isobarically or at first compressed in the solid state to the volume (v_r) at T_2 and then cooled to ordinary temperature at constant volume.

In this method of carrying out the process according to the invention an important part of the volume reduction takes place in the liquid state before the solidification of the impregnating agent starts, and therefore the formation of cracks during solidification is practically eliminated.

In realising the process according to the invention, the cyclic processes illustrated in the diagrammatic drawing may generally not be obeyed strictly. The different tracks in the (v—T) plane may not be completely isotherm or isobaric; for instance the compression in the cyclic process II, illustrated in Fig. 2, may not take place at the exactly constant temperature T_2, nor may the cooling follow strictly parallel to the T-axis. Generally in the practical performance a cyclic process is chosen which avoids the formation of cracks and also works with temperatures and pressures which can easily be obtained in the practically available devices. Such a cyclic process can generally be pictured as an entirely enclosed curve in the (v—T) plane.

As the numeric constants of the usual impregnating agents are not known, in the following a homogeneous substance is used for demonstrating the pressures and temperatures used in the process according to the invention. This substance may have the following constants:

The melting temperature at 760 tor be $T_1=50°$ C; the change in melting temperature with pressure be 4.10^{-3} degree/atm. 1 gram of the substance shall take at ordinary temperature a volume of 1 cc. The relation between volume, temperature and pressure be the same for the solid and the liquid state and the thermal expansion coefficient be 5.10^{-4} and the compressibility 2.10^{-5}. The contraction of volume during solidification at atmospheric pressure be

$$w_1=5.10^{-2} \text{ cc/gr}$$

and the decrease in the contraction of volume with pressure be 4.10^{-6} cc/atm.

The figures given above correspond roughly to the figures of known substances, as for instance cetylic alcohol, decan etc. as can be seen from the tables of Landolt-Börnstein, the International Critical Tables etc., and from the publications on which these figures are based. The impregnating agents used practically do not differ principally in their behaviour from homogeneous substances.

Assuming a pure substancc with the above mentioned constants, the following picture is obtained for the cyclic process shown in Fig. 1 by I, which requires especially high pressures and temperatures, as compared with the cyclic processes in Figs. 2 and 3.

1 gram of the impregnating agent is heated at a pressure of 760 tor from ordinary temperature to its melting point of 50° C expanding .015 cc. The change of volume during melting amounts to .05 cc. The molten substance is further heated to about 61° C expanding .006 cc. At this temperature it is exposed to a pressure of about 2500 to 3000 atm, which makes the volume decrease to its volume at ordinary temperature and 760 tor.

If substances are used the volume contraction of which changes stronger with pressure than it is the case with the above mentioned substance, considerable smaller pressures, as for instance up to 1000 atm., are sufficient in the cyclic processes corresponding to Figs. 2 and 3.

For quite different purposes, namely for rendering harmless the traces of gas which remain in the badly evacuated condenser rolls, a small over pressure of several atmospheres has already been used on the liquid impregnating agent. It can be seen that the pressures used in the process according to the invention are of a different order of magnitude.

In Fig. 4 are shown diagrammatically the essential parts of a device adapted for performing the process according to the invention. The impregnating vessel 1 consists of a number of pressure chambers 2, suitable for taking the condenser rolls which can be tightly closed at 3. The chambers 2 are connected via bore holes 4 with the pipe line 5. This line is connected with the evacuating device 9 via valve 8. By valve 10 it is separated from the container 11 which is filled with the impregnating agent, and by valve 12 from the high pressure part 13 and the medium pressure part 15 of the compressor.

After feeding the chambers 2 with condenser rolls, container 1 is heated by an electric heater 7 fixed in an insulating envelop 6. At the same time the air expands out of the chambers through the opening of valve 8. After closing the valve 8, the impregnating agent molten in the container 11 is allowed to enter by opening the valve 10 into the lines 5 and 4 which are all heatable and heat-insulated. According to the process which has to be carried out, and according to the impregnating agent used, at first a medium overpressure may be produced with the compressor 15 in the chambers 2 which at the same time have to be heated to a suitable temperature. After closing the valve 10 the highpressure device 13 can be fed under medium pressure with impregnating agent from the compressor 15, valve 14 being open, and after opening valve 12 the chambers 2 can be put under the desired highpressure. All the auxiliary devices, as thermometers, electrical and mechanical manometers etc. are omitted in the drawing.

As mentioned at the beginning the process according to the invention can be applied with special advantage for impregnating non-inductive condensers of known construction. Such a condenser is shown diagrammatically in section in Figs. 5, 5*a* and 5*b*.

One of the electrodes of the condenser is formed by the metal foils **17** interconnected at **19**, the other electrode being formed by the foils **18** connected at **20**. Adjoining metallic turns are separated by impregnable insulating layers **16**. The higher the wanted dielectric strength of the condenser has to be, the less the layers **17** and **18** can overlap. The free border given by the distance between **21** and **22** has to be sufficiently large, what increases the length of the condenser if the capacity is kept at a constant value. Even with large borders sparking-over cannot be avoided with certainty. For explanation of this fact it is referred to Figs. 5*a* and 5*b* which reproduce the inner edge **22** of the border in large scale. Fig. 5*a* shows a condenser impregnated according to the known process and Fig. 5*a* according to the process according to the present invention, the impregnating agent being marked **23**. In the known process of impregnation small cracks and bigger cavities are formed by the strong volume contraction of the impregnating agent during solidification (compare Fig. 5*a*).

This does not assure in the region of the border safety against sparking especially after the penetration of moisture into the cracks.

By the process of impregnation according to the invention, however, a considerable uniform filling **23** free from cracks is achieved in the border region (compare Fig. 5*b*). As experiments have shown, by the process according to the invention a multiple increase in strength of breakdown is obtainable. Even with small borders safety against sparks around the border is obtained. Therefore, non-inductive condensers of a certain capacity can be manufactured with considerable smaller length with the present process than with the known processes.

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