May 10, 1949. A. G. COOLEY 2,469,951

TUNING FORK AND CONTROL SYSTEM

Filed Oct. 10, 1945 3 Sheets-Sheet 1

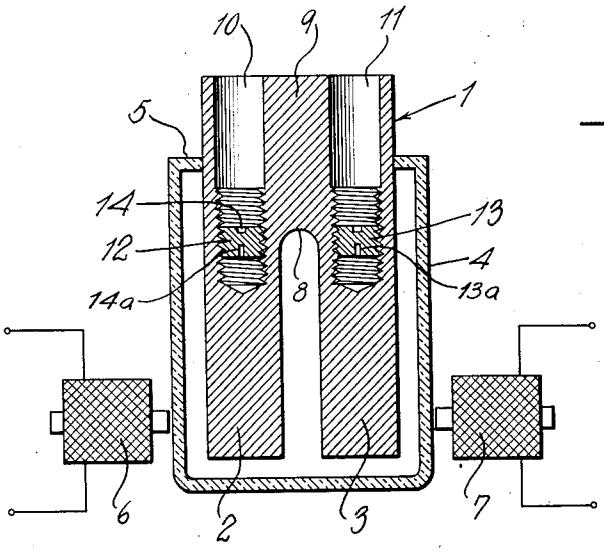


Fig. 1.

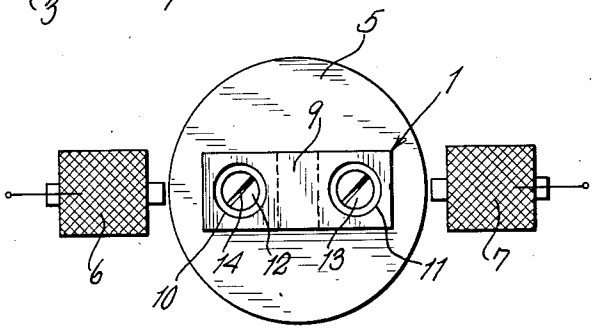


Fig. 2.

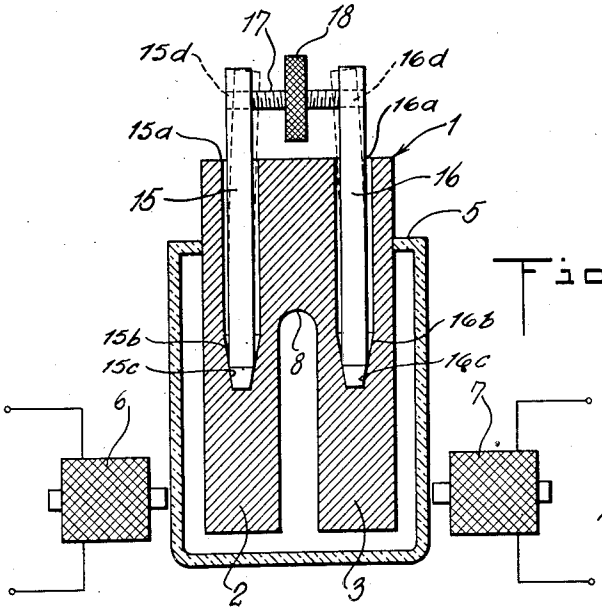


Fig. 3.

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TUNING FORK AND CONTROL SYSTEM

Filed Oct. 10, 1945 3 Sheets-Sheet 2

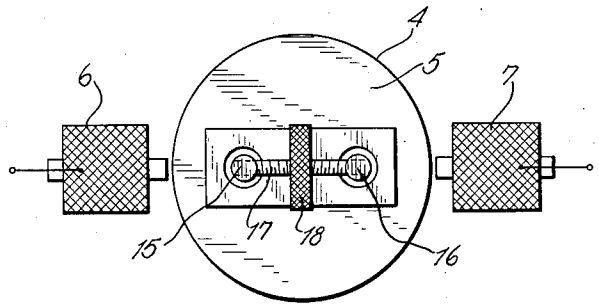


Fig. 4.

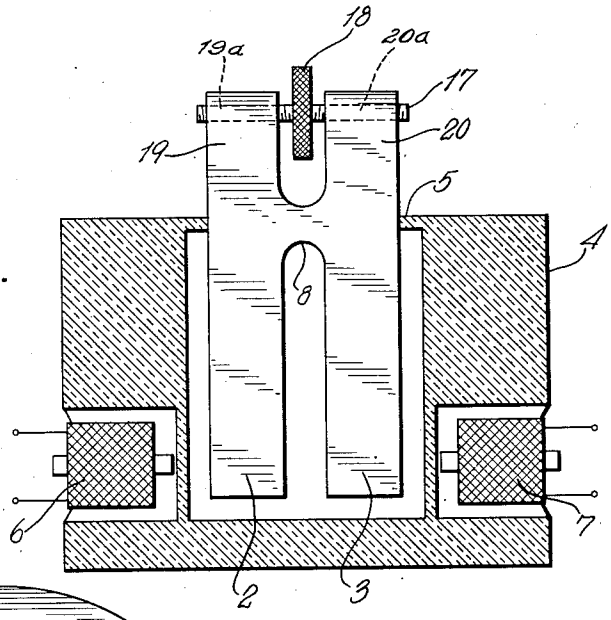


Fig. 5.

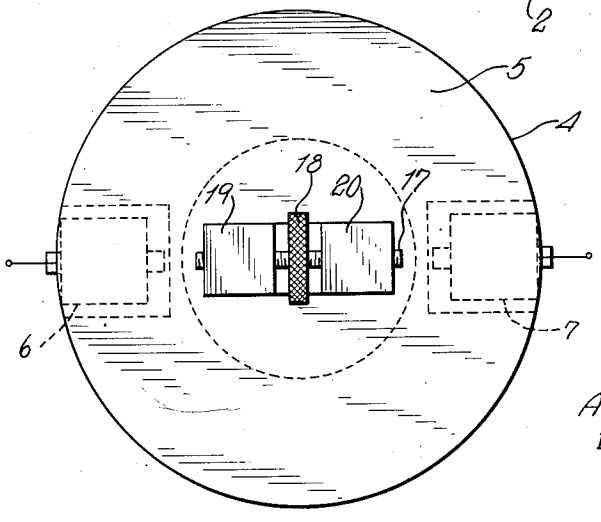


Fig. 6.

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TUNING FORK AND CONTROL SYSTEM

Filed Oct. 10, 1945 3 Sheets-Sheet 3

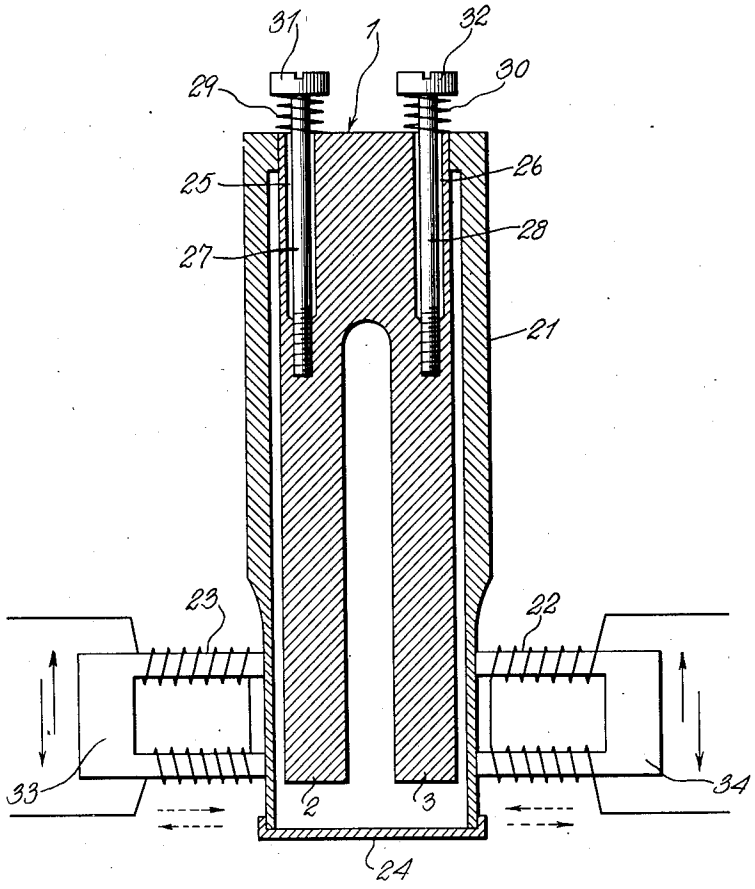


Fig. 2.

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Patented May 10, 1949

2,469,951

UNITED STATES PATENT OFFICE

2,469,951

TUNING FORK AND CONTROL SYSTEM

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Application October 10, 1945, Serial No. 621,403

21 Claims. (Cl. 84—457)

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This invention relates to frequency control apparatus and more especially to improved tuning fork constructions.

A principal object is to provide an improved tuning fork unit which has a high degree of frequency stability as compared with prior known constructions.

Another object is to provide a tuning fork which is enclosed within a sealed container, together with means for mechanically adjusting the natural frequency of the fork externally of the container.

A feature of the invention relates to novel arrangements for adjusting the natural vibrating frequency of a tuning fork or the like.

Another feature relates to an improved tuning fork unit having the fork tines mounted within an evacuated enclosure or within a gas-filled enclosure.

A further feature relates to a frequency control system of the type employing a tuning fork associated with electron tube circuits, the tuning fork being mounted and adjusted so that the frequency stability of the system is determined to a very high degree by the natural vibrations of the fork itself.

A still further feature relates to the novel organization, arrangement and relative interconnection of parts which cooperate to provide a highly stable tuning fork control system.

Other features and advantages not specifically enumerated will be apparent after a consideration of the following detailed description and the appended claims.

In the drawing which shows certain preferred embodiments,

Fig. 1 is a view, partly sectional, of a tuning fork unit embodying the inventive concept.

Fig. 2 is a top-plan view of Fig. 1.

Fig. 3 is a modification of Fig. 1.

Fig. 4 is a top-plan view of Fig. 3.

Fig. 5 is another modification of Fig. 1.

Fig. 6 is a top-plan view of Fig. 5.

Fig. 7 represents a still further modification of the invention.

In controlled frequency systems of the kind employing tuning forks as a primary frequency control element, it is desirable to have the fork oscillate at its own natural period, rather than to force the fork to vibrate at a specified frequency either by damping or over-driving by electrical excitation. In systems where the fork is "freely" vibrating as distinguished from forced or damped vibration, the frequency stability is much greater because the effect of variations in

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the associated electrical circuits is very small. On the other hand, where the fork is over-driven or damped the associated electrical circuits are not entirely stable because of the tendency of the various circuit components such as tubes, capacitors, resistors and the like to change either as a result of age or as a result of temperature or humidity conditions. These changes result in corresponding frequency instability. The desired objects according to the present invention are achieved by mounting the fork tines in a hermetically sealed container and by locating the driving and pick-up coils or magnets outside of the container. Preferably, the container is evacuated, although if desired a selected gas may be supplied inside the chamber under suitable pressure.

While it has been proposed heretofore to mount a complete tuning fork unit including its coils within an evacuated receptacle, such devices have not achieved any considerable extensive use. Where the entire unit including the tuning fork itself, the coils, permanent magnets and associated parts are sealed into an evacuated receptacle, a considerable number of difficulties are encountered in manufacture. One of the major difficulties is the problem of degassing the coils and other similar parts located within the receptacle, particularly since such coils usually contain impregnating materials and coating materials such as varnish or the like. Furthermore, with such arrangements, it is necessary to bring out the electrical connections through the wall of the receptacle and these connections must be sealed through the wall in a vacuum-tight manner. The multiplicity of such connections may lead to leaks. The problem is further complicated by the fact that the frequency of the fork when in a vacuum is different from its frequency when the fork is at atmospheric pressure. Consequently, it becomes necessary to provide means to be able to adjust the natural frequency of the fork even after it is enclosed within the evacuated or gas-filled container.

One arrangement for overcoming the disadvantages of the prior arrangements is illustrated in Fig. 1 of the drawing, wherein the tuning fork is mounted with its tines 2 and 3 located within a suitable container or housing 4. The housing 4 where the fork 1 passes therethrough is sealed vacuum-tight in any suitable manner by means of a header 5, it being understood that the joint between the header 5 and the fork 1 is hermetically sealed or vacuum-tight sealed in any well-known manner, for example as shown in U. S.

Patent No. 1,093,997. The inside dimensions of housing 4 are chosen so as to provide sufficient space for the vibrations of the fork tines, and of course the housing 4 should preferably be constituted of a non-magnetic material.

Suitably mounted exteriorly of the housing 4 adjacent the lower end of the fork tines are a driving electromagnet 6, and a pick-up electromagnet 7. Magnet 6 may be energized from any suitable source of pulsating or alternating current of a frequency equal to or closely adjacent to the natural frequency of vibration of the fork 1. If desired, the electromagnet coil 6 may form part of a conventional electron tube oscillator feedback circuit. Since it is not always possible to estimate with the desired accuracy the amount of change in natural frequency which the fork will exhibit when mounted in a vacuum as compared with its natural frequency at atmospheric pressure, it is necessary to provide means for adjusting the natural frequency of the fork after it is sealed through the receptacle 4. It will be understood of course that the fork is sealed in, to a point beyond the heel portion 8 so that the entire length of the tines is within the housing 4. Heretofore, it has been the usual practice to adjust the frequency of the system as a whole by changing the electromagnetic driving force on the fork tines or by changing the electromagnetic load on the fork tines. However, since it is desirable to have the driving load as small as possible for the sake of frequency stability, it is not possible to achieve much in the way of frequency adjustment by the usual driving or magnetic loading of the electrical controls. However, in order to achieve the necessary adjustment of the frequency of the system while maintaining the fork freely vibrating at its natural period, the yoke portion 9 is provided with bores 10 and 11, which extend part way into the body of the respective tines 2 and 3. The internal surfaces of each of the bores 10 and 11 are threaded to receive corresponding threaded plugs 12, 13. Each of the plugs is provided on its upper face with a slot 14 to enable it to be turned so as to vary its position interiorly of its respective bore. Preferably also, the lower face of each of the plugs is slotted at 13*a*, 14*a* so that the lower end of each plug is slightly sprung outwardly to provide a relatively tight and resilient pressure between the plug and the bore at its lower end. This results in giving the plug a lock-nut effect. It will be understood of course, that any other well-known means may be provided for locking the plugs 12 and 13 in their adjusted positions within their respective bores. By adjusting one or both of the plugs 12 and 13, the natural vibrating frequency of the tuning fork can be adjusted to the desired frequency of the system to be controlled. Under these circumstances, the fork acts as the primary frequency control member and the frequency of the system is determined by the natural vibratory frequency of the fork tines.

Referring to Figs. 3 and 4, there is shown a modified arrangement for effecting frequency adjustment of the fork, and parts of Fig. 3 which correspond to those of Fig. 1 are designated by the same numerals. In this embodiment, the bores 15*a* and 16*a* instead of being internally threaded, have two rods 15, 16, fastened at their lower ends within the lower ends of each of the bores. For this purpose, the lower end of each bore may be tapered at 15*b* and 16*b* and the rods 15, 16, may likewise have their lower ends tapered at 15*c*, 16*c* so as to provide a drive fit between the rods and the fork tines. As shown in Fig. 3, the rods 15 and 16 are of smaller diameter than their corresponding bores so as to allow the rods to be drawn together or spread apart at their upper ends. For this purpose, the upper ends of the rods 15 and 16 are provided each with a threaded opening 15*d*, 16*d* to receive the ends of a threaded arm 17 to which is rigidly attached an adjusting thumb nut 18. The threads on the ends of member 17 and the threads in the rods 15 and 16 are so arranged that by turning the nut 18 in one direction, the rods 15 and 16 are drawn closer together, and when nut 18 is turned in the opposite direction the said rods are spread apart. By this means a closely adjustable stress can be placed on the rods 15 and 16, and this stress will be transferred to the tines 2 and 3 to affect correspondingly the natural frequency of vibration.

Figs. 5 and 6 represent a modification of Fig. 3, and the parts which are similar in both figures bear the same designation numerals. In this embodiment, the rods 15, 16, and the corresponding bores are omitted. However, the yoke 9 is provided with two external arms 19, 20, which may be considered as integral extensions of the fork tines 2, 3. The arms 19 and 20 have threaded openings 19*a*, 20*a* to receive the right and left-hand threaded end sections of the adjusting rod 17 which carries thumb nut 18. Therefore, by turning the nut 18, the natural period of vibration of the fork tines 2, 3, can be very closely and accurately regulated. If desired, the rods 15 and 16 in the embodiment of Fig. 3 may be chosen of some suitable metal so that any change in frequency of the fork tines which tends to result from temperature changes is compensated for by a corresponding but opposite change in the rods 15 and 16. To a certain extent, this automatic temperature compensation is inherent in the construction of Fig. 5. Thus, change in temperature which tends to increase the natural frequency vibration of the fork tines changes the stress on the arms 19 and 20 in such a way as to tend to lower the natural frequency of vibration of the fork an equal amount.

Referring to Fig. 7, there is shown a further modification wherein the tuning fork 1 is enclosed within a cylindrical metal tube 21 which is of seamless and stainless steel tubing which however is substantially non-magnetic and has a comparatively high electrical resistance. An example of such steel that may be used is that sold under the trade designation Stainless Type 304 manufactured by Allegheny Ludlum Steel Corporation. The member 21 at its lower end has its wall thickness considerably reduced so as to enable the drive electromagnet 22 and the pick-up electromagnet 23 to be positioned as close as possible to the fork tines 2, 3. The lower end of member 21 is vacuum-tight sealed by means of a metal cap 24 which is brazed or solder-sealed to the lip of tube 21. Likewise, the upper end of the fork 1 is brazed or solder-sealed around its periphery to the corresponding wall of the member 21. For the purpose of adjusting the frequency of the fork, the lower end of each of the bores 25, 26, is threaded to receive an adjusting bolt or screw 27, 28. Each of the adjusting screws is provided with a coiled compression spring 29, 30, one end of which abuts against the end of the nut and the other end of which abuts against the corresponding screw head 31, 32. It has been found that by turning the screws 27 and 28, a precise adjustment of the natural

frequency of the fork can be obtained. It has also been found that for a final adjustment, if required, the magnets **22** and **23** may be adjusted along the length of the fork tines a slight amount as indicated by the full-line arrows. When the magnets have been properly adjusted, they may be fastened in position by means of suitable clamps (not shown) which connect the heel portions **33**, **34**, to a suitable rigid frame (not shown). Instead of sliding the magnets **22** and **23** along the length of the fork tines to adjust the frequency, these magnets may be moved slightly away from the member **21** as indicated by the dotted line arrows. In order to insure further the vacuum-tight sealing of the fork unit, comprising members **1**, **21** and **24**, this unit may be dipped in vacuum sealing varnish of any well-known kind, such for example as that sold under the trade name "Apiezon W" manufactured by Technical Products, Ltd., London, England. A further precaution against leakage may be provided by exteriorly tinning the fork unit.

It will be understood that the dimensional configurations shown in the embodiments of Figs. 1 to 6 are merely representative and preferably the dimensions for the various units should be as indicated in the embodiment of Fig. 7.

While certain specific embodiments have been disclosed herein, it will be understood that various changes and modifications may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

1. A frequency control device comprising an evacuated housing, a tuned vibratory member hermetically sealed through a wall of said housing with a portion thereof interior of the housing and with a portion exterior of the housing, a passage-way in said member but accessible from the exterior of said housing, and an adjusting member in said passage-way and accessible from the exterior of said housing for mechanically adjusting the natural frequency of said vibratory member.

2. A frequency control device comprising a tuning fork, a gas-tight housing within which the tines of the fork are hermetically sealed, said fork having a portion external of the housing, and means mechanically attached to said external portion of the fork for mechanically adjusting the natural frequency of said tines without affecting said seal.

3. A frequency control device comprising a tuning fork, a gas-tight housing within which the tines of the fork are hermetically sealed, a passage-way into at least one of the tines which passage-way is external to said housing, and a member in said passage-way and accessible externally of said housing to adjust mechanically the natural frequency of vibration of the fork.

4. A frequency control device according to claim 3 in which said passage-way is internally threaded and a corresponding threaded plug is adjustably located therein.

5. A frequency control device comprising an evacuated housing, a tuning fork a portion of which is sealed in a vacuum-tight manner through a wall of said housing and with the fork tines located within the housing, a passage-way in the body of each fork tine, and external to said housing and accessible from the exterior of the housing, and a member in each of said passage-ways for mechanically adjusting the natural frequency of the fork.

6. A frequency control device according to

claim 5 in which each of the last-mentioned members comprises a plug which is adjustable lengthwise within the corresponding passage-way.

7. A tuning fork having a pair of bores each communicating with the interior of a fork tine, and an adjustable plug frictionally held within each of said bores for mechanically adjusting the natural frequency of vibration of the fork.

8. A tuning fork having a pair of spaced extensions integrally united with the fork tines and extending from the heel of the fork in a direction opposite to that of the tines, and adjustable means connecting said extensions for subjecting said extensions to an adjustable stress and thereby to control mechanically the natural frequency of vibration of the fork.

9. A tuning fork according to claim 8 in which said extensions have oppositely threaded openings to receive a bar having corresponding oppositely threaded end portions, and means to turn said bar to control the stress on said extensions.

10. A tuning fork unit comprising an evacuated enclosing receptacle having a portion of its peripheral wall thinner than the remaining portion, electromagnetic fork control means mounted externally of said receptacle adjacent said thin wall portion, a tuning fork mounted within said receptacle and with the tine ends located adjacent said thin wall portion of the receptacle, the heel of the tuning fork being sealed in a vacuum-tight manner through a wall of said receptacle.

11. A tuning fork unit according to claim 10 in which said receptacle is of seamless metal tubing with the heel of the fork hermetically sealed through one end of the tubing and the other end of the tubing is hermetically sealed by a metal cap.

12. A tuning fork unit according to claim 10 in which the fork is provided with two bores which are accessible exteriorly of the unit each bore having a threaded rod therein and a compression spring between the external end of each rod and the end of the unit.

13. A tuning fork unit comprising an evacuated enclosing receptacle having a portion of the wall thereof constituted of a material which is substantially non-magnetic, said portion of the wall being of thinner cross-section than the remainder of the wall, a tuning fork within said receptacle and having its heel portion sealed through another part of the receptacle wall so that the fork tines are adjacent said thinned wall portion, and electromagnetic fork control means located exteriorly of said thinned wall portion and adjustable with respect to the tines to control the operating frequency of the fork.

14. A tuning fork unit according to claim 13 in which said thinned wall portion is of stainless steel.

15. A tuning fork unit according to claim 13 in which said receptacle is of stainless steel one end of which is sealed by a metal cap, the said heel portion of the fork being sealed through the opposite end of said receptacle and with the fork tines in close proximity internally with respect to said thinned wall portion.

16. A frequency control device, comprising a tuned vibratory member, a hermetically sealed housing, said tuned member having a portion of its length located within said housing and a portion external to said housing, and means adjustably connected to said external portion for ad-

justing the natural frequency of said member without affecting the said seal.

17. A frequency control device, comprising an evacuated housing, a tuned vibratory member having a portion hermetically sealed through a wall of said housing and having the greater part of its length within the housing and a portion external to the housing, and means adjustably attached to said external portion for mechanically adjusting the natural frequency of vibration of said member.

18. A tuning fork having a tine thereof with at least one part of its length hollow, and means movable in said hollow portion for mechanically adjusting the natural frequency of vibration of the fork.

19. A tuning fork unit, comprising an evacuated enclosing receptacle for the fork and having at least a portion of the receptacle wall constituted of a material which is substantially nonmagnetic, a tuning fork having its heel portion attached to one end of said receptacle, the tines of the fork extending interiorly of the receptacle to a point adjacent said wall portion, and electromagnetic means located exteriorly of said wall

portion in magnetic alignment with the end portions of the tines for controlling the operating frequency of the fork.

20. A tuning fork unit according to claim 19 in which the said heel portion is integrally united with one end of said receptacle, the other end of said receptacle being hermetically closed by a cap.

21. A tuning fork unit according to claim 19 in which said receptacle is in the form of a stainless steel tube.

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