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CAVITY RESONATOR

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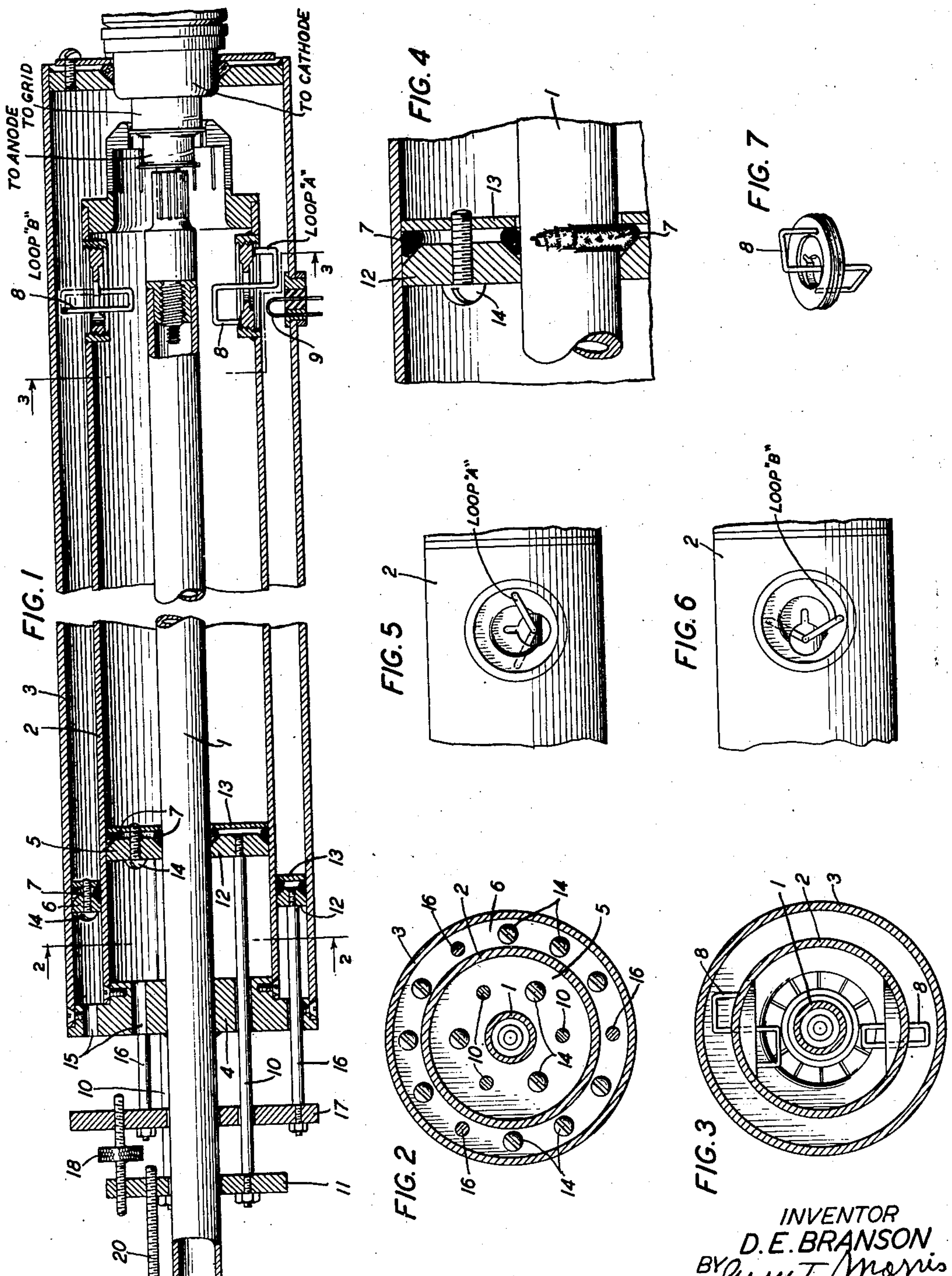

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CAVITY RESONATOR

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3 Claims. (Cl. 178—44)

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This invention relates to an organization comprising tunable, magnetically coupled, cavity resonators and also to collateral elements contained therein affecting the tuning and coupling characteristics.

A comprehensive object of the invention is to achieve an organization as above which has the maximum flexibility and versatility and therefore is most adaptable for use in a variety of electrical environments such as oscillators, amplifiers, wave meters and the like, all requiring two or more tunable cavity resonators. The object may be realized, as herein, in an organization in which there may be either an individual or a simultaneous tuning of said resonators while preserving initial desirable characteristics of said resonators as to impedance and radiation characteristics and the like, and with a desired predetermined quantity and kind of coupling therebetween. These results are largely achieved by the plunger and dirigible coupling loop to be referred to below which also, however, have capabilities of use independently of the general organization.

A subsidiary object of the invention is, in a tunable cavity resonator where tuning is a function of the movement of a plunger to correspondingly vary the axial dimension of the resonator, to provide an electromagnetic seal between the plunger and contiguous resonator wall having optimum electrical contact resistance characteristics at the same time as insuring a minimum of electromagnetic radiation leakage between said plunger and wall.

Another subsidiary object is to provide a simple, variable, energy coupling means between a pair of said resonators which, consistently with extreme simplicity, is capable of continuous variation in degree of coupling and of choice of coupling as between positive or negative. These terms "positive" and "negative" achieve their special meanings only in connection with the organization as a whole in which said pair of resonators are used but it is sufficient at this point to say that the coupling means of the invention may be varied or adjusted so as to achieve any desired relationship between the component resonators so that for example, in the more general organization, such as an oscillator in which this resonator organization is included, their effects may be caused to aid or oppose at will.

The invention is exemplified in an organization in which the coupled resonators are constituted by the interspaces in a triple-conductor coaxial system. In practice the inner middle and outer concentric cylinders bounding the resona-

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tors are connected respectively to the anode, control electrode, and cathode, respectively of an electron tube which cooperates with the coaxial to constitute the whole, an oscillator. The two resultant concentric annular-shaped, cavity resonators are made completely closed, as is necessary in practice, by a common, fixed end closure member at one, common, end and at the opposite ends by movable piston-like plungers whose axial positions determine the effective lengths of the respective resonators and hence their frequencies. These two plungers, which of course are annular like the cross-sections of the related resonators and are concentric with each other, are coupled together and to a common operating means. This operating means is in the form of a plurality of rods which are constrained to move axially of the resonator and are screw actuated to adjust the two plungers as a unit. The system of actuating rods is divisible into rods specific to each said plunger and screw means are adapted to operate one component set with relation to the other so as to achieve a relative adjustment of the two plungers. The organization as a whole therefore is adapted to achieve any desired adjustment of the plungers. The principle, of course, may be readily adapted to a greater number of resonators and plungers, which themselves may be adapted to a versatility of shapes and cross-sections.

One of the two specific features which round out and make the organization as a whole effective under the adverse conditions imposed is a means for sealing the peripheries of the plungers within the inside walls of the resonators. This comprises a special element interposed between each tuning plunger and its cooperating wall to insure not only a low resistance electrical connection therebetween during movement of the plunger but a complete closure so as to minimize loss by electromagnetic leakage radiation. The relation between plunger, and resonator wall partakes of the obviously quite non-analogous function and structure of a piston ring and cylinder of an internal combustion engine and the special element therefore resembles a piston ring. It differs radically from it in texture (as of course it does for other reasons in its over-all purpose) because of being non-rigid. It is made of fabric-like material with elastic backing that might be provided by rubber, vegetable fiber or the like. The fabric-like material, of course, must be conducting so that it partakes of the character of a braided shield of a shielded conductor or cable. This means will be described in the detailed description to follow and in the claims by use of such terms as "plunger packing" and "packing ring."

The prior art is replete with would-be alternatives which have not been entirely satisfactory in practice. These have most commonly taken the form of spring fingers attached to the plunger and extending from them in an axial direction, their outer extremities, of course, bearing on the inside walls of the cooperating resonator. Sometimes a wire helix is used in a peripheral groove, which helix may even, as in the present invention, be compressed to squeeze it tightly against the resonator wall. Even metal balls confined in a race, as for ball bearings, have been used. These expedients all involve comparatively rigid movable contacts or bearing elements. The packing of the invention has certain specific advantages over these alternatives, especially the spring fingers which perhaps come closest in their desirable attributes, which can perhaps be better mentioned here than in the detailed description, these advantages being of extremely great significance as frequently making a particular installation practicable when it would otherwise be impracticable.

(a) The wear after long continued use is very much less and even at the extreme tends to be proportional rather than to be subject to the hazard of an unexpected complete breakdown.

(b) Since the fabric-like plunger packing of the invention so easily accommodates itself to imposed conditions as compared with its alternatives, its use obviates the holding of the resonator tubes to as exact dimensions as would otherwise be required.

(c) The qualities of good electric conduction and high elasticity in spring fingers or the like are antithetical so that the spring fingers, at a resultant increased expense, must be plated with conducting material that will be retained, a difficult combination of requirements. Also the spring fingers must be long enough to properly guide the springs without binding or injury and this tends to increase the over-all length of the resonator. Since spring fingers themselves partake of the characteristics of a transmission line their lengths are electrically significant, that is, if too short their ends remote from the plunger would tend to be more nearly at current points than at voltage points so that extra good contact would be required. To avoid this condition so that the ends would be at a voltage point the fingers would have to be one-quarter wavelength long and therefore even longer than would otherwise be required and which at the best would tend to introduce or increase the serious disadvantages that have been mentioned.

(d) Besides the fact that the packing of the invention results in a smaller contact resistance than in its alternatives including the spring fingers, the use of the spring fingers tends to result in capricious changes in its contact resistance to obviate which requires a certain inconvenient and tedious discipline in the adjustment of the plungers during reversal of direction of adjustment. For instance it was found to be always necessary to approach the desired plunger setting from the same direction since an overshoot could not be corrected merely by reversing the direction of the control. With the present considered packing there is no comparable effect.

(e) The above advantages and the other advantages to be cited are not only not attended by

compensatory increased cost but the use of the packing causes the organization as a whole to distinctly cost less than when any of its alternatives are used.

(f) The packing results in a more complete closure so that the magnetic leakage is definitely less than in the alternatives. The leakage has two walls to go through in the packing hence the shielding effect is double that of spring fingers and there are no spaces, corresponding to the spaces between the spring fingers, for leakage.

The organization as a whole is perfected in its flexibility and versatility of use by the variable coupling feature whereby the resonators are adequately intercoupled. In any one adjustable position of this coupling, the effect may not be much different from that achieved by the prior art means, usually comprising a simple loop in one resonator connected to a like loop in the other. However, in this instance the two loops are rigidly interconnected to form a figure roughly the equivalent of a conventionalized figure 8 or letter S (thought of as resting on their sides instead of being upright) with means for rotating the combination about a line corresponding to the vertical axis of this figure or letter. Furthermore, the two loops constituting the figure or letter are not in a common plane but one is twisted or "skewed" relatively to the other about this axis which will be denominated the "skew axis" by about 120 degrees. This means that, depending on the particular rotational adjustment of the loop as a whole about this same axis, the coupling may be made to partake of the characteristics of a positive or a negative coupling at will, with a range of variation for each. As affecting the operation of an oscillator of which the resonators are a part, the result may be described as either a regenerative (positive) or a degenerative (negative) coupling or feedback. A flat loop (both component loops in same plane) would give either positive or negative feedback in adjustable amount but not adjustable from positive to negative. If the component loops are warped out of the same plane, as in the invention, they may be adjusted from a maximum negative to a maximum positive feedback smoothly.

The currents on the opposite walls of the grid tube cause the respective magnetic field in the two cavities to be in directions reversed to each other. The projected cross-section of the loop, when said loop is positioned so that the cross-section is S shaped indicates a coupling to aid or strengthen the normal relations of the magnetic fields, to be known as positive feedback, and when the projected cross-section of the loop is O or D shaped indicates a coupling to oppose or weaken the normal relation of the magnetic fields, to be known as negative feedback. The above indications assume that the coupling loop has the physical appearance of a conventionalized letter S although an analogous condition would apply if it more nearly resembled a conventionalized figure 8.

An important incidental effect of this coupling is that at the proper location (see detailed description) the double resonator organization as used in an oscillator or amplifier may be made to function smoothly over a greater practicable range of frequencies than with prior alternatives if the feedback may be adjusted to suit the extreme ends of the range, this for an amplifier possibly sometimes requiring a change from positive to negative feedback or vice versa. In a practical case it is possible to get only as much as a

2 to 1 range with it in a fixed position whereas if adjusted the range might well be increased to about 2.3 to 1 (ideally the location as well as the rotational position of the loop should be subject to adjustment). This increased range might have been cited as an additional object of the invention.

The invention and the foregoing and other features thereof will be understood more clearly and fully from the following detailed description with reference to the accompanying drawing in which:

Fig. 1 is a longitudinal cross-sectional view of a coaxial resonator system embodying the features of the invention;

Figs. 2 and 3 are cross-sectional views at lines 2—2 and 3—3, respectively;

Fig. 4 illustrates in cross-section a fragmentary part of the Figs. 1 to 3 organization, specifically of the inner tube and plunger in order to disclose in greater detail the packing of the invention and its compressing means;

Figs. 5 and 6 comprise graphic devices, although in the nature of a transverse elevation view of the coupling loop, to illustrate the operation of the loop and its effect in different adjusted positions; and

Fig. 7 illustrates said coupling loop and its immediate structural environment in perspective.

Referring now to the drawings, and especially to Figs. 1, 2 and 3 which show the organization as a whole, the three metallic tubes (the material might well be brass, although there is a considerable choice), 1, 2 and 3 constitute a coaxial conductor system and by their interspaces determine the two cavity resonators here concerned, these resonators being completed by rigid heading, or main assembly plug, 4 and axially adjustable annular disc-like plunger elements 5 and 6. In a particular over-all organization in which these resonators have been successfully used in practice and as is suggested by the fragmentary showing of the associated electron tube at the right in Fig. 1, these tubes 1, 2 and 3 are attached respectively to the anode, grid, and cathode of an electron tube, the whole organization, with the help of the magnetic coupling between the resonators which will be commented on presently, constituting an ultra-high frequency feedback oscillator of a quite common generic type.

The main assembly plug 4 is integrally attached, as by soldering, to the central tube 1 and tubes 2 and 3 may most appropriately be connected to said plug by separable connections as by the screw threaded means shown. Figs. 1, 2 and 3, which are at present under consideration, show, although the details will be discussed in connection with other figures, two important subsidiary features of the organization and which enable the two or more resonators to be most effective in the over-all organization in which said resonators are used. These are the plunger packing means 7, an instance of which occurs at each of the four places of contact between the plungers and adjacent resonator walls, and the dirigible feedback coupling or loop 8.

Output energy may be derived in various ways represented by the simple loop 9. Of course, this output loop could be equally well related to the other resonator and various modifications could be used. This output means is not shown with great elaboration of detail since it does not constitute a part of the invention. As here shown it should preferably be close to the fixed closure end of the resonator and, best of all, in the plane of the connecting bars of the component loops of the coupling means.

Considering now the actuating means for the plungers, and therefore the means for tuning the corresponding resonators, the inner plunger 5 is made with a loose fit over inside tube 1 and is pushed by three rods such as rods 10 of Fig. 1, the others being uniformly with it distributed about the common axis and as shown in section in Fig. 2. These rods are attached remotely from the plunger to guide, or push, plate 11. They are attached to the plunger by plate 12 thereof, constituting the major part of the disc-like plunger. The plunger packings 7 are squeezed against the adjacent tube (resonator) wall within the triangular spaces bounded by the bevel edges of said plate 12 and cooperating plate 13. Of course the conformity of the wall bounding this space is not critical and could differ widely from the triangular conformity shown. The desired force is obtained by adjusting screws 14 threaded through plates 12 and 13. The screws are reached through holes 15 in the plug 4. The screw heads are shown in sectional view Fig. 2 which indicates that, in the particular arrangement here disclosed, three such adjusting screws are used (nine similar screws being shown for the outer plunger). These adjustments are made when the plungers are all the way to the left. The plunger disc is maintained radial since it slides on tube 1 and the relationship of the rods 10 to said tube 1 is made constant by the constraint of their movement through fixed holes in said plug 4. The rods would determine the effective length of the plunger as a unit. The fact that the guide plate 11 must be outside of the support for the tubes, that is, outside of the resonators, need not appreciably change the overall length of the resonator assembly or oscillator. As has been pointed out in the statement of invention, said over-all length is considerably less than if spring fingers were used instead of the packing of the invention.

The outer resonator has a similar plunger operating means, comprising rods 16 and guide plate 17. These elements are related to said cooperating elements precisely as in the instance of the innermost resonator and like structural elements have like labels.

The operating means for the two plungers are linked together by differential screw means 18 to make possible any specific adjustment of either plunger without necessary affect on the other plunger. The main drive, which is common to both plungers and sets of driving rods, is from stationary block 19 which is fixed to the innermost tube 1, by screw 20 through guide plate 11. This enables a common adjustment of the two plungers and therefore a simultaneously tuning of the two resonators, something which frequently becomes convenient of accomplishment in the various applications of this double resonator system and particularly in its application to the oscillator here in mind.

Although the attachment of the grid and anode tubes to the electron tube is shown as by means of spring fingers or the like, the attachment of the cathode tube must be more positive because this is the principal reliance for the attachment of the electron tube and resonator assembly as a whole and accordingly a packing similar to that used for the plungers may be used and is here illustrated. The packing is similar to the extent that it also requires the braided copper or the like outer element to provide a good conductive connection but the resilent core may be made harder so that a more rigid grip may be obtained to more definitely hold the tube in place. The element corresponding to plate 13 of the plunger assembly is integral with the electron tube assembly so that the clamping of the cathode tube against it through the intermediation of the packing satisfies the requisite condition of rigidity. Since the junction of the cathode tube, through the packing, to the electron tube is the important consideration the plate corresponding to element 13 of the plungers need not be conductive at this particular junction.

The packing element itself is best shown in Fig. 4 which shows in section a portion of the inner resonator adjacent the plunger. The packing has the physical appearance of a section of cable of a particular kind, namely, with a single center conductor covered by a small amount of rubber insulation, in turn covered by a double cotton braid and finally by a tinned-copper braided shield. In an actual installation which proved to be effective in practice the packing was made up in this way, the braided shield being taken from a shielded conductor and having inserted in it a portion of a cable comprising the other elements including a 19-gauge conductor, the outer diameter being about ⅛ inch. Of course the outer braid serves as the conductive connection and if the copper is hard, it contributes a considerable spring action by itself, although later experience has shown that soft copper is nearly as good and that its tinning is not essential. The only utility of the inner conductor and insulation is to satisfy a presumed requirement strength since the packing is quite tightly wrapped around the plunger. However, this has since been found not to be essential. The cotton braid and rubber serves as a cushion for, and gives a soft support to, the copper braid. In practice the packing is wrapped around the plunger and cut off the proper length to insure a reasonably tight butt joint, but the ends are not soldered together. The packing is then tightened to the desired amount with the plungers pulled all the way out so as to line up the packing concentrically. The packing ring is clamped quite rigidly so that the packing will be "formed" with the entire circumference of the plungers and then loosened up slightly. The concentricity will then be preserved when the plungers are pushed away from the supporting ends. Other variations than above indicated, in the physical make-up of the packing ring, while preserving the essential characteristics of the outer non-rigid conductive element and the inner cushion, have been used. Where made up ab initio the cushion means could well have the texture of rubber and the packing material could be constituted by only said rubber core with the braided covering. In one installation the cushion is made of varnished cambric. In another and perhaps the one best adapted for large scale manufacturing and otherwise being at least as effective as the particular one here shown, a core material known in the trade as Vinylite is used which is an extruded plastic material having the general configuration of spaghetti, in fact being the modern equivalent of "spaghetti" as the term is used to describe common material used in the art of electric conductors.

The coupling loops are shown in two aspects in Figs. 1 and 3 in their intended environment. Two such loops are disclosed, both in deference to the fact that in the usual case a plurality of symmetrically positioned coupling loops would be used and to illustrate the two extremes in their adjustment for particular purposes. In most common practice the adjustments would be alike for the two loops. Loop A is in regenerative adjustable position and loop B is in degenerative adjustable position. Figs. 5 and 6 are respectively related to loops A and B and show them as they would appear when looked at in the direction of the down stroke of the conventionalized S. It is apparent that the planes of the component loops are not the same, one being displaced (skewed) by about 120 degrees from the other. This is well shown in Figs. 5 and 6 and in perspective view Fig. 7. The loop as a whole is rotatable about an axis corresponding to the direction of the down stroke of the S that is, of the skew axis. The effect of so rotating the loop as between regeneration and degeneration for example is determined by the relative disposition of the two component loops in the respective resonators. This relation obviously could not change if the loop as a whole were in a single plane, that is, without the distortion that characterizes the loop of the invention. With the loop of the invention, it is obvious from the disclosure that a radical change results from the 90 degree rotation of the loop as a whole from the position of loop A to that of loop B. For instance following the line of attack used in the statement of invention, it is evident that in the position of loop A there is a symmetry about the down stroke element of the figure (the skew axis) whereas in the position of loop B there is a dissymmetry about the same. This is well shown in Fig. 1. This result would come about with any deviation from a zero angle or 180 degree angle between the planes of the component loops (the letter S as it appears on this sheet representing the 180 degree displacement). The deviation here used, which represents a 60 degree deviation from a flat letter S, corresponds to the maximum possible change that may be effected by a rotation of the loop as a whole, the rotation for this maximum change being 90 degrees. The physical explanation of this phenomena is contained in the statement of invention and will not be repeated at this place. The bar joining the component loops would generally be coincident with the skew axis but it could, without substantial sacrifice be at an angle with respect to the same. Also the mounting would ordinarily and preferably be such that the planes of the component loops are normal to the next adjacent walls of the tubes on which they are mounted. Also, although the simple compact structure shown commends itself to practical use the principle governing its mode of operation would be consistent with the component loops being far separated but having the necessary integral functional relationship by a connecting mechanical movement.

Although specific embodiments of the invention have been shown and described, it will be understood, of course, that they are but illustrative and that various modifications may be made therein without departing from the scope and spirit of this invention as defined in the appended claims.

What is claimed is:

1. A tunable cavity resonator comprising a tuning plunger having its periphery conformable generally with the inner cooperating wall of the resonator, a clamping member adjustably related to said plunger and having a cut-out peripheral

conformity so as to define a space between said plunger, clamping member and wall, and a resilient element positioned to completely electromagnetically seal the said space between said plunger, clamping member, and wall and provide a good electrical connection therebetween, said element comprising a fabric-like conductive outer member with an interior cushion of resilient material.

2. A tunable cavity resonator comprising a tubular wall portion, a closure element at one end, and a tuning plunger comprising the remainder boundary structure, said plunger comprising two peripheral elements at least one of which is beveled at the corner opposite to the other, so as to define a space between the tubular wall and themselves, means connecting said elements at a plurality of peripherally spaced points and adapted to adjust the longitudinal spacing therebetween and therefore the extent of said space, and a resilient element positioned to completely electromagnetically seal said space and to provide a good electrical connection between wall and plunger, said resilient element comprising a fabric-like conductive member with an interior cushion of resilient, non-conductive material.

3. The structure defined in claim 2 in which said resilient element comprises a braided metal

sheath enclosing the cushion, the whole simulating in apearance a conductive sheathed section of insulated conductor, and adapted to be wrapped around the plunger and compressed in the space between said relatively adjustable peripheral elements.

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