Feb. 2, 1965 C. D. HARRISON 3,167,886

LAPPING DEVICE

Filed Dec. 22, 1961 2 Sheets-Sheet 1

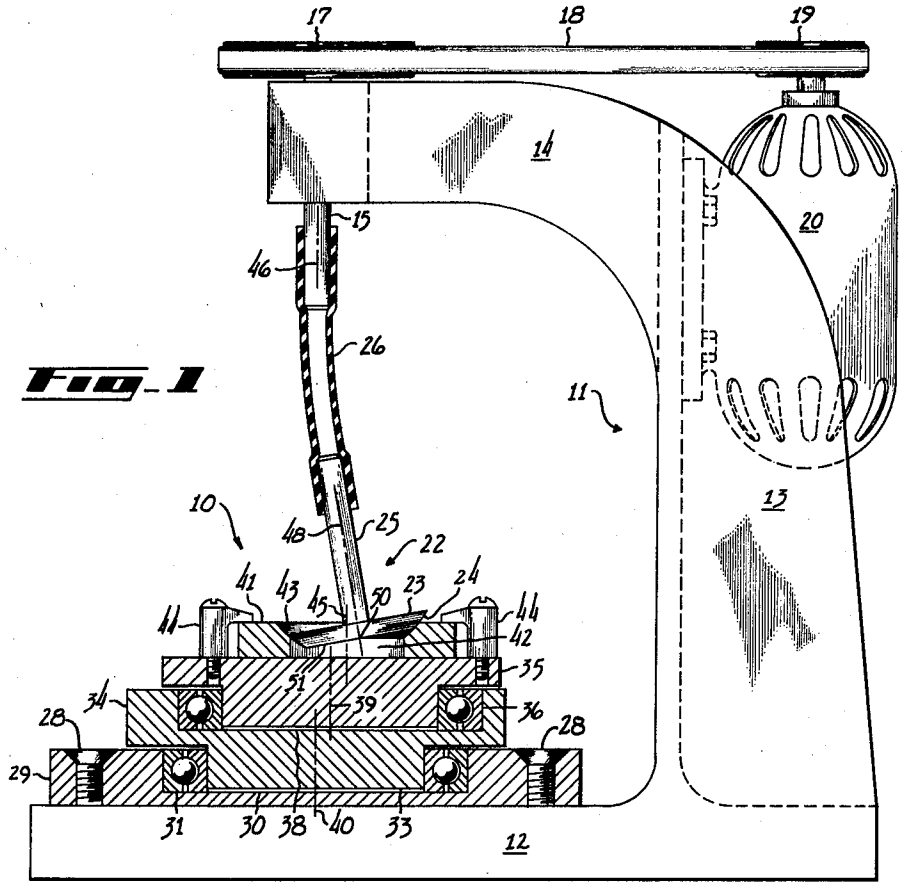
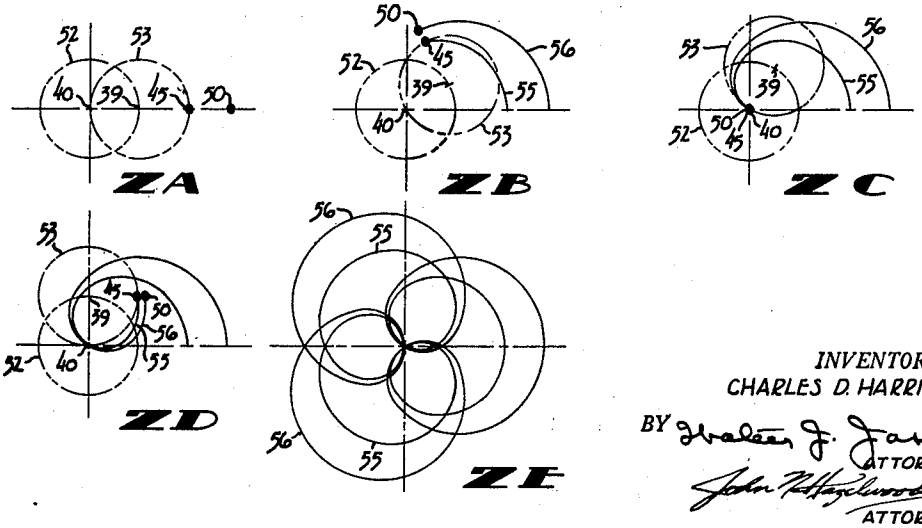


Fig. 1

Fig. 2



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Filed Dec. 22, 1961 2 Sheets-Sheet 2

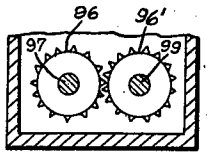


Fig. 4

Fig. 3

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United States Patent Office 3,167,886 Patented Feb. 2, 1965

3,167,886

LAPPING DEVICE

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Filed Dec. 22, 1961, Ser. No. 161,527
4 Claims. (Cl. 51—26)

The present invention relates generally to lapping devices, and more particularly to a device adapted for lapping objects having spherical surfaces.

There are numerous objects on which it is advantageous to form close tolerance spherical surfaces. For example, such spherical surfaces are commonly employed on valves and valve seats, ball and socket joints, races for self aligning bearings and lenses for various optical instruments, to mention but a few.

Presently available lapping machines, while differing from each other slightly in construction, employ essentially the same functional elements and operate much in the same manner. In general, either the part to be lapped or the lapping tool is mounted eccentrically upon a spindle, gear or pulley such that the axis of the lapping tool interesects the axis of the part at an angle. During operation of the machine the axis of one of the above members circumscribes a conical surface, the angle between the respective axes remaining constant. This arrangement causes a wiping action, as well as relative rotation, to occur between the two members.

The preferred form of the present invention, comprises a doubly eccentric arrangement of freely rotatable members operating in conjunction with a lapping tool for engaging the part to be lapped and a driving means for effecting relative rotation between the part, the lapping tool and the rotatable members.

An advantage of the subject lapping device, as contrasted with the above described lapping devices, is that it provides for a spiral motion between the part and the lapping tool, i.e., the angle between the axes of the part and the lapping tool changes constantly, varying from a maximum to a minimum, the latter corresponding to a position wherein the axes are coincident. This type motion results in a more perfectly spherical surface having an exteremely fine finish. Other advantages of this lapping tool are its simplicity of construction and operation.

It is, therefore, an object of the present invention to provide a device for lapping spherical surfaces.

Another object is to provide a device for lapping spherical surfaces which will effect a spiral motion between the part being lapped and the lapping tool.

Another object resides in the provision of a device for lapping spherical surfaces which is imple in construction and operation.

These and other objects and advantages will be apparent to those skilled in the art upon consideration of the following description of the appended drawings wherein:

FIGURE 1 is an elevation view, partly in section, of an embodiment of the invention as adapted for lapping the spherical surface of a valve;

FIGURE 2 is a series of diagrammatic representations, 2A, 2B, 2C, 2D, and 2E, of the motion of the centerlines of the lapping tool and valve shown in FIGURE 1;

FIGURE 3 is an elevation view, partly in section, of a device adapted for lapping two ball and socket joints simultaneously; and

FIGURE 4 is a cross-sectional view of the gear drive taken on the line 4—4 of FIG. 3.

Referring now to FIGURE 1 of the drawings, the lapping device of the present invention, generally indicated by the numeral 10, is shown as it may be mounted upon a supporting structure 11, the latter including a lower horizontal portion 12, an integral upright portion 13 and an upper horizontal portion 14 which carries a rotatable spindle 15 having a pulley 17 affixed to its upper end. A V-belt 18 connects such pulley 17 with another pulley 19 which is attached to the shaft of an electric motor 20 mounted on the upright portion 13 of the supporting structure. The part to be lapped, in this instance a valve 22 including a body portion 23 having a spherical surface 24 and an integral stem portion 25, is attached to the spindle by means of a flexible, variable length member 26. It is desirable that member 26 be of variable length in order that it be capable of imposing a continuous downwardly directed force upon the valve 22 as same bears against the lapping tool. As will presently become apparent, the variable length feature of member 26 arises out of a requirement to accommodate a variation in distance between the driving means and the valve as it bears against the lapping tool during the lapping operation. There are several devices which may be employed to attach the valve to the spindle. However, for the sake of simplicity, it has been found desirable to employ a section of fabric reinforced, rubber hose, such as ordinary welding hose which, by virtue of its resilience, offers the desired continuous downwardly directed force upon the valve. The internal diameter of the hose is slightly smaller than the diameters of the spindle and valve stem so that friction therebetween assures a common angular velocity.

To the lower horizontal portion 12 of the supporting structure there is affixed, by means of bolts 28, a stationary member 29. A circular cavity 30 is formed in such member 29 wherein is disposed a bearing 31. Within the inner race of such bearing is positioned the journal 33 of a first, or lower, rotatable member 34. In order to assure free rotation of member 34, it is necessary to provide clearance between the lower surface of journal 33 and the bottom of cavity 30, as well as between the under surface of the member 34 shoulder and the adjacent upper surface of stationary member 29. This may be accomplished most simply by making the diameter of the journal slightly larger than the inner diameter of the bearing inner race, so that the journal may be pressed or force fitted into the bearing to a level slightly above the latter's lower surface.

A second, or upper rotatable member 35 is similarly mounted in a lower rotatable member 34 by means of bearing 36 disposed within cavity 38. The centerline 39 of the upper rotatable member 35 is offset from the centerline 40 of lower rotatable member 34 so that an eccentric relationship is established therebetween. On the upper surface of rotatable member 35 is mounted a lapping tool 41 having a central bore 42 merging at its upper end in a flared concentric spherical surface 43 adapted to engage surface 24 of valve 22. Clamping devices 44 are employed to affix the lapping tool in position. The centerline 45 of the lapping tool bore is offset from the centerline 39 of the upper rotatable member 35, thereby introducing a second eccentric relationship into the lapping device.

In the form of the invention illustrated in FIG. 1 the geometric relation between the members of the lapping device are as follows: the centerline 40 of the lower rotatable member 34 is colinear with the centerline 46 of spindle 15; and the centerline 45 of lapping tool 41 is offset from the centerline 39 of upper rotatable member 35 by a distance which is preferably equal to the distance separating the latter from the centerline 40 of the lower rotatable member 34, for a purpose to be explained below. With the centerlines 39, 40, 45, and 46 positioned in a common vertical plane, the condition of FIGURE 2A, the centerline 48 of valve 22 lies in the same plane and

is disposed at a maximum angle relative to the vertical, as in FIGURES 1 and 2A. As will be explained below, during operation of the machine the valve 22 and lapping tool 41 follow paths which spiral inwardly from this assumed initial position of FIGURES 1 and 2A to the positions shown in FIGURE 2C, in which latter the centerlines thereof are colinear with centerlines 40 and 46 of lower rotatable member 34 and spindle 15, respectively. Such a position of valve 22 corresponds to a zero angle between the valve centerline and the vertical.

The length of the hose 26 is initially adjusted such that there is a continuous downward force exerted upon the valve by virtue of longitudinal compressive stresses within the hose induced as the valve bears against the lapping tool 41. Conventional lapping compound is employed between the valve and lapping tool and it is to be understood that such pressure is not great enough to set up frictional forces between the valve and lapping tool sufficient to lock them together and prevent relative rotation therebetween. Thus rotation of the valve at a given rotational velocity, by actuation of electric motor 20, results in a somewhat slower rotation of the lapping tool and upper rotatable member 35 because of the slippage permitted between the tool and valve. Rotation of member 35, in turn, causes a still slower rotation of lower rotatable member 34, as a result of frictional forces within bearing 36. As heretofore indicated, the paths of the centerlines 45 and 48 of lapping tool 41 and valve 22, respectively, are schematically illustrated in FIGURE 2. Since centerline 48 is normally angularly disposed with respect to the vertical, and not readily projectable in a horizontal plane, for purposes of illustration a point 50, corresponding to the point at which centerline 48 intersects the lower surface 51 of the valve, is used to show the path of such centerline.

Referring now to FIGURE 2A which corresponds to the positions of the respective centerlines shown in FIGURE 1, during operation of the present lapping device the centerline 39 of the upper rotatable member revolves about centerline 40 of the lower rotatable member in a circular path indicated at 52. The centerline 45 of bore 42, in turn, also follows a circular path 53 about centerline 39. The point 50 is located in the same plane as centerlines 39, 40, 45, in the initial position shown in FIGURE 2A. It has been found that in general a satisfactory ratio between the rotational velocities of the upper rotatable member 35 and the lower rotatable member 34 is approximately four-to-one. It is to be noted that the effectiveness of the present invention in accomplishing its intended purpose is not dependent upon such a relationship, and that the invention is not limited thereto since this ratio may vary over a relatively wide range.

Assuming a four-to-one ratio, and counterclockwise rotation of the members, when the centerline 39 has rotated through 30 degrees about centerline 40, the centerline 45 and point 50 have revolved 120 degrees about centerline 39. The resultant paths of centerline 45 and point 50 are indicated at 55 and 56, respectively, in FIGURE 2B. It will be noted that the distance separating centerline 45 and point 50 in FIGURE 2B is less than their original separation as shown in FIGURE 2A. This results from a decrease in the angle between the centerline of the valve and the vertical. After 60 degrees rotation of centerline 39, and 240 degrees rotation of centerline 45 and point 50, the paths of the latter appear as in FIGURE 2C. By making the distance between the centerline 45 of the lapping tool 41 equal to the distance separating the latter from the centerline 40 of the lower rotatable member 34, at this stage the centerline of the valve extends in a vertical direction and point 50, as well as the lapping tool bore centerline 45, coincides with centerline 40 of the lower rotatable member and with the centerline of the spindle; and the separation between centerline 45 and point 50 has been reduced to zero. Thus during a lapping operation, the relationship between the valve and lapping tool varies between one of maximum eccentricity, as in FIGURE 2A, and one of zero eccentricity, as in FIGURE 2C. The paths traversed by centerline 45 and point 50 in traveling from the positions shown in FIGURE 2A to that shown in FIGURE 2C are seen to be generally spiral in form. After passing through the positions of FIGURE 2C, the centerline 45 and point 50 begin to separate and spiral outwardly as shown in FIGURE 2D. The complete paths of such centerline 45 and point 50 are shown in FIGURE 2E, as indicated at 55 and 56, respectively.

From the foregoing description of the respective paths of the valve and lapping tool, it may be readily seen that, in addition to relative rotation between these two members, there also occurs a "wiping" action, i.e., relative movement therebetween transverse to the axis of rotation of the lapping tool. Such wiping action prevents the formation of grooves on the valve's spherical surface, thereby assuring the formation of a smoothly lapped surface.

Although the lapping device illustrated in FIGURE 1 has been described in conjunction with the lapping of a valve, it will be apparent to those skilled in the art that this device may also be employed to lap a valve seat, or to lap simultaneously both a valve and a valve seat, the latter arrangement being desirable in applications wherein an extremely close tolerance fit between matching surfaces is required to effect a virtually perfect seal at the valve-valve seat interface.

Referring now to FIGURE 3 there is shown another embodiment of the invention adapted for lapping simultaneously two ball and socket joints. This lapping device includes a supporting structure 61 which is preferably in the form of a box, one face of which is open. A main drive shaft 62 extends between the two opposite vertical sides 65, 66. One end of the drive shaft 62 extends beyond the side 65 of the supporting structure and has a main drive pulley 67 affixed thereto. Such pulley 67 is connected, by means of a V-belt 68, with another pulley 69 on the shaft of an electric motor 70 mounted on the top of the supporting structure 61. On the inside of the supporting structure there is affixed to the main drive shaft pulleys 71, 72 and 73. The pulley 71 is connected by means of V-belt 74 with a pulley 75 affixed to a shaft 76, the latter being journaled within a bearing 77 in side 65 of the supporting structure 61. Pulley 72 is connected with a large pulley 79 by V-belt 80, such large pulley 79 being rotatable about shaft 76 by virtue of a bearing 81 disposed therebetween. Near the edge of the large pulley 79 an aperture 82 is formed wherein is positioned a bearing 83. Extending through such bearing 83 is a shaft 85 to the inner end of which is attached a plate 86. To this plate is affixed by means of clamping devices 89 one of the socket portions 87 of the assembled joint 88 to be lapped. To the opposite end of shaft 85 is attached a pulley 91 which is connected, by means of V-belt 92, to another pulley 93 which is preferably integrally connected with pulley 75.

From the foregoing description of the construction of the left hand members of the lapping device shown in FIGURE 3 it may be seen that actuation of the electric motor 70 results in the rotation of the main drive shaft 62 and pulleys 71, 72 which, in turn, drive integrated pulleys 75 and 93, and pulley 79, respectively. Rotation of pulley 93 is transmitted through V-belt 92 to pulley 91, thence to plate 86 and socket 87. Because of the relationship between the diameters of the respective pulleys, the pulley 79 rotates at a relatively slow rate with respect to pulley 91. Thus while the joint 88 is being rotated in an orbit about the centerline of shaft 76, the socket portion 87 thereof also rotates about the shaft 85, but at a considerably greater angular velocity.

The construction of the right hand portion of the lapping device is essentially the same as that of the left hand portion. Thus the components on the right are

designated by the same numerals as were used above to identify their counterparts on the left, the subscript "*a*" being added to the right hand numerals to differentiate between the two sides.

In order to achieve a greater wiping action during the lapping operation, it is desirable that the pulleys of the right hand portion be rotated in a direction opposite to the rotation of those on the left. This may be effected by means of a small gear box **95**, attached to the upper horizontal portion of the supporting structure **61**, and enclosing a first, or input, gear **96** having an input shaft **97** integrally connected thereto, and a second, or output, gear **96'** having an output shaft **99** integrally connected thereto, the right hand end of the latter being rotatably supported in the right hand vertical member of supporting structure **61**. The input shaft **97** is connected, by means of a pulley **101** and V-belt **102**, to pulley **73** on main drive shaft **62**, such that the input gear rotates in the same direction as the latter. The output gear and the output shaft **99**, therefore, rotate in the opposite direction. Affixed to the output shaft **99** are pulleys **71***a* and **72***a*, the former being connected to pulley **75***a* by V-belt **74***a*, the latter being connected to large pulley **79***a* by V-belt **80***a*. Thus, as may be readily seen, pulleys **75***a*, **79***a*, **91***a*, **93***a*, as well as plate **86***a* and socket **87***a*, rotate in the opposite direction from their counterparts in the left hand portion. As will be apparent to those skilled in the art, the oppositely directed rotation between the right and left hand members of the lapping device is not a requisite condition for the satisfactory operation thereof. All that is required is relative rotation between such right and left hand members. For example, by employing a pulley to drive large pulley **79***a* whose diameter is somewhat larger than pulley **72**, relative rotation between large pulleys **79**, **79***a* would be effected and, consequently, lapping of the joints would occur.

After mounting the assembled socket portions **87**, **87***a* of the ball and socket joints **88**, **88***a* upon the mounting plates **86**, **86***a*, respectively, the ball portions **105**, **105***a* of the joints are connected with an expansible member **106** which includes a pair of stem members **107**, **107***a*, the outer ends of which are threadably engaged with balls **105**, **105***a*, respectively. The inner ends of such stem members are enlarged, as indicated at **108**, **108***a*, and are retained within a tube **109** comprising a pair of sleeve members **110**, **110***a* aligned end to end and threadadly connected by means of an intermediate collar member **111**. To the outer ends of members **110**, **110***a* are connected apertured cap members **112**, **112***a*. A spring **113** is disposed within the tube **109** between ends **108**, **108***a* of stem members **107**, **107***a* which serves to bias the latter outwardly, thereby causing a continuous bearing force between the ball portions **105**, **105***a* and the socket portions **87**, **87***a* of the joints **88**, **88***a*. Conventional lapping compound is employed intermediate these ball and socket portions. The internal diameter of tube **109** is slightly larger than that of stem enlargements **108**, **108***a* such that the latter are freely slidable therein. This interconnection between the ball portions of the joints, in conjunction with the eccentric mounting of the joints upon pulleys **79**, **79***a*, provides the desired doubly eccentric relationship between the rotatable members of the lapping device.

Since the large pulleys **79**, **79***a* are rotated in opposite directions during operation of the lapping devices, the linear separation between the ball and socket joints varies constantly between a maximum separation and a minimum separation, the former corresponding to the positions shown by full lines, and the latter corresponding to the positions shown by the broken lines at **114** and **114***a*. This variation in separation between the joints is made possible by the slidable relation between the stems **107**, **107***a* and the tube **109**. Such maximum and minimum linear separations correspond respectively to maximum and minimum angular separations between the axis of the ball and the axis of the socket. As will be apparent, with the pulleys **79**, **79***a* rotating in opposite directions, preferably at the same speed, the total angle through which the balls move relative to the sockets is equal to twice the maximum angular separation therebetween.

Although the ball portions of the joint are free to rotate with respect to tube **109**, they are prevented from rotating at the same rate as the socket portions by the wiping action resulting from the constant angular variation therebetween resulting from the wobble action of the tube. Thus, during operation of this lapping device, there occurs both a relative rotation and a wiping action between the ball and socket portions of the joints. The combination of these two types of motion results in surfaces which are virtually perfectly spherical and have an extremely fine finish.

While it is not required for the satisfactory operation of the lapping device shown in FIGURE 3, it is desirable that the shafts **76**, **76***a*, about which the large pulleys **79**, **79***a* rotate, be axially aligned, and that the shafts **85**, **85***a*, about which the socket portions **87**, **87***a* of the joints **88**, **88***a* rotate, be spaced from the shafts **76**, **76***a*, respectively, by equal distances. Such alignment and spacing results in the centerlines of the sockets **87**, **87***a* and the centerlines of the balls **105**, **105***a* coinciding when same are in positions **114**, **114***a*. By so reducing the minimum angle between such centerlines to zero, greater wiping angle is achieved between the ball and socket portions of the joints **88**.

Although only certain preferred embodiments of the invention have been herein shown and described, it is not to be construed that the invention is limited thereto, as numerous modifications will be apparent to those skilled in the art, and the invention is to be given the broadest possible interpretation within the terms of the following claims.

What I claim is:

1. In a device for lapping simultaneously two ball and socket joints each comprised of a ball and a socket portion, the combination of a supporting structure having opposite wall portions, a pair of relatively large rotatable members mounted on said wall portions facing each other, mounting means carried by each of said members for rotation about axes displaced from the axes of rotation of said rotatable members for mounting each of the ball and socket joints thereon to permit relative rotation between their respective ball and socket portions, variable length means interconnecting the ball portions of the joints while biasing said portions against the socket portions and imparting a wobble action to said ball portions, and driving means for effecting said relative rotation between said ball and socket portions and for effecting the said wobble action of said interconnecting means by driving said large rotatable members in rotation relative to each other.

2. In a device for lapping simultaneously two ball and socket joints each comprised of a ball and a socket portion, the combination of a supporting structure having opposite wall portions, a relatively large rotatable member mounted on each of said wall portions, a rotatable mounting means eccentrically positioned on each of said large rotatable members for mounting the ball and socket joints, variable length means interconnecting said ball and socket joints, a first drive shaft for driving one of said large rotatable members in one direction, a second drive shaft for rotating the other said large rotatable member in the opposite direction, means associated with each of said mounting means for rotating said mounting means and the socket portions of said joints relative to said large rotatable means.

3. A device for lapping ball and socket joints comprising, in combination, a support structure including a pair of spaced apart support members, a rotatable member mounted upon each of said support members, rotatable

mounting means eccentrically carried upon each of said rotatable members and at least one of which includes provision for mounting a ball and socket joint comprised of ball and socket portions to permit relative swivel movement between the said ball and socket portions, variable length means interconnecting said rotatable mounting means being connected through said ball and socket joint to one of said rotatable mounting means and at its other end also permitted swivel movement, said variable length means including means maintaining the said ball and socket joint portions in abutment, and driving means for effecting said relative swivel movement between said joint portions by driving said rotatable members in rotation relative to each other and said rotatable mounting means in rotation relative to said rotatable members.

4. A device for simultaneously lapping two ball and socket joints comprising, in combination, a support structure including a pair of spaced apart support members, rotatable members mounted upon said support members, mounting means carried by each of said rotatable members for rotation about axes displaced from the axes of rotation of said rotatable members, said mounting means

each including provisions for mounting ball and socket joints comprised of ball and socket portions to permit relative swivel movement between the said ball and socket portions, variable length means operably interconnecting said rotatable mounting means through said ball and socket joints and provided with means for biasing the said ball and socket joint portions into abutment for lapping coaction, and driving means for effecting said relative swivel movement between said joint portions by driving said rotatable members in rotation relative to each other and said rotatable mounting means in rotation relative to said rotatable members.

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