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A. FINLAY, JR., ET AL
MULTIPLE-CONTACT SWITCH

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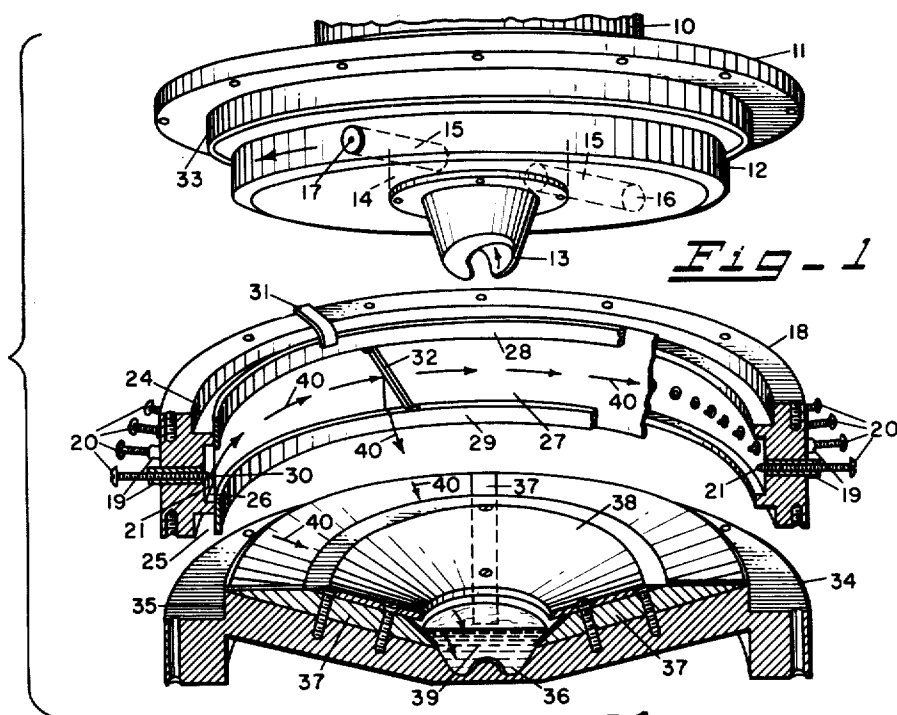


Fig - 1

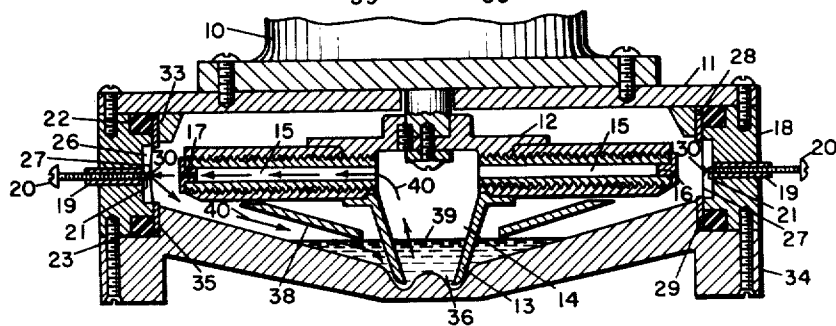


Fig - 2

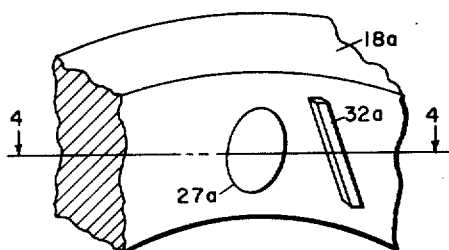


Fig - 3

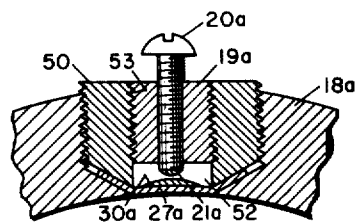


Fig - 4

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MULTIPLE-CONTACT SWITCH

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This invention relates to electrical switches. It has to do more particularly with a novel multiple-contact switch that is mechanically driven and is capable of providing rapid switching with a minimum of noise.

A primary object of the present invention is to provide an electric switch having a large number of contacts and capable of scanning the contacts rapidly.

Another object is to provide a mechanically-operated high-speed switch having a low electrical noise level. The switch preferably should be small and light and should be low in its consumption of driving power.

A further object of the invention is to provide a switch having good electrical characteristics and good mechanical characteristics, and providing reliable operation.

Still another object is to provide a switch having improved high-speed low-noise-level electrical switching performance.

Switches available in the past have had various shortcomings. Electrically operated and magnetically operated switches have the disadvantage that the switching action itself produces an electrical output from the switch. In a typical switch using an electron tube, the switching element is maintained in an inactive or open-circuit condition by means of a negative cutoff voltage on a grid circuit. To close the circuit, the grid voltage is made more positive to a value at which electron flow is obtained in the plate circuit of the tube, producing an output from the switching device. Such a switch cannot be used in applications where the output produced by the switching is similar to the signal in the circuit in which the device is used to provide switching.

Another disadvantage is the necessity for uniformity of the switching devices. Transistors, crystal diodes, magnetic devices, electron beam switches, vacuum tubes, and similar devices can be assembled in groups of similar elements to produce multicircuit switches, but the output from such switching elements may be in the neighborhood of 1000 times as large as the signal in the circuit to which the switching is applied. A circuit can be designed to provide a voltage equal and opposite to that produced by the switching element and thereby cancel the output from the switching. If the cancellation circuit is placed at the output of the switch in such a way as to be common to all of the circuits, each switching element must be identical to all the other switching elements to a degree less than the order of magnitude of the signal in each circuit to be switched. Otherwise, false outputs are obtained. Even if a separate cancellation circuit is provided for each switching element, aging of components and other uncontrollable variations cause difficulty.

Mechanically operated switches avoid the difficulties of large electrical output and need for uniformity. Sliding contact commutator-type switches, capacitive-type switches, and switches utilizing rotating jets of mercury as the moving elements can be used for multiple-contact switching.

Although much work has been done in the past to reduce the noise caused by sliding contacts, switches of the

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sliding-contact commutator-type have high noise levels. Another disadvantage of sliding-contact-type switches is their inability to operate at high speeds.

Tests made on capacitive-type switches rotated at high speeds showed the presence of noise signals of large amplitude that would seriously interfere with any signal present in the circuits in which such switches might be connected. The noise apparently is generated while the capacitor plates are mashed and is believed to be caused by friction between the rotating member of the switch and air and dust particles in the switch. The noise amplitude is roughly proportional to speed. At a rotational speed of about 3000 R. P. M., the noise voltage has a value equivalent to a signal input of about 3 millivolts. The noise level in capacitive-type switches is more than 10 times as great as the noise level in switches according to the present invention.

Rotating mercury jet switches can be operated at high speeds. In a typical rotary mercury jet switch, mercury from a pool is driven by a rotor producing, by centrifugal force, a continuous outward stream of mercury that impinges upon contact members spaced around the periphery of the switch. When the stream impinges on a contact member, an electrical circuit is completed through the contact member to the mercury jet to the rotor and through the mercury pool to the base of the switch. With contacts arranged in a circle around the periphery of the switch, sequential closing of a plurality of circuits can be obtained. In such a switch there is relatively little noise until the time just preceding contact closure, when the random noise increases to about 1 millivolt. A large random noise pulse is produced upon closure of the contact and the pulse continues for a period at least three to four times the length of the closed circuit interval. The maximum amplitude of the noise pulse may be as high as 2 or 3 millivolts.

The noise present just prior to contact closure appears to be the result of friction between the rotating mass of air in the switch and the contact member. The random noise pulse is caused by splash of the mercury. This splash is relatively insignificant before contact closure but when the mercury jet strikes the contact member, considerable splash and breakup of the mercury stream result. It appears that when a large body of mercury breaks up, the small particles produced acquire random charges and random polarity, despite the fact that the original body of mercury is neutral. It is not known whether this is a normal result of the breakup of a larger body or whether the charge is produced by friction with the atmosphere. In a multiple-contact switch, the splash from one contact member causes increased noise preceding the closure of nearby contacts. The noise in a rotary mercury-jet switch can be reduced slightly by improving the mechanical design, but the noise generated is excessive even with optimum design.

An object of the present invention is to avoid the disadvantages and limitations of the types of switches described above.

Another object is to provide a low-noise, high-speed rotary switch in which the motion of the switch elements is small and in which the switch elements are electrically shielded from the fast-moving members and materials producing the switching action, and in which the contact members are not exposed to the rotating atmosphere inside the switch.

The foregoing and other objects and advantages are provided by the invention disclosed herein.

A switch according to the present invention comprises a plurality of contacts, diaphragm means comprising electrically conducting material spaced from the contacts in the absence of flexure, and means for providing in successive portions of said diaphragm means flexure toward

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the contacts to provide electrical contact between the diaphragm means and each of the contacts successively.

In a preferred form of switch according to the present invention, the centrifugal force from a rotating jet of mercury impinges against a thin metal diaphragm causing the diaphragm to deflect and to make electrical contact with another contact element to close the switch and complete an electrical circuit. As the rotating mercury jet passes the region adjacent a contact element, the diaphragm springs back away from the contact element opening the switch and breaking the electrical circuit. The jet of mercury does not comprise any part of the electrical circuit at any time, but is used only to provide the force that deflects the diaphragm and closes the circuit.

In the drawings:

Fig. 1 is an exploded perspective view, partly cut away, of a preferred form of switch according to the present invention;

Fig. 2 is a cross-sectional view of the switch of Fig. 1;

Fig. 3 is a perspective view, partly cut away, of a modified form of a portion of the switch; and

Fig. 4 is a cross-sectional view taken on the plane 4—4 of Fig. 3.

Referring to Figs. 1 and 2, a motor 10 of any convenient type, such as a universal series-type electric motor, mounted on a flat circular top housing member 11 is connected to drive a rotor 12 including a mercury pickup scoop 13. A vertical conical passage 14 through the mercury pickup scoop 13 and a radial passage 15 communicating therewith are provided in the rotor 12. One end of the radial passage 15 terminates in a solid wall 16, while the opposite end of the radial passage 15 terminates in a small orifice 17. The top housing member 11 is tightly secured as by screws to a cylindrical side housing member 18. Mounted in radial holes in the side housing member 18 are a plurality of annular sleeve insulators 19—19 made of any suitable insulating material. Mounted in each insulator 19 is a contact member 20 made of any suitable conducting material. The inner end of each contact member 20 preferably is coated with silver or other good contact material as is indicated at 21. The contact members 20—20 preferably are threaded, as shown in the drawing, so that the positions of the contact ends 21—21 can be accurately adjusted. Rubber O rings 22 and 23 fit snugly in the upper and lower annular recesses 24 and 25, respectively, of the side housing member 18. The contact ends 21—21 of the contact member 20—20 protrude into a central annular recess 26 in the side housing member 18.

A ring-shaped diaphragm 27 made of thin metal, preferably stainless steel, is rigidly secured as by spot welding to the outer surface of an upper support ring 28 and to the outer surface of a lower support ring 29. The diaphragm assembly 27, 28, 29 fits snugly inside the side housing 18 and the O rings 22, 23. The middle portion of the outer surface of the diaphragm 27, which is located opposite the contact ends 21—21 of the contact member 20—20, preferably is coated with silver or other good contact material as is indicated at 30. At least one grounding strap 31 provides electrical connection between the diaphragm assembly 27, 28, 29 and the housing members 11, 27. At least one deflector 32 is mounted against the diaphragm between the upper support ring 28 and the lower support ring 29 at a small angle, preferably about 30 degrees, from the vertical. An annular shoulder 33 on the top housing member 11 holds the upper support ring 28 of the diaphragm assembly 27, 28, 29 in fluid-tight assembly against the side housing member 18 and the upper O ring 22.

The side housing member 18 is tightly fastened as by screws to a bottom housing member 34 having an annular shoulder 35 that presses the lower support ring 29 of the diaphragm assembly 27, 28, 29 in fluid-tight assembly against the side housing member 18 and the lower O ring 23. The inner surface of the bottom housing

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member 34 is a shallow cone with an annular groove adjacent its apex, forming a mercury sump 36. Vertical radial baffles 37—37 are rigidly secured to the bottom housing member 34 and support a conical ring baffle 38 mounted thereon and spaced above the inner conical surface of the bottom housing member 34. The mercury sump 36 contains a pool of mercury 39.

The switch operates as follows:

The motor 10 drives the rotor 12 causing the mercury pickup scoop 13 to rotate in the mercury sump and to impart rotary motion to the mercury pool 39 therein. The centrifugal force resulting from the rotary motion of the mercury 39 causes it to be forced away from the center of rotation and, since the wall of the vertical passage 14 is conical with its largest diameter at the top, the mercury 39 is forced upward into the radial passage 15. At one end of the radial passage 15 the mercury is forced against the end wall 16, while at the other end of the radial passage 15 the mercury is forced through the orifice 17 providing a mercury jet having substantial pressure. The dead-end portion of the radial passage 15 is included merely to provide mechanical balance.

The continuous stream of mercury 39 provided by the centrifugal force of rotation through the orifice 17 impinges upon the annular diaphragm 27 in a horizontal path, deflecting the diaphragm outwardly against the successive contact members 20—20 as the point of impingement progresses around the diaphragm 27, providing successive closing of the respective circuits to which the contact members 20—20 are connected. After the mercury 39 impinges upon the diaphragm 27 it tends to continue in a horizontal path and to collect on the diaphragm, but it is deflected downward by the deflector 32 and flows down the conical inner surface of the bottom housing member 34 into the mercury sump 36, providing a continuous supply of mercury for the switch action. The conical ring deflector 38 protects the rotor 12 from the splashing of mercury upward from the inner surface of the bottom housing member 34. The vertical radial reflectors 37 interrupt the rotational component of motion of the mercury 39 preventing undesirable swirl as it flows back into the mercury sump 36. The flow of the mercury 39 in the switch is indicated by the arrows 40—40.

In this form of the switch using a single annular diaphragm, the diaphragm 27 provides a common connection through the ground strap 31 for each of the circuits to be switched, the contact members 20—20 comprising the other terminals for the respective switching circuits. The single annular diaphragm construction provides good economy of space. The deflection of the diaphragm 27 preferably is in the order of 0.004 inch. There is no apparent contact bounce or diaphragm oscillation after the mercury jet has excited a particular part of the diaphragm. It is believed that, because of the particular physical shape of the diaphragm, no resonance exists having a "Q" great enough to cause a sustained mechanical oscillation. A switch 5 to 6 inches in diameter having 100 contacts 20—20 can be operated with 50 to 60 percent total "on time," with each individual circuit closed from 0.5 to 0.6 percent of the time.

The noise generated in this switch is negligible, and can be minimized by providing a film of oil or similar material on the surfaces in the annular space bounded by the annular groove 26 and the diaphragm 27.

A typical embodiment of the switch of Figs. 1 and 2 has 100 contacts that can be scanned in 0.01 second. The electrical noise level is so low that it is masked by the noise generated in the amplifying equipment used to test the operation of the switch. The device is small, requires little power, and is reliable. The unit is 5½ inches in diameter and 1½ inches high, exclusive of the motor, and the entire unit, including the motor, weighs only 4 pounds, 2 ounces. The power consumption is 23

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watts. Tests show very clean and reliable contact operation with an on-time of about 50 to 60 microseconds, and with a current of about 50 microamperes flowing through the contacts. Tests of the noise level of the switch made using amplifying equipment having a noise level of about 10 microvolts peak over a band from about 20 cycles to 100 kilocycles showed that the noise level of the switch is less than 10 microvolts, as no noise was present above the noise level of the amplifying equipment itself. It is likely that the noise level of the switch is much less than 10 microvolts. Even if the noise level of the switch should be as high as 10 microvolts, it still would be much lower than that of any prior high-speed mechanical switch, and would be low enough for virtually any switching use. The switch was tested also for any possible interference between adjacent contacts. There was no measurable interference of any kind, even when one contact was energized with several millivolts and an adjacent contact was operated with no signal applied.

The ring and diaphragm assembly shown in Figs. 1 and 2 has important advantages. The diaphragm 27 preferably is spot welded to the outside surfaces of the relatively heavy rings 28, 29. This produces an annulus of diaphragm material with the heavy rings at the ends. The assembled member is fitted into the housing assembly with the upper and lower O-rings 22, 23 in the annular grooves 24, 25 providing a seal when the top housing member 11 and the bottom housing member 34 are secured to the side housing member or switch body 18. The switch elements are thus shielded mechanically and electrically from the fast-moving members and materials producing the switching action, and from the rotating atmosphere inside the switch. The components are fairly simple to fabricate and easy to assemble. The arrangement has the further advantage that the switch body or side housing member 18 is completely sealed from the mercury reservoir and can be made of a light material, such as aluminum, that need not be resistant to mercury.

Figs. 3 and 4 illustrate a modification of the switch, in which a separate diaphragm is associated with each contact member. The switch is identical to that shown in Figs. 1 and 2 except that the side housing member 18a is a simple annular member rectangular in cross section as is shown in Fig. 3, and each contact 20a is mounted as shown in Fig. 4. The side housing member 18a is made of metal and comprises a common switch connection for all of the circuits to be switched. A threaded hole tapered at the inside end as shown in Fig. 4 is provided for each contact member in the side housing member 18a. A unit diaphragm 27a shaped like a tiny pie pan having a flat circular body and a shallow conical periphery is mounted in the tapered hole so as to be flush with the inner surface of the side housing member 18a. Each diaphragm 27a preferably is coated in the region of contact with silver or other good contact material as indicated at 30a. A threaded metal plug 50, tapered at the end, holds the diaphragm firmly in place, and in electrical contact with the side housing member 18a. The metal plug 50 is provided with a cylindrical recess 52, a portion of which is threaded as is indicated at 53. An insulator sleeve 19a is held in the threaded portion 53 of the metal plug 50, and the contact member 20a is held in the insulator sleeve 19a. The contact member 20a preferably is threaded as shown so that adjustment can be made of the position of the contact end, which preferably is coated with silver or other good contact material as indicated at 21a. The contact assemblies are mounted at spaced intervals along the center plane of the side housing member 18a just as the contact assemblies are mounted in the side housing member of Fig. 1. The combination of the side housing member 18a with its associated diaphragm and contact assemblies is substituted for the combination of the side housing member 18 with its associated assemblies comprising the middle assembly shown in the exploded view of Fig. 1.

The operation of the switch incorporating the modifica-

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tion shown in Figs. 3 and 4 is identical to the operation as described in Figs. 1 and 2 except that, instead of providing a continuous moving deflection as on the annular diaphragm of Figs. 1 and 2, the rotating jet of mercury provides deflection of one unit diaphragm 27a providing contact with its associated contact member 20a, then impinges upon a portion of the inner wall of the side housing member 18a, then provides deflection of the next unit diaphragm 27a and so on to the rest of the diaphragm contact assemblies. The side housing member 18a may have at least one deflector 32a to deflect the mercury downward into the mercury sump as does the deflector 32 of Fig. 1. Adequate damping of the motion of the diaphragm 27a is obtained by applying a coating of silicone varnish or the like to the contact side of the diaphragm 27a, which is not subject to the abrading action of the mercury jet. A baked-on layer of varnish about 0.008-inch thick provides sufficient damping to avoid any objectionable oscillation.

To provide switching of a larger number of circuits, switches according to the present invention may be ganged using a single driving motor in obvious ways, or they can be operated in parallel, each switch having its own motor. More than one jet of mercury can be used where it is desired to close the circuits more than once during a single rotation of the rotor. More than one row of contact members can be included in the same switch with at least one jet of mercury provided for each row of contacts, and with either the contacts or the mercury jets or both staggered where desired, depending upon the particular switching needs. In any application where it might be necessary to provide switching of circuits not having a common ground or other common connection, a thin layer of insulation can be provided in the region of contact on the diaphragm of either illustrated form of the invention, and a small contact can be mounted thereon opposite each fixed contact member and connected by a flexible insulated conductor to an insulated binding post on the outside of the switch housing. While the forms of the invention herein disclosed constitute preferred embodiments, it is not intended herein to describe all of the possible equivalent forms or ramifications of the invention. It will be understood that the words used are words of description rather than of limitation and that various changes, as in shape, relative size, and arrangement of parts, may be made without departing from the spirit or scope of the invention herein disclosed.

What is claimed is:

1. A switch comprising: a plurality of spaced contacts arranged in a circle; thin metal diaphragm means closely spaced inwardly from said contacts in the absence of flexure and capable of flexing outwardly into electrical contact with said contacts; and means for applying rotary motion to a liquid and for directing said liquid in a rotating jet by virtue of centrifugal force to impinge against successive portions of said diaphragm means adjacent said contacts to provide outward flexure thereof toward said contacts and to provide contact between said diaphragm means and each of said contacts successively.
2. A switch according to claim 1, in which said diaphragm means comprises an annular diaphragm member.
3. A switch according to claim 1, in which said diaphragm means comprises a plurality of spaced diaphragm members arranged in a circle, with each said diaphragm member located adjacent one of said contacts.
4. A rotary jet-actuated switch comprising: a cylindrical housing; a plurality of contact members mounted in and insulated from said housing, arranged in spaced relationship in a circle with their contact surfaces facing inward; an annular diaphragm in said housing located adjacent said contact surfaces of said contact members, with the outer surface of said diaphragm closely spaced from said contact surfaces; a sump containing a liquid in said housing; other means including a pick-up scoop

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immersed in said liquid and having a passage therein for conducting liquid from said sump by means of centrifugal force and communicating with an orifice in said rotor for directing a jet of said liquid against said diaphragm toward said contacts; and means for rotating said rotor; wherein liquid from said sump is driven by centrifugal force through said passage and through said orifice to impinge against said diaphragm along a line adjacent to said contact surfaces, progressively flexing said diaphragm into contact with each of said contact surfaces in succession.

5. A switch according to claim 4, including means for conducting said liquid back to said sump after impingement against said diaphragm.

6. A switch according to claim 5, in which said last-mentioned means comprises at least one deflector adjacent to said diaphragm so positioned as to deflect said liquid downward from said diaphragm and at least one radially positioned baffle for reducing swirl in said liquid as it returns to said sump.

7. A switch according to claim 4, in which said annular diaphragm is rigidly secured to a supporting ring at each end, and in which liquid-tight sealing means are provided between each end of said supported diaphragm and said cylindrical housing, whereby the contacting portions of said switch are isolated from said liquid and from the rotating atmosphere in said switch.

8. A switch according to claim 4, in which said annular diaphragm has a film of oil on its outer surface.

9. A rotary jet-actuated switch comprising: a cylindrical housing; a plurality of contact members mounted in and insulated from said housing, arranged in spaced relationship in a circle with their contact surfaces facing inward; a plurality of spaced diaphragms arranged in a circle in said housing with each said diaphragm located

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adjacent the contact surface of one said contact member, and with the outer surface of each said diaphragm closely spaced from said contact surface; a sump containing a liquid in said housing; rotor means including a pick-up scoop immersed in said liquid and having a passage therein for conducting liquid from said sump by means of centrifugal force and communicating with an orifice in said rotor for directing a jet of said liquid against said diaphragms toward said contacts; and means for rotating said rotor; wherein liquid from said sump is driven by centrifugal force through said passages and through said orifice to impinge against said diaphragms along a line adjacent to said contact surfaces, successively flexing said diaphragms into contact with each of said contact surfaces.

10. A switch according to claim 9, including means for conducting said liquid back to said sump after impingement against said diaphragms.

11. A switch according to claim 10, in which said last-mentioned means comprises at least one deflector adjacent to said housing in the line of impingement of said liquid so positioned as to deflect said liquid downward toward said sump and at least one radially positioned baffle for reducing swirl in said liquid as it returns to said sump.

12. A switch according to claim 9, in which each said diaphragm has a coating of silicone varnish on its outer surface.

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