Oct. 3, 1950 N. B. WALES, JR 2,524,213

GASEOUS DISCHARGE TUBE SYSTEM

Original Filed June 18, 1947 2 Sheets-Sheet 1

Fig. 1.

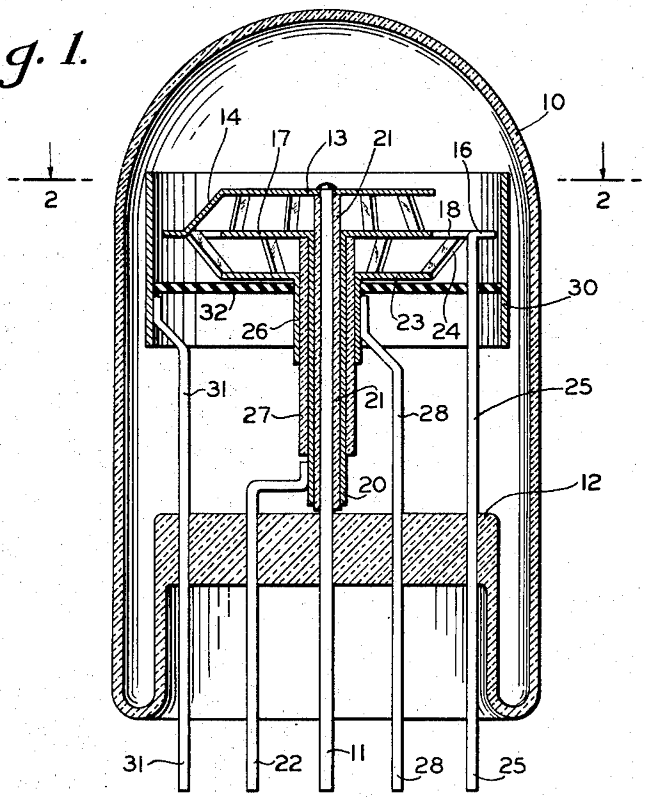
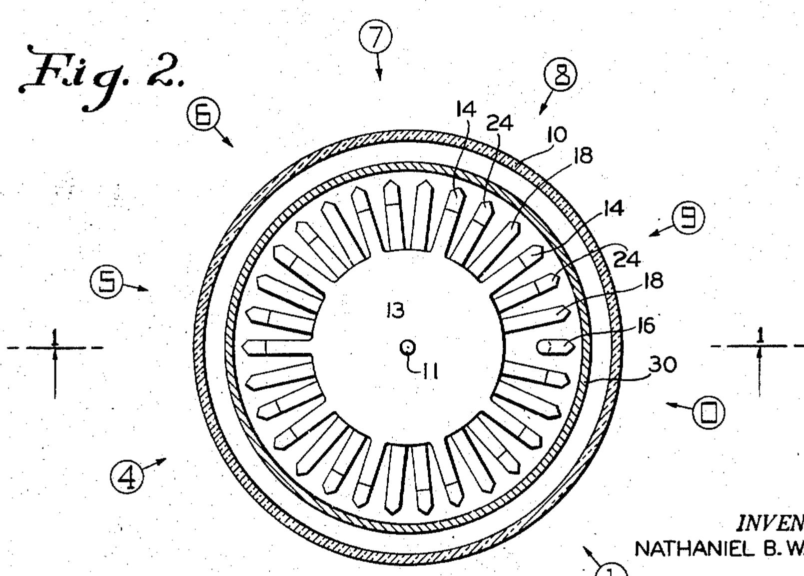


Fig. 2.



INVENTOR.
NATHANIEL B. WALES JR.

ATTORNEY.

Ralph H. E. Bitner.

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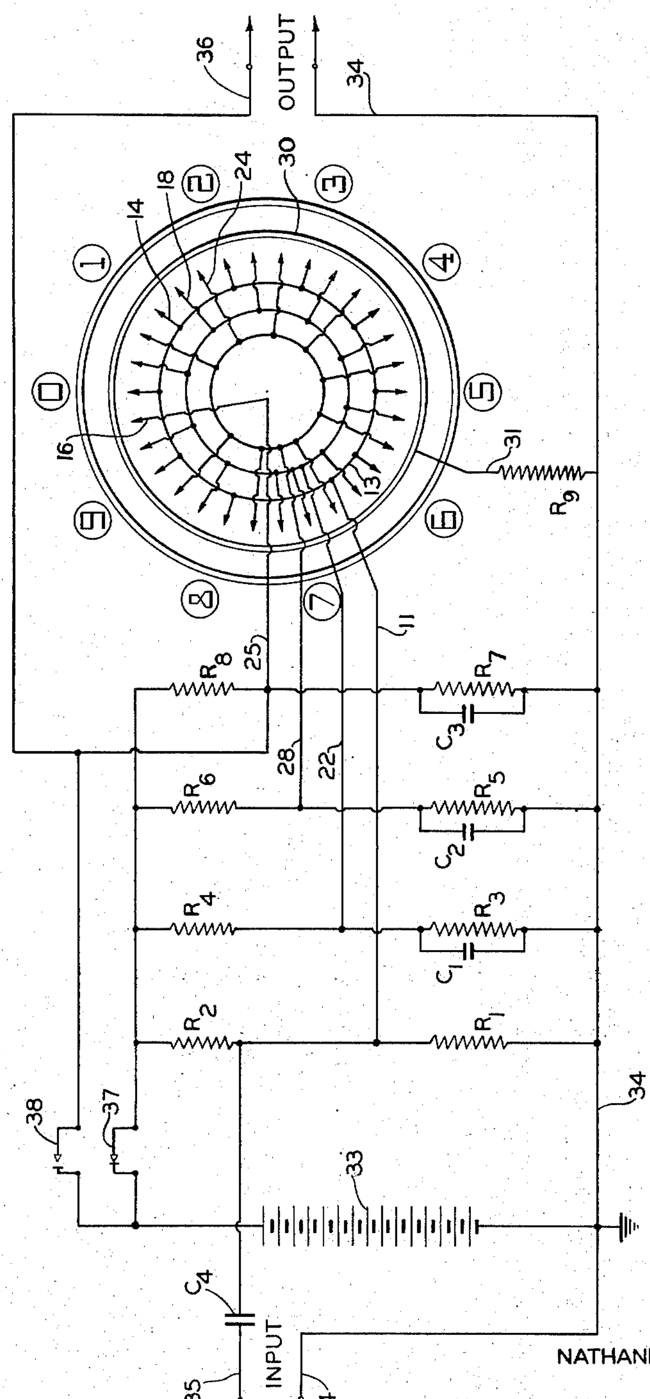

Fig. 3.

INVENTOR.

NATHANIEL B. WALES JR.

BY Ralph W. E. Bitner

ATTORNEY.

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GASEOUS DISCHARGE TUBE SYSTEM

Nathaniel B. Wales, Jr., Morristown, N. J., assignor to Remington Rand, Inc., New York, N. Y., a corporation of Delaware

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5 Claims. (Cl. 315—201)

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This invention relates to a supply circuit for a multi-discharge tube and more particularly relates to the energizing circuit for a counter and storage tube which is fully described in my copending application, Serial No. 755,529, filed June 18, 1947, now Patent No. 2,443,407, issued June 15, 1948, for a Gaseous Discharge Device, of which the present application is a division.

In the preferred form of my invention I provide a circuit for supplying a discharge tube having a system of three anodes, each having a plurality of spaced discharge points, so positioned as to form a path of sequentially alternate anodes with respect to a common cathode located parallel to this path, all of these electrodes being supported within a suitable preferably low pressure gaseous discharge atmosphere. Thus, in this form of my invention, when a potential in excess of the breakdown voltage is applied to any one of these anodes relative to the common cathode and through a cathode series load resistor, a visible discharge will take place at only one of the plurality of discharge points for that anode because of the fact that as soon as one discharge is established at a discharge point, its discharge current passing through the series load resistor causes a drop in the anode-to-cathode potential such that this lowered potential is inadequate to initiate a second discharge at any other point on this anode. It is this mutually exclusive discharge feature which is the basis of the integrating characteristics of the system.

My invention provides for the transfer of discharge from one discharge point of the master electrode to its next discharge point by causing an input pulse which is to be counted or integrated, first to de-energize the master electrode, and then to energize sequentially the other two intervening discharge electrodes before re-energizing the master electrode, thereby physically transferring the discharge through a definite directed displacement representing one step on the multiple master electrode. The reason why the discharge will transfer only to the adjacent discharge point instead of to some arbitrarily remote point of the same adjacent multiple electrode, is that the presence of ions in the region surrounding the discharge and persisting even after the exciting voltage for the discharge has been removed, sets up preferential conditions for the re-establishment of a discharge in the neighborhood of the region in which a discharge has just terminated. Thus, if only two multiple

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alternate electrodes were used there would be an ambiguity as to which of the adjacent points would capture the terminating discharge, whereas with three sequentially alternate electrode systems there will be a positive directed preference for the discharge to move along the electrode path determined by the order of excitation of the electrodes adjacent to the master electrode.

It is to be noted that my invention will operate equally well using a common anode and three multiple cathodes, or indeed, the same electrode geometry will operate when excitation is supplied by alternating potentials. Further, the path of the alternate discharge points may be closed so as to comprise a cyclic or self-resetting counter, or the path may be linear or non-cyclic with special means provided for resetting. Also, within the principle of my invention, any number of sequentially alternate multiple electrodes above three may be used for special applications where it is desired to separate the possible points of discharge by a greater distance than is possible with three sets of discharge points.

The sequential transfer of the arc discharge between the three multiple electrodes and the common electrode is accomplished by my preferred circuit shown in the accompanying drawings. In this circuit the transfer is effected by supplying the intermediate electrodes with capacitance stored potentials of progressively lower values than that of the master electrode so that on the momentary removal, by an incoming pulse to be counted, of the master electrode potential the discharge is captured and maintained for a short time by the adjacent electrode until its capacitor is exhausted. This time the second sequential adjacent electrode takes over the discharge thereby bringing the region of discharge to a position adjacent to that master electrode point which is one removed and in the desired direction of displacement from the initial master electrode discharge. On re-excitation of the master electrode the discharge is thus established at this displaced position. In this case the preferential direction of discharge transfer is determined by the direction of descending potential applied to the intervening electrodes, since the higher of the two electrode potentials adjacent to a terminating discharge will capture it, providing, of course, a symmetrical surface condition and geometry obtains.

In the preferred form of my invention I disclose a cyclic closed discharge path provided with a special electrode for resetting the counter to a zero or index position. Means are shown for causing this device to yield an output impulse each time the discharge passes this index position. Thus a group of such counting tubes connected in cascade so that the successive tubes in the series are caused to count in response to the index output impulses of the preceding stage will comprise a system capable of counting in any number system as determined by the number of discharge points provided on each of the master electrodes. In the decimal system each such tube thus comprises a decade counter.

It is to be noted in the art of electronic counting that an electronic decade of either the Eccles-Jordan or thyratron ring type employs a minimum of four to ten tubes together with appreciable associated circuitry, in contradistinction to the single unit simplicity of the present invention in which the register is visibly indicated on a calibrated dial.

In addition, this invention has utility as a frequency divider, such as those used in television synchronization circuits, and as a predetermined limiting counter, such as those used in packaging machinery.

One object of this invention is to provide a simple and visible means for registering the count of rapid or random impulses in any number system.

A second object is to make possible a self resetting visible counter of compact and economical construction.

A third object is to provide an electrical device capable of yielding one output pulse in response to the accumulation of each predetermined number of input impulses.

Other objects are implicit in the accompanying specification and claims.

In the drawings:

Fig. 1 is a cross-section taken through the axis of the counting tube.

Fig. 2 is a sectional view of Fig. 1 taken along line **2—2** of that figure.

Fig. 3 is a schematic diagram of connections of the circuit used with the counting tube.

Referring now to the drawings, the electrode structure of the counting tube is mounted within an envelope **10** which is evacuated, degassed, and then filled with a suitable discharge gas at reduced pressure. The central electrode support wire **11** passes through and is supported by the press of the envelope **12**. The electrode spider **13** (hereinafter called the master electrode) comprises a group of nine radial fingers **14** at 36° intervals stamped from a single sheet of metal and doubly bent so that the pointed ends of the discharge fingers **14** lie in a plane displaced below but lying parallel to the central circular hub **13** of the electrode. Spider **13** is centrally secured to and supported by lead wire **11**. It is to be noted that the tenth discharge finger of electrode **13** is missing, and that the place which it would occupy is taken by the resetting or index electrode **16**.

The mid-electrode spider **17** comprises a flat stamped metal piece having ten radial equispaced pointed discharge fingers **18** which lie in the same plane as the ends of discharge fingers **14** of the upper electrode **13**, but spaced therefrom by 12° displacement. Spider **17** is centrally secured to metal sleeve **20** which is supported on and insulated from central wire **11** by the glass sleeve **21**. Lead wire **22** is secured to and affords external connection to sleeve **20** and its electrode **17**.

The lower electrode spider **23** is similar to spider **13** but has its ten radial equispaced discharge fingers **24** bent upward and outward so that the discharge points lie in the same common plane as electrode points **14** and **18**. The points of the electrodes **14**, **18**, and **24** thus lie on a common circle and, together with the radially bent electrode discharge point **16** which is supported by wire **25** and the press of envelope **10**, form a series of **30** equispaced sequentially alternate discharge electrodes. Electrode **23** is centrally secured to metal sleeve **26** which in turn is insulated from and supported by glass sleeve **27** concentric with and supported on sleeve **20**. Lead wire **28** passing through the press of envelope **10** is secured to sleeve **26** and forms external connection to electrode **23**.

The common electrode comprises a cylinder of metal **30** supported on lead wire **31** and maintained concentric with the circle of discharge points by the mica insulating spacer disk **32**.

The external connections to the tube are thus: master electrode **11**, first transfer electrode **22**, second transfer electrode **28**, index electrode **25**, and common electrode **31**.

The circuit of Fig. 3 comprises a voltage supply shown as a battery **33** leading to a network of resistors R_1 to R_8 which may be considered to be a series of four parallel voltage dividers or bleeders. The master electrode lead **11** is connected to the junction of resistors R_1 and R_2. The values of R_1 and R_2 are chosen such that the potential of the junction is well above the breakdown voltage of the master electrode **13**, say 150 volts, and such that enough current may flow through R_2 to sustain the discharge without dropping the potential of the junction to the extinction potential. In contradistinction to this discharge sustaining value of R_2, the values of the resistors R_4, R_6, and R_8 are such as to be unable to sustain a discharge from energy supplied by battery **33**. The first transfer electrode lead **22** is connected to the junction between R_3 and R_4 and the values of these are chosen so as to maintain the potential of **17**, relative to the ground lead **34**, at a point lower than that of the master electrode. For 150 volts on the master electrode this potential might be 140 volts. The second transfer electrode lead **28** is in turn connected to the junction of resistors R_5 and R_6 and the values are chosen so that this potential is maintained lower again than first transfer electrode **17**. On the same scale this value might be 130 volts.

The index electrode lead **25** is maintained at a potential substantially identical with that of second transfer electrode **28** by its own voltage divider R_7, R_8. Consequently, since it geometrically occupies a position in the tube corresponding to the location of the discharge points **24** of electrode **23** it will perform identically, from a functional standpoint, with the behaviour of electrode **28**.

All discharge currents passing through the tube also pass through the common electrode load resistor R_9. It is the voltage drop across this resistor which causes the discharge within the tube to be mutually exclusive of the several alternative discharge points.

The capacitors C_1, C_2, and C_3 are so connected as to supply transient current to the transfer electrode leads **22**, **28**, and **25** respectively. The time constant of the values R_3 C_1, is chosen so as to be small with respect to the length of input pulse which is to be counted. The time constants R_5C_2 and R_7C_3 are chosen to be equal to or greater than the pulse duration in order to provide overlap.

The operation of my invention is as follows: Let it be assumed that it is desired to count electrical input impulses in the form of square waves applied to terminals **34**, **35**. These input impulses after passing through the coupling condenser C_4 will produce voltage impulses appearing across resistor R_1. For the correct magnitude and polarity of these impulses these transient potentials will oppose the potential appearing across R_1 by virtue of the battery **33**, and consequently the potential of the master electrode **13** will drop with respect to the common electrode **30** until it is inadequate to sustain the discharge which has been maintained from one of the fingers **14** of master electrode **13**. As before noted, since the values of R_4, R_6, and R_8 are sufficiently high that no discharge may be maintained through them by energy flowing from the battery, the steady state of the system necessarily requires that a continuous discharge be taking place at one of the master discharge points **14**. As this discharge approaches extinction due to the opposing pulse voltage across R_1 the diminishing discharge current through common electrode **30** resistor R_9 causes the potentials of all the remaining electrodes to rise with respect to the common electrode. However, since the first transfer electrode lead **22** is at the highest potential relative to the common electrode as determined by the voltage divider R_3 R_4, and since one of its discharge fingers **18** is adjacent to the ionized region through which the discharge had been maintained, that finger of the first transfer electrode will capture the discharge in preference to the finger **24** of the second transfer electrode which is on the other side of the master electrode finger which had maintained the discharge, because of the higher potential of **18**. As soon as electrode **18** captures the discharge the current through R_9 again drops the anodes-to-cathode potentials so that no other discharge is possible. However, the current of this captured discharge is being supplied by condenser C_1 and consequently in a short time this charge will be exhausted allowing the current through R_9 to drop again and the relative anodes-to-cathode potentials to rise. At this point since the potentials on **14** and **18** are respectively disabled and exhausted the only remaining appreciable potential gradient and adjacent to the last point of discharge is that between the second transfer electrode finger **24** and the common electrode **30**.

For this reason, the discharge will now pass to the adjacent finger **24** of the second transfer electrode, and the discharge will remain there until the decaying potential across condenser C_2 becomes inadequate to sustain the discharge. By this time, however, the blocking pulse on resistor R_1 will have disappeared thereby allowing the discharge to pass to the master electrode **14** again. Thus, in response to the pulse the discharge has progressively transferred itself from one finger of the master electrode to its next one thereby visibly registering the addition of the impulse. This process is repeated for successive impulses until the index position is reached. When the input impulse which will make the transit of electrode **16** occur, the discharge moves as above described from the number **9** finger of the master electrode to the adjacent finger of the first transfer electrode. Thence the discharge moves on to discharge point **16** because the electrical conditions on it are identical to those of the second transfer electrode. From point **16** the discharge moves as before back on to the "zero" finger of the master electrode **14**, but in the process of discharging condenser C_3 of the index electrode a transient change of the potential of lead **25** has been generated. Since this transient occurs only once per revolution of the electrode cycle, it may be utilized as an output pulse appearing at output terminals **36**, **34**. This output pulse may be coupled to the input connections of another such system as shown in Fig. 3 thereby comprising a two decade counter, and the process may obviously be extended to any number of cascade counter decades. Alternatively, since the output pulse frequency has an exact fractional relation to the input frequency, it may be utilized as a frequency divider. It is evident that any desired number of discharge points may be incorporated in the discharge cycle, either for the purpose of counting in other number systems than the decimal system, or for specific applications where particular frequency divisions or predetermined counting limits are desired.

It may be noted that there is an optimum duration and form of the input pulses which are to be counted, but in practice it is found that there are wide limits as to these specifications due to the long persistence of ions in the neighborhood of the last transfer electrode discharge. For this reason a minimum of input pulse shaping circuitry is necessary.

In the circuit of Fig. 3 means are provided for resetting the system to the zero position. These comprise the two switches **37** and **38**. To reset the decade the normally closed switch **37** is opened thus causing all discharge in the tube to die out in a very short time by opening the lead to battery **33**. Normally open switch **38** is thus closed thereby impressing the full battery voltage on the index electrode **16**. This initiates a discharge at this point which will then transfer to the zero finger of the master electrode on the reclosing of switch **37** and the subsequent opening of switch **38**.

It will be evident that there are a great number of geometrical forms and circuit means for incorporating the principle of my invention, and for this reason it is not to be construed as a limitation of the scope of my concept that only one geometry and one circuit are shown in the drawings.

What is claimed is:

1. A gaseous discharge tube system comprising; a gas filled envelope; a cathode; a plurality of anodes each having a number of discharge fingers equally spaced from the cathode in sequentially alternate arrangement; a direct current supply circuit for each of said anodes supplying electrical power causing a glow discharge between one of the fingers and the cathode, each of said supply circuits including a voltage divider connected across a common source of direct current, a connection between the mid-point of each voltage divider and one of the anodes, and a common resistor connected between the cathode and the negative terminal of the source of direct current; and a transient control circuit causing the glow discharge to move from one anode finger to another, said circuit including input terminals where a negative pulse may be applied between the negative terminal of the source of direct current and one of the anodes,

2. A gaseous discharge tube system comprising; a gas filled envelope; a cathode; a master anode and two transfer anodes each having a number of discharge fingers equally spaced from the cathode in sequentially alternate arrangement; a direct current supply circuit for the master anode and the transfer anodes supplying electrical power causing a glow discharge between one of the fingers and the cathode, each of said supply circuits including a voltage divider connected across a common source of direct current, a connection between the mid-point of each voltage divider and one of the anodes, and a common resistor connected between the cathode and the negative terminal of the source of direct current; and a transient control circuit causing the glow discharge to move from one anode finger to another when a negative pulse is applied thereto, said circuit including input terminals for receiving a negative pulse and applying it across the negative terminal of the source of direct current and the master anode.

3. A gaseous discharge tube system comprising; a gas filled envelope; a cathode; a master anode and two transfer anodes each having a number of discharge fingers equally spaced from the cathode in sequentially alternate arrangement; a direct current supply circuit for the master anode and the transfer anodes supplying electrical power causing a glow discharge between one of the fingers and the cathode, each of said supply circuits including a voltage divider connected across a common source of direct current, a connection between the mid-point of each voltage divider and one of the anodes, and a common resistor connected between the cathode and the negative terminal of the source of direct current; a transient control circuit causing the glow discharge to move from one anode finger to another when a negative pulse is applied thereto, said circuit including input terminals for receiving a negative pulse and applying it across the negative terminal of the source of direct current and the master anode; and a capacitor connected between each transfer anode and ground.

4. A gaseous discharge tube system comprising; a gas filled envelope; a cathode; a master anode having a plurality of discharge fingers for sustaining a gaseous discharge between one of the fingers and the cathode in the absence of an input pulse, and two transfer anodes each having a plurality of discharge fingers, the discharge fingers of the three anodes arranged in alternate sequential arrangement; a direct current supply circuit for the master anode supplying electrical power and causing a glow discharge between one of the master anode fingers and the cathode; a direct current supply circuit for each of the transfer anodes supplying electrical power and causing a transient glow discharge between one of the transfer anode fingers and the cathode when a negative pulse has been applied to the system, each of said supply circuits including a voltage divider connected across a common source of direct current, a connection between the mid-point of each voltage divider and one of the anodes, and a common resistor connected between the cathode and the negative terminal of the source of direct current; a transient control circuit causing the glow discharge to move from one anode finger to another when a negative pulse is applied thereto, said circuit including input terminals for receiving a negative pulse and applying it across the negative terminal of the source of direct current and the master anode; and a capacitor connected between each transfer anode and ground.

5. A gaseous discharge tube system comprising; a gas filled envelope; a cathode; a master anode having a plurality of discharge fingers for sustaining a gaseous discharge between one of the fingers and the cathode in the absence of an input pulse; two transfer anodes each having a plurality of discharge fingers, the discharge fingers of the three anodes arranged in alternate sequential arrangement equidistant from the cathode; an index anode comprising a single discharge finger for supplying an output pulse; a direct current supply circuit for the master anode supplying electrical power and causing a glow discharge between one of the master anode fingers and the cathode; a direct current supply circuit for each of the transfer anodes and the index anode supplying electrical power and causing a transient glow discharge between one of the anode fingers and the cathode when a negative pulse has been applied to the system, each of said supply circuits including a voltage divider connected across a common source of direct current, a connection between the mid-point of each voltage divider and one of the anodes, and a common resistor connected between the cathode and the negative terminal of the source of direct current; a transient control circuit causing the glow discharge to move from one anode finger to another when a negative pulse is applied thereto, said circuit including input terminals for receiving a negative pulse and applying it across the negative terminal of the source of direct current and the master anode, and capacitors connected between the transfer anodes and the index anode and ground; and an output circuit connected across the index electrode and ground for applying an output pulse to a load circuit.

NATHANIEL B. WALES, Jr.

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