Jan. 27, 1970 M. L. HUNDLEY ETAL 3,491,564

ELECTRO-HYDRAULIC FLAT FORMING SYSTEM

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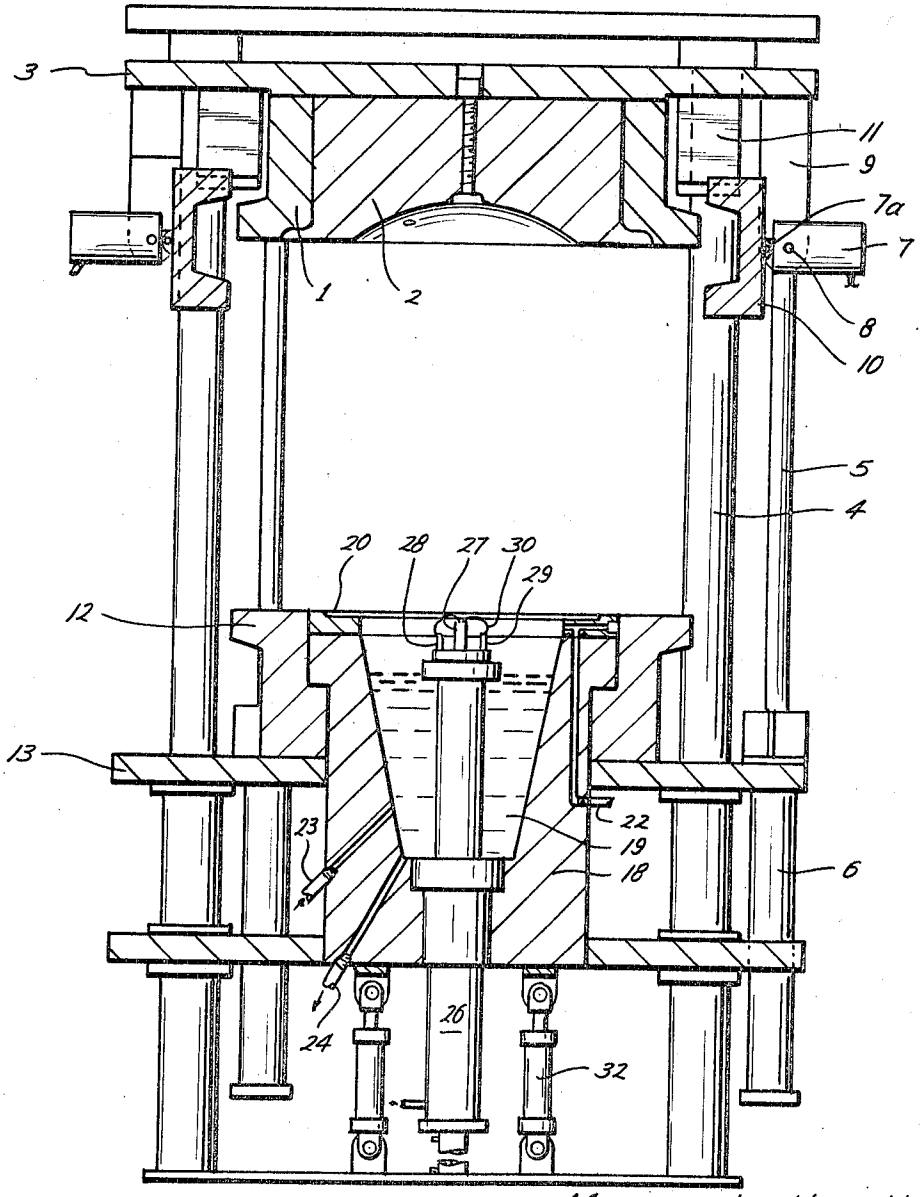


Fig. 1

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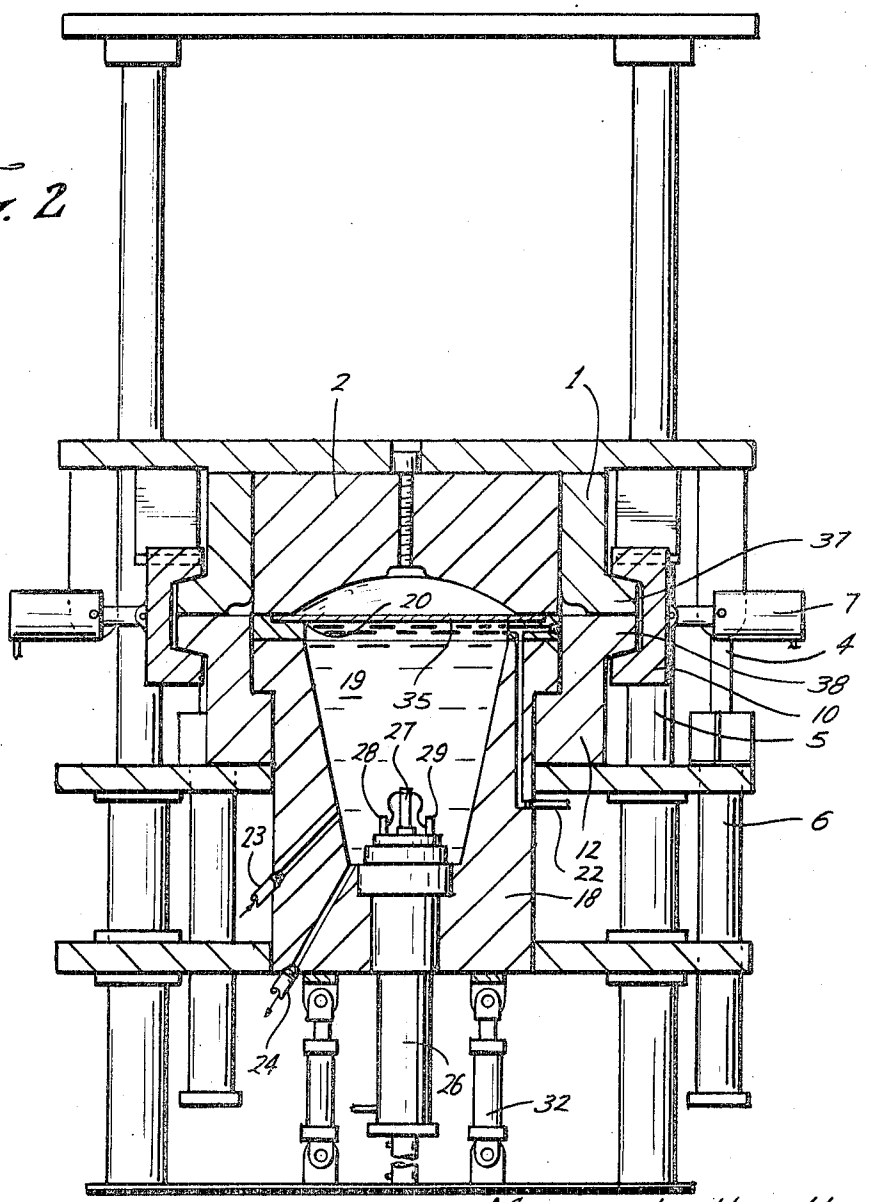
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Fig. 2



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Fig. 3



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ELECTRO-HYDRAULIC FLAT FORMING SYSTEM

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Fig. 4

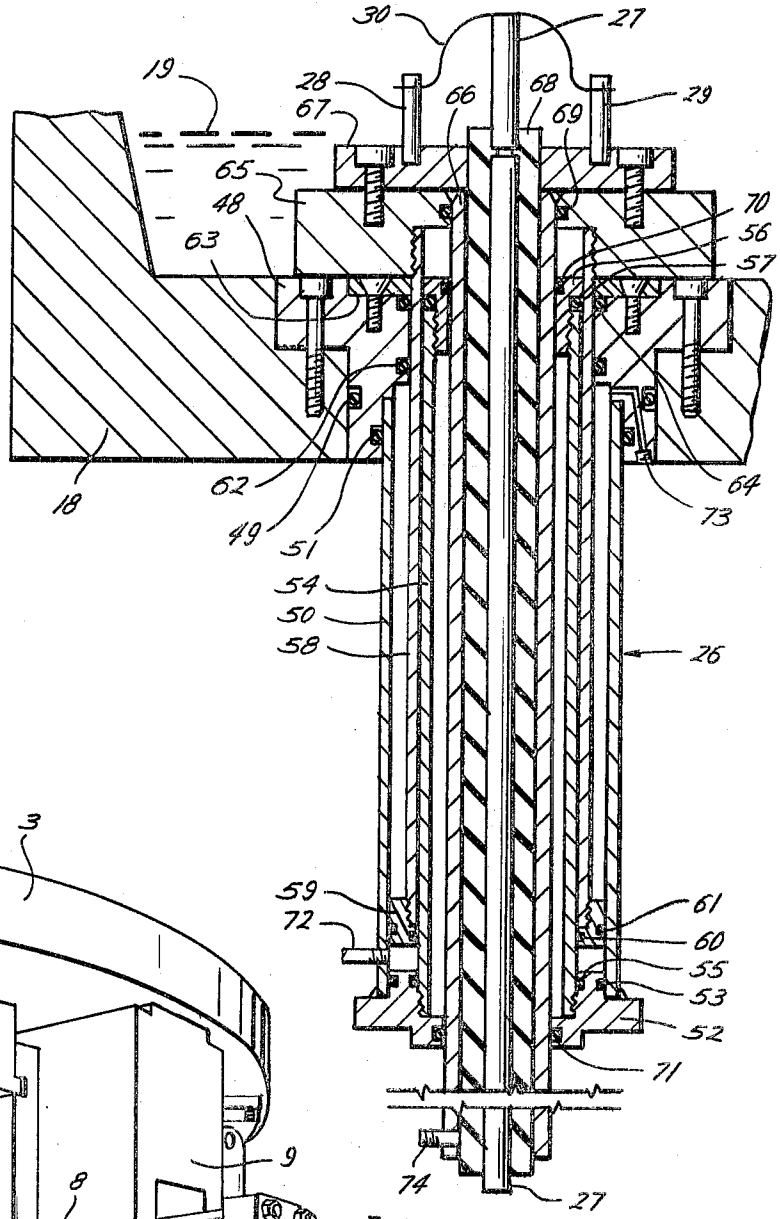
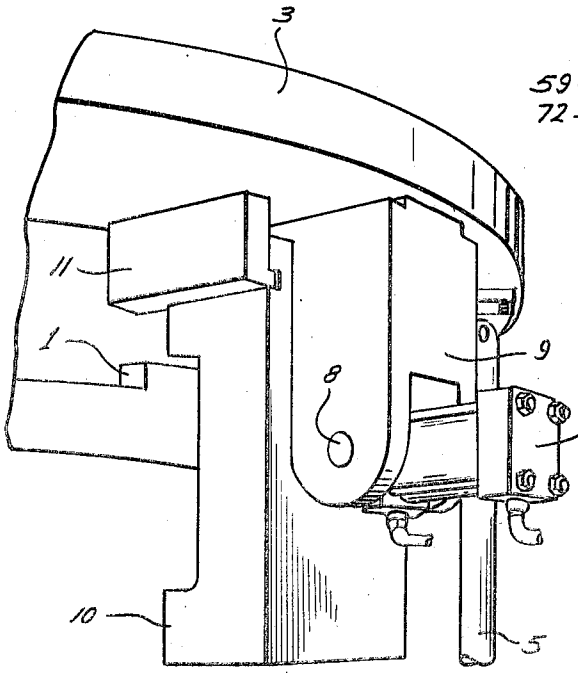


Fig. 5



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ELECTRO-HYDRAULIC FLAT FORMING SYSTEM

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Int. Cl. B21d 26/06
U.S. Cl. 72—56 5 Claims

ABSTRACT OF THE DISCLOSURE

An electro-hydraulic forming apparatus including upper and lower portions which are maintained in a closed position during the forming operation by trunnion mounted clamps which wedgedly engage adjacent flanges of the upper and lower portions. The lower portion includes a firing chamber and electrode assembly. The firing chamber includes means for adding and draining an incompressible fluid and evacuating any gases in the chamber while the two portions are in the closed position. The electrode assembly includes two or more electrodes positioned inside the chamber and means for moving the electrodes vertically within the chamber.

BACKGROUND OF THE INVENTION

This invention relates to apparatus for shaping workpieces of deformable material. More specifically, the invention pertains to apparatus for shaping workpieces by electro-hydraulic forming.

Electro-hydraulic forming refers to a method of forming a workpiece by discharging electrical energy in a contained incompressible fluid medium. The shock developed by the discharge is transmitted by the fluid to a workpiece which is suitably mounted in a forming die.

In a flat forming apparatus, a flat workpiece is positioned between a die portion and a container portion of the incompressible fluid. Electrodes are positioned in the fluid with a connecting wire which is detonated by the electrical discharge.

The two portions must be rigidly supported to prevent separation thereof by the shockwave developed by the electrical discharge. However, because of the extremely high pressure developed by the electrical discharge, a suitable support presents a major problem. Hydraulic cylinders will not absorb the high pressures without some movement, and rigid clamps present problems in alignment.

Often it is desirable to use two or more discharges in forming one workpiece. To carry out the subsequent discharges, more fluid must be added to accommodate the increased space due to the deformation of the workpiece. Further, the fluid is often contaminated during the electrical discharge and must be replaced before the next discharge. Also, since the discharge disintegrates the wire connecting the electrodes, a new wire must be provided for each electrode discharge. Replacing the wire is more difficult when the wire is submerged in the fluid.

SUMMARY OF THE INVENTION

In accordance with this invention an electro-hydraulic forming apparatus is provided including novel die assembly and die support means.

The die assembly has a lower portion which includes a fluid container having a firing chamber filled with an incompressible fluid and in which electrodes are positioned and an upper portion which includes the die. Advantageously, the workpiece is supported above the incompressible fluid and the die is positioned above the workpiece. The two portions have flanges which mate when the portions are in a closed position. Trunnion mounted

die holding clamps wedgedly engage tapered contact surfaces on the flanges and maintain the two portions in the closed position during the electro-forming operation.

Two or more electrodes are provided in the bottom portion to carry out the electrical discharges. The electrode assembly includes means for moving the electrodes vertically above the contained fluid, thereby facilitating the attachment of wires to the electrodes without the necessity of draining the fluid. Means are also provided to drain the fluid or add fluid to the apparatus after each electrical discharge without disassembling the apparatus.

Means are provided to apply pressure to the workpiece when the die assembly is closed and thereby maintain a fluid tight seal during the forming of the workpiece.

The invention will be more fully understood from the following description and appended claims when taken with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a cross-sectional view of one embodiment of the electro-forming apparatus with the die portion and support means in a raised position.

FIGURE 2 is a cross-sectional view of the apparatus of FIGURE 1 in a closed position.

FIGURE 3 is a cross-sectional view of a workpiece after the electro-forming operation.

FIGURE 4 is a cross-sectional view of the electrode assembly and seal.

FIGURE 5 is an isometric view of the actuating means for the die clamping apparatus.

DETAILED DESCRIPTION OF THE ILLUSTRATIVE EMBODIMENTS

Referring to the drawings, and in particular to FIGURE 1 and FIGURE 2, electro-forming apparatus in accordance with the invention is illustrated in cross-section. In FIGURE 1, the upper portion including die retaining ring **1** and die **2** is in a raised position. Die retaining ring **1** is attached to die holder platen **3** which is movably mounted on guide rods **4**. Pistons **5** of hydraulic cylinders **6** are connected to die holder platen **3** and provide the movement of the upper portion along the rods **4**. Hydraulic cylinders **7** are pivotably connected by pins **8** to supports **9** depending from die holder platen **3**. The rod **7***a* of hydraulic cylinder **7** is also connected to retaining clamp **10** by pin means, thereby providing a trunnion mount for the clamp. Retaining clamp **10** slidably engages a guide **11** which also depends from the die holder platen **3**, and the retaining clamp **10** is horizontally movable by means of hydraulic cylinder **7**. The clamp and actuating means are further described below with reference to FIGURE 5.

The bottom portion of the apparatus includes retaining ring **12** which is supported by the base structure **13**. A fluid container **18** having a firing chamber **19** is supported by retaining ring **12**. The firing chamber **19** is shown partially filled with an incompressible electrically non-conductive fluid such as water. The top surface of container **18** has a recessed area **20** for accommodating a flat work piece. A vacuum port **22** is provided in the container **18** to evacuate air from the firing chamber **19** after a work piece is assembled and the upper portion is lowered to close the apparatus. Fluid intake **23** and fluid drain **24** are also provided in container **18** to circulate the fluid in the firing chamber **19** as required. Electrode assembly **26** is mounted through the bottom of container **18** with coaxial electrodes **27**, **28** and **29** positioned in the firing chamber. The electrodes are in a raised position to facilitate the attachment of wires **30** to the electrodes. The electrode assembly is described in detail below with reference to FIGURE 4.

Hydraulic cylinders **32** are connected to the bottom of container **18**. These cylinders function to maintain a pressure seal on the work piece during the forming operation as shown in FIGURE 2.

In FIGURE 2, a work piece **35** is positioned in the recessed area **20** of the container and the upper portion of the apparatus is lowered by means of hydraulic cylinders **6** until the die **2** abutts the work piece and flange **37** of the die retaining ring **1** are adjacent to flanges **38** of the retaining ring **12**. The flanges have tapered contact surfaces which are wedgedly engaged by clamps **10**. The trunnion mounting of hydraulic cylinder **7** to support **9** and the trunnion mounting of clamp **10** to the rod of cylinder **7** allow the clamp freedom of vertical pivotal movement and thereby effect proper alignment of the clamps in engaging the flanges.

After the apparatus is closed as shown in FIGURE 2, the firing chamber **19** is completely filled with the incompressible electrically nonconductive fluid which is added through fluid intake **23**. Air within the chamber is removed through vacuum port **22**. A sealing pressure is maintained on the work piece by moving the fluid container **18** upwardly by means of cylinders **32**. Clamps **10** are maintained in pressure contact with the flanges of the retainer rings **1** and **12** by cylinders **7**.

Prior to the forming operation the coaxial electrodes **27**, **28** and **29** are lowered by the electrode assembly **26** as shown in FIGURE 2.

A large charge of current is then passed through wires **30** connecting electrodes **28** and **29** to electrode **27**. The current detonates the wires which effects a shock wave that is transmitted to work piece **35** by the contained fluid. Typically, the electrical charge is in the order of 100,000 joules and is released in a period of a few hundred milliseconds. The discharge disintegrates the wires which must be replaced before the next discharge between the two electrodes.

Should the fluid in the firing chamber **19** become contaminated after many firings, the fluid can be replaced, if necessary, by draining through port **24** and adding new fluid through port **23**.

FIGURE 3 is a cross section of work piece **23** after electroforming. The configuration of the work piece is defined by the die.

FIGURE 4 is a cross-sectional view of the electrode actuator assembly **26** and the coaxial electrodes **27**, **28** and **29**. The electrode actuator assembly **26** consists of a head **48** which is slidably inserted in the lower portion of the fluid container **18** and suitably retained by bolts or the like. The head is sealed by O-ring **49** to prevent leakage of fluid from the firing chamber **19**. Outer cylinder sleeve **50** is retained in head **48** and sealed at that point by O-ring **51**. End cap **52** is inserted in the lower end of sleeve **50** and threadably engages inner sleeve **54**. O-ring **53** seals the lower end of sleeve **50** at end cap **52**, and inner cylinder sleeve **54** is sealed at end cap **52** by O-ring **55**. The upper end of inner cylinder sleeve **54** threadably engages inner guide ring **56**. Inner wiper ring **57** is retained between the inner ring guide **56** and the inner cylinder sleeve and is in slidable contact with the inside diameter of the piston sleeve **58**. Piston sleeve **58** threadably engages piston sleeve ring **59** and is slidably movable between the inner and outer cylinder sleeves. Piston sleeve ring **59** is sealed by O-rings **60** and **61**. Piston sleeve **58** contacts head **48** and is sealed by means of O-ring **62**. Wiper retainer plate **63** retains wiper ring **64** which is in slideable contact with the outside diameter of piston sleeve **58**. Electrode adaptor flange **65** threadably engages the upper end of the piston sleeve **58**.

The coaxial electrodes consist of an outer conductor tube **66** and flange **67**, which comprise a unitary structure, and electrodes **28** and **29** which are threadably or otherwise attached to flange **67**. A center electrode **27** is positioned in the center of the outer conductor tube **66** and is insulated therefrom by a suitable insulation material **68**.

In practical application, the coaxial electrodes are inserted through the electrode adaptor flange **65**, the inner ring guide **56** and the end cap **52** and the flange **67** is attached to the electrode adaptor flange **65** by screws or other suitable means. Sealing is provided by O-rings **69**, **70** and **71**.

The electrode assembly is raised by air pressure applied at port **72** which consequently exhausts air from port **73**. Conversely, the electrode assembly is lowered by applying air pressure to port **73**. The outer conductor tube **66** is long enough to allow full extension of the electrode assembly within the firing chamber without interference with the ground conductor connector **74**.

After the electrical discharge, wire **30** must be replaced. With this novel electrode assembly, the electrodes **27**, **28** and **29** are raised in the firing chamber **19** above the contained fluid, and new wires are attached without the necessity for draining the fluid. After the wires are attached, the electrodes are again lowered until flange **65** abuts head member **48** at the bottom of the firing chamber **19**.

FIGURE 5 is an isometric view of a portion of the electro-forming apparatus of FIGURE 1 and FIGURE 2, and further illustrates the trunnion mounting of hydraulic cylinder **7** to the support **9** depending from die holder platen **3**. Pin **8** connects the cylinder to the support, and allows the cylinder to have freedom of vertical pivotal motion. The trunnion mounting of the cylinder to support **9** along with the trunnion mounting of the cylinder rod to clamp **10** (not shown) enables the clamp **10** to seek proper alignment when moved to engage the tapered flanges on die retaining ring **1** and retaining ring **12** as shown in FIGURE 2. Thus critical tolerances can be maintained with this apparatus since the clamp is properly aligned when engaging the flanges.

While the invention has been described with reference to specific embodiments, the description is illustrative and is not to be construed as limiting the scope of the invention. Various modifications and changes may occur to those skilled in the art without departing from the scope of the invention as defined by the appended claims.

What is claimed is:

1. An electrohydraulic forming apparatus comprising:

an upper die adapted for vertical movement and having an outer flange with tapered upper surface;

a lower firing chamber member having an outer flange with a tapered lower surface, said lower firing chamber member being adapted to hold an incompressible fluid and to close with said die member to hold the work piece therebetween;

means for initiating an explosive pulse in said firing chamber member;

clamp means comprising a plurality of C-clamps having inner clamping surfaces adapted to wedgedly engage the tapered surfaces of said outer flanges on said die member and firing chamber member;

means mounting each of said C-clamps for limited pivotal motion in a vertical plane;

means to actuate said clamp means into engagement with said flanges; and

means for applying pressure between said firing chamber and said die member in addition to pressure exerted by said clamp means to hold a work piece therebetween.

2. The apparatus of claim **1** wherein said means for initiating an explosive pulse includes:

a first electrode extending into said firing chamber;

a second electrode insulated from said first electrode and disposed axially about said first electrode;

an explodable wire disposed between said electrode; and

means to raise said first and second electrodes with respect to said firing chamber member to enable replacement of said wire after use.

3. The apparatus of claim 2 including a support member within said firing chamber for supporting said electrodes and an air cylinder mounted vertically through said firing chamber member including a stationary inner sleeve, a stationary outer sleeve, and a movable piston sleeve between said inner and outer sleeves, said movable piston sleeve being attached to said support member to raise and lower said support member and said electrodes.

4. The apparatus of claim 1 including means immediately below said work piece to evacuate gas from said firing chamber member between said work piece and said incompressible fluid when said work piece is in place to permit filling said chamber completely with such incompressible fluid when the work piece is in position.

5. The apparatus of claim 1 wherein said means for applying pressure between said firing chamber member and said die member comprise a plurality of hydraulic cylinders disposed below said firing chamber member and adapted to exert upward pressure on said firing chamber member against said die member.

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