Oct. 29, 1968 J. D. NORTH ETAL 3,407,745

HYDRAULIC APPARATUS

Filed July 18, 1966 2 Sheets-Sheet 1

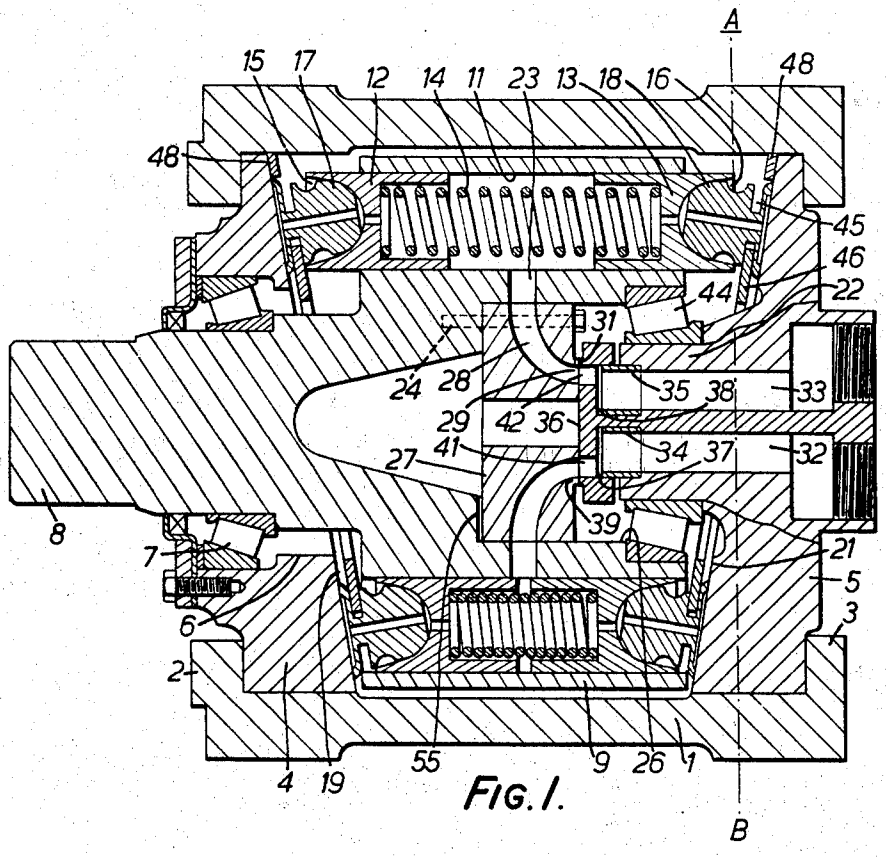


FIG. 1.

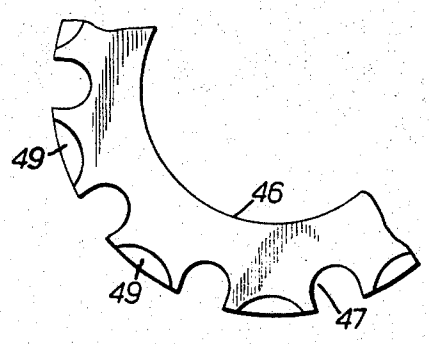


FIG. 2.

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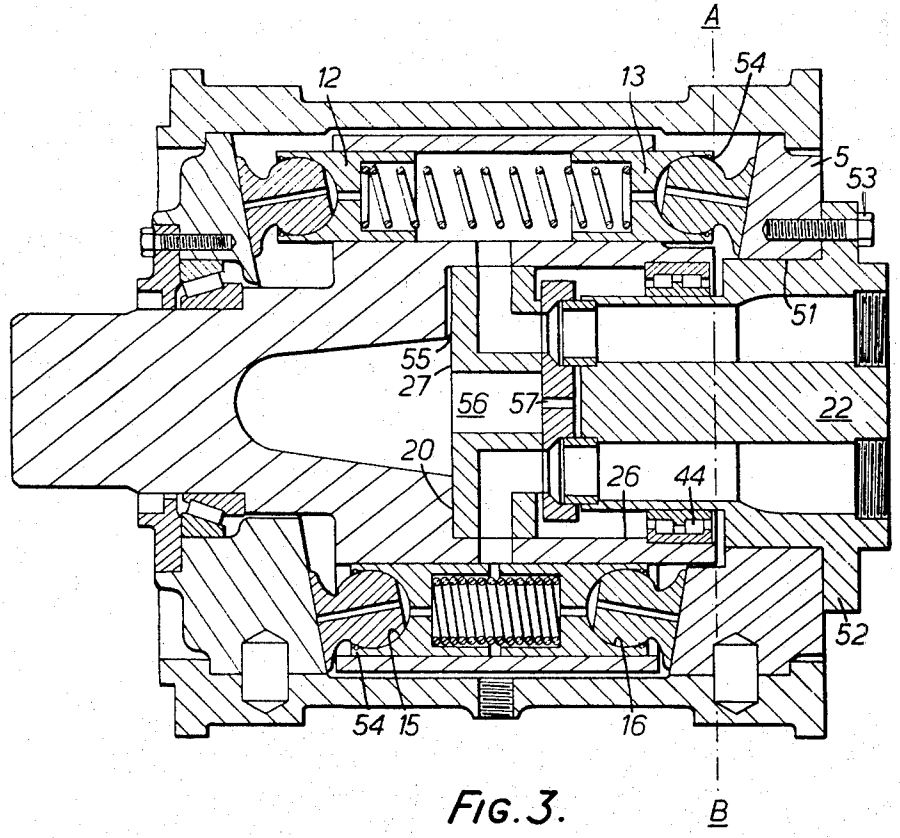


FIG. 3.

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3,407,745

HYDRAULIC APPARATUS

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7 Claims. (Cl. 103—162)

ABSTRACT OF THE DISCLOSURE

A hydraulic machine is disclosed which includes a rotatable cylinder block having cylinders therein and a fixed swash plate adjacent each end of the block. At each end of the block pistons project from cylinders opening thereinto, and the pistons engage the adjacent swash plates in such a way that rotation of the block induces their reciprocation in the cylinders. In addition, there is a casing which rigidly secures the swash plates together in a fixed spaced relationship and encloses the cylinder block. The cylinder block is rigidly supported on bearings by virtue of there being (1) a fixed bearing support extending into a recess in one end of the block from the adjacent swash plate and a bearing engaged between the recess and the support, and (2) a shaft extending from the other end of the block through a hole in the adjacent swash plate and a bearing engaged between the shaft and the hole. Valve means are movably supported on the bearing support for connecting the cylinders in the block alternately to supply and return passages for liquid extending through the bearing support. The cylinders are alternately connected in synchronism with rotation of the block and reciprocation of the pistons in the cylinders.

This invention relates to hydraulic pumps and hydraulic motors of the swash plate type. Hydraulic pumps or motors are known which comprise a rotatable cylinder block having cylinders therein parallel to the block axis, a first swash plate adjacent to one end of the block and engageable by pistons projecting from the cylinders which open into that end of the block and a second swash plate adjacent the other end of the block and engageable by pistons projecting from the cylinders which open into said other end of the block whereby rotation of the block induces reciprocation of the pistons in the cylinders. It has also been proposed that such a swash plate pump or motor should include a valve located in a recess within the block. The main purpose for the construction of a pump or motor, as above described, is to provide a pump or motor of compact dimensions for a required liquid volumetric displacement per revolution. However in these earlier proposals the rotatable cylinder block was provided with a shaft or axle extending from both ends thereof. The object of the present invention is to provide a pump or motor, as described above, in which the shaft extends from one end only of the cylinder block, thereby to reduce the total overall length of the pump or motor in a direction parallel to the rotation axis.

In accordance with the present invention, a hydraulic pump or a hydraulic motor includes a rotatable cylinder block having cylinders therein, a first swash plate adjacent to one end of the block and engageable by pistons projecting from the cylinders which open into that end and a second swash plate adjacent to the other end of the block and engageable by pistons projecting from the cylinders which open into said other end of the block, whereby rotation of the block induces reciprocation of the pistons in the cylinders, bearing means for the block disposed within a recess in an end of the block and valve means movably

supported on the bearing means for connecting the cylinders in the block, alternately to a supply passage for liquid and a return passage for liquid in synchronism with the reciprocation of the pistons in the cylinders.

The bearing means may be a bearing support extending into the recess and a ball or roller bearing acting between a part of the support and a part of the wall of the recess. The ball or roller bearing is preferably located to lie substantially or entirely on the cylinder block side of a plane which intersects the rotational axis perpendicularly at the point of intersection of the rotational axis with the second swash plate surface.

The valve means may comprise a valve plate mounted on the bearing support in the recess for axial and tilting movement to engage a flat valve surface formed on the block in the recess, the plate including supply and return points connected to supply and return passages extending through the support and the valve surface including cylinder ports extending one from each cylinder.

The cylinder ports may be formed in a cylinder port plate secured in the recess and having ports co-operating with passages extending to the cylinders.

The cylinder port plate is preferably made an interference fit within the recess so that the cylinder ports sealingly connect with the cylinder passages.

Preferably the cylinders each extend from end to end of the block and each include a pair of pistons extending one from each end of the block.

A drive shaft may extend from the end of the block opposite to the recess for transmission of the driving torque to or from the block. Preferably the cylinder block is of forged metal and the recess is formed roughly during forging such that the displaced metal extends from the opposite end of the block to form the drive shaft.

The drive shaft may be located by a bearing spaced from the cylinder block.

The bearing associated with the shaft may be adapted to resist end thrust such for example as may be generated by the valve plate.

How the invention can be carried into effect will hereinafter be particularly described with reference to the accompanying drawings, in which,

FIGURE 1 is a longitudinal cross-section through one embodiment of the invention intended particularly for use as a motor,

FIGURE 2 is a plan view of a detail employed in FIGURE 1 and,

FIGURE 3 is a cross-section through another embodiment of the invention also for use as a motor.

Reference is made initially to FIGURES 1 and 2 of the drawings. A cylindrical motor casing **1** includes at either end an inwardly-directed flange respectively **2** and **3**. A swash plate **4** is engaged within the casing **1** against the flange **2** and a swash plate **5** is engaged within the casing against the flange **3**. For purposes of assembly, the casing **1** is split in a diametrical plane, but details of the split do not appear in the drawings. A central hole **6** extends through the swash plate **4** and encloses a taper roller bearing **7** within which a drive shaft **8** is rotatably mounted, the axis of the drive shaft being parallel to the longitudinal axis of the casing **1**. Within the casing **1** the drive shaft **8** is connected fixedly to a rotary cylinder block **9** or may be integral therewith.

The cylinder block **9** includes a plurality of cylinders **11** each parallel to the block rotation axis and bored through the block from end to end. Within each cylinder **11** a pair of pistons **12** and **13** are slidably mounted, these pistons being urged apart by a compression spring **14** within the cylinder. The outer ends of the pistons **12** and **13** are each socketed respectively at **15** and **16** to receive respectively the ball ends of slippers **17** and **18**. The slippers **17** engages the inclined cam surface **19** of

swash plate 4. The slippers 18 engage the inclined cam surface 21 of the swash plate 5. A fixed bearing member 22 is integrally formed with the swash plate 5 and enters a central recess 26 formed in the cylinder block 9 at the end opposite to the drive shaft 8. Preferably the cylinder block 9 and the shaft 8 are made as a single forging, the displacement of metal during formation of the recess 26 causing extrusion of metal from the other end of the block to form the shaft 8. Securely fixed within the base of the recess 26 is a valve member 27 within which are formed passages 28 leading one to the centre of each cylinder 11 and terminating as ports 29 in a flat block surface 31, extending perpendicular to the axis of block rotation. The passages 28 each make a sealed connection to a passage 23 extending in the block 1 from the centre of each cylinder 11. The valve member 27 is preferably arranged to be an interference fit within the recess 26 to ensure sealing engagement between the passages 28 and 23. A plurality of bolts 24 may be provided extending through the valve member 27 into the block to ensure that it remains in position. Grooves 55 in the base of the valve member 27 prevent build up of pressure by leakage which otherwise might move the member 27 axially.

The bearing member 22 includes a pair of passages 32 and 33 extending from the outer to the inner ends thereof, these passages performing supply and return functions for liquid fed to the motor. At the inner end of the member 22 the passages 32 and 33 each have a short cylindrical sleeve respectively 34 and 35 fixedly secured therein to extend parallel to the rotation axis. On the end of the sleeves 34 and 35 a valve plate 36 is mounted by means of recesses 37 and 38 in the valve plate. The sleeves 34 and 35 includes seals which ensure their engagement in the recesses 37 and 38 in a liquid tight manner. The face 39 of the valve plate opposite to the sleeves 34 and 35 is formed as a flat valve surface which engages the block surface 31. Within the valve surface supply and return ports 41 and 42 are formed, these ports being of conventional or kidney shape for engagement by cylinder ports 29. A taper roller bearing 44 engages between the bearing member 22 and the outermost part of the recess 26. It will be noted that the roller bearing 44 is located on the support 22 on the cylinder block side of a plane A–B which intersects the rotation axis perpendicularly at the point where the plane swash plate surface 21 intersects the rotation axis. By this means substantially the entire radial force generated by the engagement of the slippers 18 on the swash plate surface 21 is transferred directly through the bearing 44 to the support 22.

The cross-section through the bearing member 22 is shown in a plane at right angles to the cross-section through the remainder of FIGURE 1 in order to show more conveniently the sleeves 34 and 35 and the ports 41 and 42. Normally these sleeves and these ports would not appear in the section of FIGURE 1.

Each of the slippers 17 and 18 includes a deep circumferential groove 45 which is engaged by a slipper plate 46. A part of the slipper plate 46 is shown in plan view in FIGURE 2. Generally the slipper plate 46 is in the form of an annulus having recesses 47 opening from its circumference. The recesses 47 fit around the bottoms of the grooves 45 to ensure substantial engagement between the plate 46 and both sides of each groove 45 in each slipper. The function of the plate 46 is to assist in holding each slipper 18 in contact with its swash plate surface. It will be appreciated that in operation only some of the pistons will receive liquid under pressure which will urge them outwardly so that their slippers engage the adjacent swash plate surface. The few slippers that are strongly held by their pistons against the swash plate surface will act on the slipper plate 46 to hold it or tend to hold it parallel to the swash plate surface. The forces exerted will react on all other slippers adjacent to that swash plate to hold them, or tend to hold them, against the swash plate surface. In the described embodiment the sockets 15 and 16 in the ends of the piston are arranged so as not to be capable of retaining the slippers if a pulling force is exerted on the slipper by the plate 46 to move it out of the recess. The springs 14 act on their associated pistons always to urge them outwardly to tend to ensure that the sockets 15 and 16 always engage their respective slippers. However, the springs are not a positive assurance that the pistons will always engage their respective slippers since if the unit described is to act as a pump and suction has to be exerted on liquid to cause it to enter the cylinders, the occasion might arise when the springs 14 cannot exert a sufficient force to provide the necessary suction and these slippers may then disengage from their pistons. Alternatively, if the unit acts as a pump and is driven at high speed, it can well occur that the springs 14 are not of sufficient strength to urge the piston out of the cylinders in the short period available for the outward stroke against the inertia of the pistons. Again the slippers would then disconnect from their pistons. A guard ring 48 is fixed to the periphery of each swash plate surface 19 and 21 to engage the slippers in the event that they then tend to centrifuge outwardly from the plate 46 if disengaged from their pistons. The guard ring 48 extends over about three-quarters of the circumference of the swash plate surfaces at positions where the slippers extend substantially from the cylinders. At the positions where the slippers are almost fully in the cylinders, as shown, on the bottom cylinders, of FIGURE 1, the guard ring is unnecessary.

At positions between the recesses 47 parts of the circumference of the slipper plate 46 are reduced in thickness, as shown at 49. The purpose of these reductions in thickness is to avoid actual contact between the slipper plate and the cylinder block between adjacent cylinders at the innermost positions of the pistons. The reduced portions 49 again serve to enable the swash plates to be located very close to the cylinder block thus reducing total overall length.

In operation of the motor, liquid at pressure is supplied to one of the passages 32 and 33 depending on the direction of rotation desired and return liquid at low pressure is taken from the other passage. Assume that such high pressure liquid is supplied to the connection 32. The pressure liquid passes through the sleeve 34 and in the recess 37 will act on the valve plate 36 to urge it into engagement with the block surface 31. Liquid from the recess 37 will then pass through the main port 41 into the cylinder ports 29 which are in connection with it. Liquid at pressure will then be conveyed to all cylinders whose pistons will move outwardly with the desired rotation of the cylinder block by virtue of the slopes of the cam surface 19 and 21. The cylinders in connection with the other port 42 will discharge liquid at low pressure into the passage 33 since their pistons will move inwardly by virtue of their engagement with the cam surfaces. The cross-sectional area of the recess 37 which engages on the sleeve 34 is so chosen in relation to the cross-sectional area of port 41 that the valve plate 36 is held with a slight excess of hydraulic force on the block surface 31. Since the cylinders are all of constant diameter and they each include two pistons acting oppositely on the surfaces 19 and 21, no resultant axial hydraulic force reacts on the cylinder block from the pistons. However the pressure of liquid acting in the port 41 produces a force which is transferred to the block itself. This axial force is resisted by the taper roller bearing 7. The radial thrust exerted on the cylinder block by virtue of the engagement of the pistons with the cam surfaces 19 and 21 are re-acted through the taper roller bearings 7 and 44. The cylinder block 9 is therefore located in the casing by the bearings 7 and 44 for rotation only, any other movements of the block being resisted by

the bearings. The valve plate **39** is free to tilt and to move axially on the sleeves **34** and **35** to engage the block surface **31** quite independently of any radial thrust exerted through the taper roller bearing **44** and any slight deflections that might occur of the bearing support **22**.

Reference is now made to FIGURE 3 of the accompanying drawings. This figure shows a motor which differs in detail only from the motor shown in FIGURES 1 and 2. Detailed description of FIGURE 3 is not proposed except to point out the essential differences in structure. Where possible similar reference numerals in FIGURES 1 and 3 will refer to similar parts thereof. In FIGURE 3 the support member **22** is not integral with the swash plate **5** but is made as a separate item for fixing to the swash plate **5**. For this purpose a central hole **51** is provided in the swash plate **5** to receive the support member **22**. A flange **52** around the support member **22** is secured by bolts **53** to the swash plate **5**. In FIGURE 3 the bearing **44** in the recess **26** is a parallel roller bearing rather than a taper roller bearing and it is located more closely to the plane A–B than is the bearing **44** in FIGURE 1. In FIGURE 3 no slipper rings are employed to locate the slippers but alternatively the recesses **15** and **16** in the ends of the pistons **12** and **13** are provided with circlips **54** which locate the ball ends of the slippers in the recesses so that there is no danger of the slippers parting from their associated pistons. On the occasions when the springs **14** are not able to urge the pistons out sufficiently quickly during pump action of the illustrated unit, the slippers will part from the cam surfaces for short periods during rotation.

In FIGURE 3 the cylinder port plate **27** rests on a shoulder **20** in the bottom of the bore **26** which includes relief recesses **55** whose function is to prevent build-up of liquid pressure behind the port plate **27** which might move it axially. Central holes **56** in the port plate **27** and **57** in the valve plate **36** will vent any such leakage liquid to the interior of the casing from whence it is drained by a suitable drain connection.

In FIGURE 3, as in FIGURE 1, the cross-section through the bearing support **22** is shown in a plane at right-angles to the cross-section of the remainder of the drawing.

The operation of the FIGURE 3 embodiment of the invention is substantially the same as that described for the FIGURE 1 embodiment.

In a further modified form of motor the cylinders **11** are of stepped form so that the ends of the cylinders adjacent to the bearing member **22** are of slightly smaller diameter than the ends of the cylinders adjacent the drive shaft **8**. The difference in diameter of the cylinders is so calculated that the total axial thrust exerted by the pistons and the recesses **37** and **38** under pressure is extremely small. In this way the taper roller bearings **7** and **44** of FIGURE 1 or the bearing **7** of FIGURE 3 can be relieved of substantially all axial load.

Whilst in the described embodiments the valve plate is secured against rotation about the block axis, it is within the scope of the present invention for the valve plate to be adjustable through a small angle about the block axis to vary the phasing between reciprocation of the pistons and the connection of the cylinders to the supply and return ports in order to vary the effective hydraulic displacement per revolution of the pump or motor. For this purpose the support **22** may be rotatably mounted in the swash plate **5**.

In the described embodiment the cylinder block is supported by the two bearings **7** and **44** of which the bearing **7** is external of the block. In a modified form of the invention the block may be supported completely by internal bearings between the support **22** and the block. Rotary driving torque may then be transmitted to or from the block by means of gear teeth disposed around the periphery of the block.

Whilst the valve means in the illustrated embodiments is of the face valve type hydraulically urged into engagement with the face **31** of the block it is within the scope of the present invention that the valve means may take any other conventional form. For example, it could be a simple pintle valve engaging in a cylindrical valve surface in the block.

In the described embodiment the cylinders **11** are shown to extend completely through the cylinder block. However it is possible to modify this arrangement by providing for example separate cylinders extending into the block from the two ends thereof. Such cylinders may be either parallel to or inclined to the block rotation axis.

What is claimed is:

1. A hydraulic machine including a rotatable cylinder block having cylinders therein, a first fixed swash plate adjacent to one axial end of the block, pistons projecting from cylinders which open into said one end of the block and engaging the first swash plate, a second fixed swash plate adjacent to the other end of the block, pistons projecting from cylinders which open into said other end of the block and engaging the second swash plate, whereby rotation of the block induces reciprocation of the pistons in the cylinders, a casing enclosing the cylinder block and rigidly securing the swash plates together in fixed spaced relationship to one another, a bearing support fixedly connected to the first swash plate and extending from the latter swash plate into a recess in the one end of the block, a bearing engaged between the peripheries of the recess and the support and acting as the sole means for supporting axial and radial forces imposed on the one axial end of said cylinder block, a valve means supported on the bearing support for axial movement in relation thereto, whereby the cylinders in the block are alternately connected to a supply passage for liquid and a return passage for liquid extending through the bearing support in synchronism with rotation of the block and reciprocation of the pistons in the cylinders, a shaft extending from the said other end of the block through a hole in the second swash plate, and a bearing engaged between the shaft and the hole.

2. A hydraulic machine as claimed in claim **1** wherein the bearing between the recess and the support is arranged to lie substantially or entirely on the cylinder block side of a plane which intersects the rotation axis perpendicularly at the point of intersection of the rotation axis with the first swash plate surface.

3. A hydraulic machine, as claimed in claim **1**, including a cylinder port plate fixedly connected to the block in the recess thereof, and having one surface forming the said block surface, the ports in the port plate having connecting passages to the cylinders.

4. A hydraulic machine, as claimed in claim **3**, wherein the port plate is an interference fit within the recess.

5. A hydraulic machine as claimed in claim **1** wherein the valve means comprises a circular valve plate mounted on the bearing support for axial and tilting movement in relation thereto so as to continuously engage a flat surface formed on the block, the bearing support being of cylindrical shape and the valve plate being disposed wholly within the recess and at least as large in diameter as the bearing support.

6. A hydraulic machine as claimed in claim **1** wherein the bearings each comprise a taper roller bearing disposed to accommodate both axial and radial thrust from the block.

7. A hydraulic machine including a rotatable cylinder block having cylinders therein, a first fixed swash plate adjacent to one end of the block, pistons projecting from cylinders which open into said one end of the block and engaging the first swash plate, a second fixed swash plate adjacent to the other end of the block, pistons projecting from cylinders which open into said other end of the block and engaging the second swash plate whereby rotation of the block induces reciprocation of the pistons in the cylinders, a casing rigidly securing the swash

plates together in a fixed spaced relation and enclosing the cylinder block, a fixed bearing support extending into a recess in the one end of the block from the first swash plate, a bearing engaged between the recess and the support, a valve means movably supported on the bearing support for connecting the cylinders in the block alternately to a supply passage for liquid and a return passage for liquid extending through the bearing support in synchronism with rotation of the block and reciprocation of the pistons in the cylinders, a shaft extending from the said other end of the block through a hole in the second swash plate, a bearing engaged between the shaft and the hole, a slipper plate recessed at a plurality of positions around its periphery to fit in grooves formed in the slippers engaging a swash plate whereby slippers loaded against the swash plate by their pistons will act through the slipper plate to hold the other slippers against the swash plate, and a guard ring secured to the swash plate and at least partly surrounding the swash plate surface to limit outward centrifuging of the slippers engaging the swash plate.

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