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3,401,506

CENTRIFUGAL SEPARATORS

Original Filed June 18, 1964

2 Sheets-Sheet 1

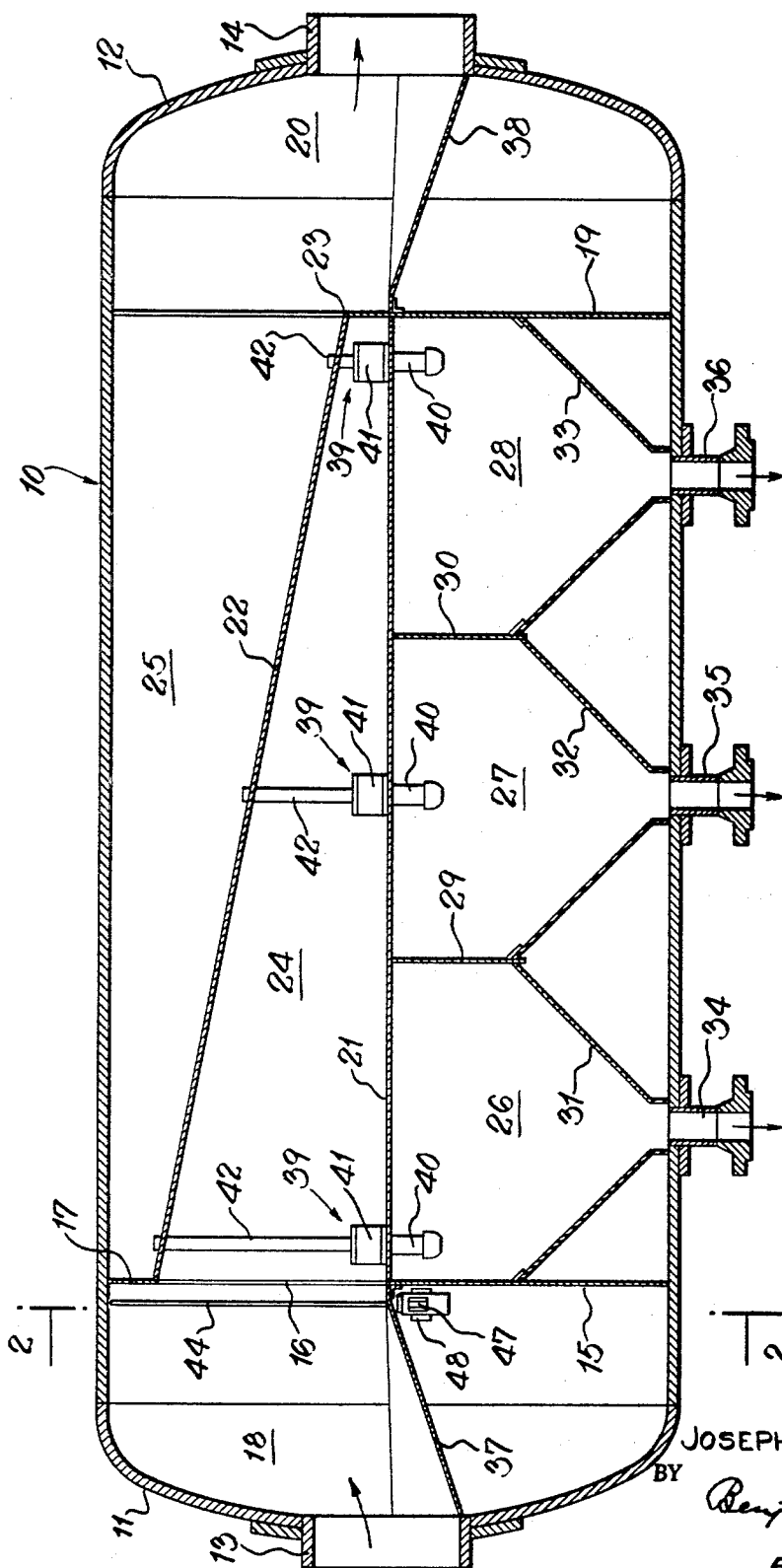


Fig. 1.

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Fig. 2.

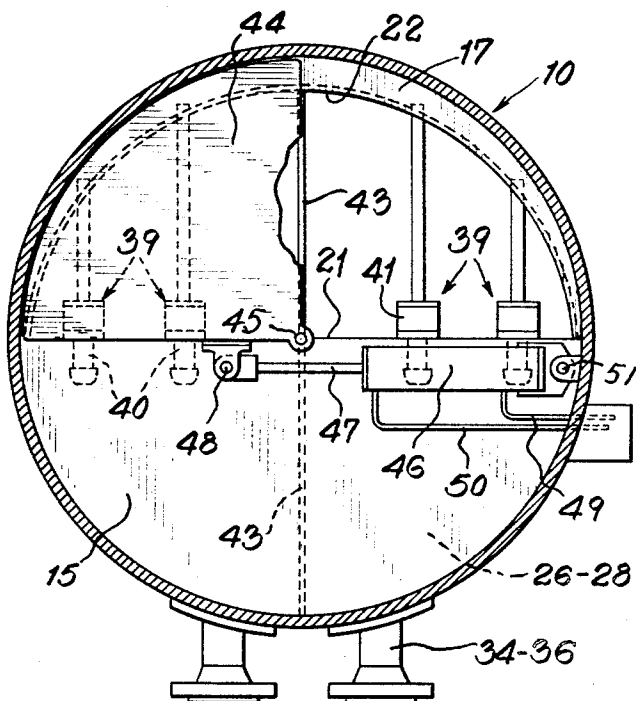
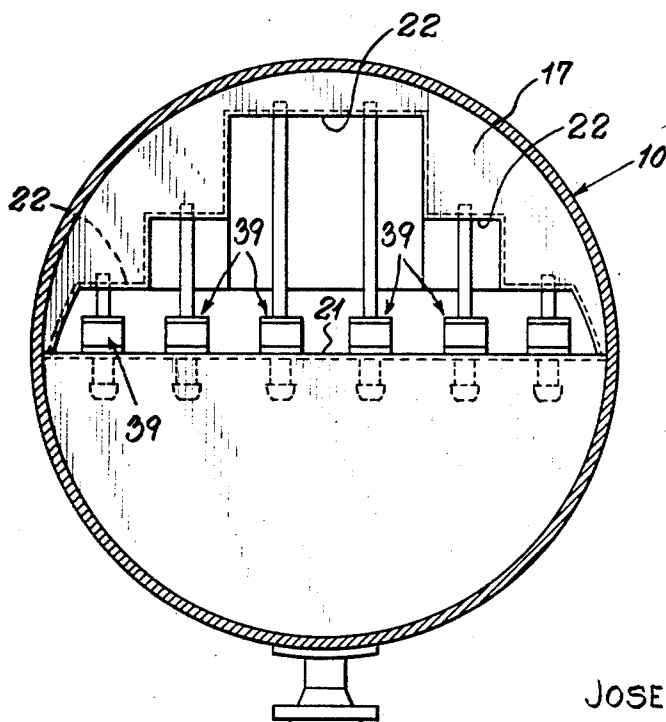


Fig. 3.



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1964. This application Apr. 27, 1967, Ser. No. 634,388
4 Claims. (Cl. 55-344)

ABSTRACT OF THE DISCLOSURE

Apparatus for separating suspended particles from gases consisting of a long horizontal closed cylinder divided by a horizontally extending flat sheet substantially in the mid-section of the cylinder, an inclined sheet extending over the horizontal sheet from the inlet end to the outlet end and formed to provide in cross-section a stepped plenum chamber. Conventional centrifugal tubes are mounted in the horizontal sheet to carry separated particles into compartments below and cleaned gas above the inclined sheet. A movable seal valve is arranged to seal-off a portion of the plenum chamber for reducing the capacity of the apparatus.

This application is a continuation of S.N. 376,047 filed June 18, 1964, now abandoned.

My present invention relates to apparatus for separating particles from gases and is particularly useful in the separation of liquid and/or solid particles from natural gas. These particles must be removed before the gas is supplied for use.

Natural gas is produced under heavy pressures and in very large quantities. The pressures may be as high as 2000 pounds per square inch or more and the quantity of gas at the producing locality may be upwards of 1,000,000,000 standard cubic feet per day, a standard cubic foot being a cubic foot of gas at about atmospheric temperature and atmospheric pressure. At 2000 pounds per square foot it would occupy much less space but the volume to be cleaned from suspended particles per day would be very large. The container in which the separation of the particles takes place must be very strong and massive to hold the gas under these high pressures. These containers are necessarily cylindrical and of limited diameter. In the present invention they are preferably horizontal.

The separation of the particles from the natural gas is most effectively and efficiently accomplished by a multitude of small centrifugal separators. Each separator comprises an open ended tube mounted in a tube sheet extending lengthwise of the container and dividing the container into a collecting chamber into which the separated particles are delivered and a plenum chamber to one end of which the particle carrying gas is supplied and from which it is delivered to the tubes in rotating movements about the axes of the tubes. An open-ended off-take pipe for each tube is mounted in a partition wall or tube sheet dividing the plenum chamber from an off-take chamber to extend axially into the inlet end of the tube to form an annular passage therein from the inlet end of the tube to the open end of the off-take pipe, which is spaced from the opposite end of the tube which delivers into the collecting chamber.

Heretofore, in an arrangement of this type, it has been found that the container must be of a limited length beyond which the efficiency of the centrifugal tubes decreases progressively with the length, a portion of the suspended particles being carried through the apparatus with the delivered gas. This has necessitated the use of a number of separating units of short length and of con-

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necting piping. This raises the cost above that of a single longer unit.

Applicant's invention provides a means whereby the length of the container may be made much longer to treat a larger amount of gas efficiently, reducing the number of units and the piping required therefor and accordingly reducing the cost of the equipment.

The efficiency of separation of the particles depends on the velocity of the gas in the centrifugal tubes and, where the number of tubes in any installation is fixed, the velocity through the centrifugal tubes is determined by the volume of gas passing through the apparatus. However, the amount of gas to be treated varies with the demand which varies seasonally or otherwise. In systems using a number of separate separating units the amount of gas, and accordingly the velocity through the units may be controlled by closing units from operation to maintain the required velocity in the remaining units.

Applicant's invention also provides means in a single large unit to control the number of units in operation in accordance with the amount of gas to be treated.

The apparatus of applicant's invention comprises a thick wall container which, to withstand heavy pressure, is of cylindrical shape with rounded ends, preferably of semi-elliptical curvature and with an inlet at one end and an outlet at the other end. In use the container is in a horizontal position, with its axis substantially horizontal. Within this container is the separating apparatus. The separating apparatus comprises a pair of end plates spaced inwardly from the ends of the container to form a gas receiving space at the inlet end and a gas delivery space at the outlet end. These end plates are sealed to the interior of the lower half of the container and are open in the upper part of the container. A horizontal tube sheet extends from the end plates below the openings in the end plates and is sealed to the inner surface of the container and to the end plates to form a collecting chamber below the tube sheet and a passage above the tube sheet through which the gas may pass from the inlet to the outlet. The centrifugal tubes are mounted in the tube sheet in the customary manner with an open end in the passage and the other end opening into the collecting chamber. The collecting chamber is divided by means of transverse vertical partitions at spaced intervals into a succession of compartments between the end plates. Each compartment has an individual drain outlet for material collected therein.

The passage above the tube sheet is divided by a longitudinal upper tube sheet extending from one end wall to the other, curved or shaped to form a plenum chamber open at the front or inlet end and decreasing in height from the plane of the front partition plate to the plane of the rear or outlet partition plate, and an off-take chamber closed at its front end and open at its rear end and increasing in height toward the outlet. The off-take pipes of the individual centrifugal tubes are mounted in this upper tube sheet to extend downwardly into the upper portion of their respective centrifugal tubes.

The container is also divided by one or more vertical partitions extending from the front plate to the rear plate and through the off-take chamber, the plenum chamber and the collecting chambers to divide these chambers into sidewise arranged sub-compartments. One or more dampers supported on the front plate may be moved to close one or more of the plenum compartments to reduce the number of centrifugal tubes in operation when the apparatus is operated at reduced capacity.

The invention is illustrated in the embodiment shown in the accompanying drawings in which:

FIG. 1 is a longitudinal vertical section through the embodiment;

FIG. 2 is a vertical cross-section on the line 2—2 of FIG. 1; and

FIG. 3 is a sectional view similar to that of FIG. 2 showing a modification.

In the embodiment shown in FIGS. 1 and 2, the apparatus for separating the suspended particles from the gas is contained in a horizontal cylindrical container 10 of a wall thickness sufficient to withstand heavy pressures and having rounded end walls 11 and 12. An inlet 13 is welded to the end wall 11 and an outlet 14 is welded to the end wall 12.

Within the container 10 and spaced somewhat from the inlet 13 is a vertical plate 15 transverse to the axis of the container sealed at its edges and extending upwardly to approximately the axis of the cylinder and having an opening indicated at 16 and a closed portion 17 above this opening. This forms an inlet space 18 between the end wall 11 and the plate 15.

Similarly a plate 19 spaced forwardly from the end 12 is sealed at its edges to the cylindrical wall of the container 10 and extends upwardly a short distance from the axis of the container to form an outlet space 20. A horizontal tube sheet 21 extends from the front plate 15 to the rear plate 19 and is joined to these plates and to the wall of the container to divide the interior of the container between the plates 15 and 19 into a lower space and an upper space.

An upper tube sheet 22 is mounted above the tube sheet 21 and extends from the upper edge of the opening 16 to the edge 23 of the rear plate 19 thereby dividing the space above the lower tube sheet 21 into a plenum chamber 24 open at its inlet end and closed toward the outlet end, and an off-take chamber 25 above the tube sheet 22 closed at the inlet end by the upper part 17 of the plate 15 and open above the upper edge of the plate 19. The space below the lower tube sheet 21 between the plates 15 and 19 is divided into several collecting compartments 26, 27 and 28 by transverse walls 29 and 30 sealed to the lower tube sheet 21 and to the wall of the container 10. Three such compartments are shown in the embodiment although there may be two or more compartments depending upon the length of the container.

These compartments may extend in contact with the container wall throughout the lower circumference of the container wall. But preferably, as shown in the drawings, they are formed to a funnel shaped portion 31, 32 and 33 respectively, to individual drain outlets 34, 35 and 36.

In the inlet space 18 a deflector sheet 37 is mounted to extend from the lower part of the inlet 13 to the level of the tube sheet 21 to guide incoming gas into the plenum chamber 24, this guide plate acts in effect as an imperforate extension of the tube sheet 21. Similarly in the outlet space 20 there is provided an imperforate guide plate 38 extending from approximately the horizontal diameter of the plate 19 to the lower part of the outlet to guide the gas to the outlet.

A number of small centrifugal separators 39 are mounted in the container between the plates 15 and 19. Only three of these centrifugal tubes are shown for simplicity, but the space between the plates is filled with these centrifugal separators spaced sufficiently to permit access of gas to them. Each of these centrifugal separating elements comprises a centrifugal tube 40 secured in the tube sheet having an open or lower end extending into one of the collecting compartments 26, 27 and 28, and an upper end opening into the plenum chamber and provided with an inlet part 41, of any suitable construction known in the art, to permit the gas to flow from the plenum chamber into the tube 40 in a rotative manner.

For each tube 40 there is provided an off-take pipe 42 mounted in the upper tube sheet 22 opening into the off-take chamber 25 and extending axially down into the upper part of the tube 40 to form an annular passage for the rotating gas entering the tube. The gas thus rotates in a spiral path about the off-take pipe to the

lower open end of the off-take pipe and then passes upwardly to the off-take chamber. In its passage through the off-take pipe 42 and tube 40 the particles are thrown out and drop into the respective collecting compartments 26-28 while the gas freed from the separated particles passes upwardly as described above.

Between the plates 15 and 19 the off-take chamber 25, the plenum chamber 24 and the collecting compartments 26-28 are divided by a vertical partition wall 43 extending through the axis of the cylinder into two side-by-side spaces. When the apparatus is operating above one-half capacity, or at full capacity, the gas passes equally in the two side-by-side divisions of the plenum chamber, thence into the respective side-by-side divisions of the off-take chamber and the separated particles correspondingly drop into the two divisions of the collecting chambers 26-28. This separating partition has no function when the apparatus is thus operated. However, should the supply of gas drop sufficiently below the full capacity of the apparatus toward or below one-half capacity, one of these side-by-side spaces into the plenum chamber is closed by a rotating seal 44 about a bearing 45, FIG. 2, co-axial with the axis of the container.

This seal 44, which may be approximately one-quarter of a circle, may be operated by means of a suitable servo device as may be known in the art. For example, such a device may include a piston and cylinder 46, a piston rod or link 47 connected to a bracket 48 on the lower edge of the seal 44. By admitting fluid under pressure through a pipe 49 to one end of the cylinder 46 the seal 44 may be swung to its closed position while admitting fluid under pressure through a pipe 50 and may turn it to open position. More specifically, a piston is located between the pipes 49 and 50 and rigidly connected to the piston rod 47 so that when fluid under pressure is admitted to the pipe 50, the piston and piston rod 47 moves to the right, and when the pipe 50 is open to exhaust by lower fluid pressures and pressure fluid is supplied through the pipe 49, the piston and piston rod moves to the left.

Piston rod 47 is pivotally connected to plate 44 below the axis of rotation of bearing or pivot 45 of the seal plate 44. Consequently, when pressure fluid is admitted through the pipe 50 forcing the piston to the right, the bracket 48 is pulled to the right downwardly and causes the seal plate 44 to rotate counterclockwise about its axis 45 thereby opening the left hand compartment to the gases to be treated. When it is desired to close this compartment pressure fluid is admitted through the pipe 49 and exhausted through the pipe 50 thereby forcing the piston and piston rod 47 and the bracket 48 to the left and causing the plate 44 to swing clockwise upwardly to close the compartment. The cylinder is pivoted, as indicated by 51 at the right hand end, so that it may swing in an arc as the plate 44 swings downwardly, the pipes 49 and 50 being suitably flexible as will be apparent to those skilled in the art so as to follow the pivotal movement of the assembly.

When the apparatus is run at full capacity or above the lower limit for the full use of all of the separating tubes, the seal 44 is below the axis of the container. When the apparatus is operated at less than a minimum for full use of all of the tubes, the seal 44 is swung to the position shown in FIGS. 1 and 2 to close one-half of the plenum chamber so that the gas passes through only one-half of the cylindrical tube elements. In this way the apparatus may be sub-divided into one-half capacity when the flow of gas decreases sufficiently, thus serving to maintain as closely as possible the speed of the gas through the separating elements. If a closer approximation to the correct speed and capacity is desired more than one partition 43 and a corresponding number of sealing elements may be employed. It may be noted as shown in FIG. 1 that each of the dividing portions of the collecting compartments 26-28 may be provided with a drain 34-36.

The upper tube sheet may be rounded toward its con-

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nection with the upper part 17 of the plate 15 converging downwardly to the edge 23 so as to provide as closely as possible for a uniform flow of gas through the plenum chamber 24 from the inlet to the closed end and correspondingly a uniform flow of the gas in the off-take chamber from the closed end 17 to the delivery space 20.

In the modification shown in FIG. 3 the upper tube sheet 22 may be of stepped form at the inlet end.

While the wall of the cylinder 10 must necessarily be thick and strong to withstand pressure, the various plates and tube sheets and partitions within the container may be of relatively light gauge sheet because they do not have to withstand but slight differences in pressure.

Inasmuch as gas will not flow unless there is a pressure gradient downwardly from the inlet pressure to the outlet pressure, the pressure in the off-take chamber 25 must be less than that in the plenum chamber 24 and the pressure must diminish progressively in the direction from the inlet toward the outlet end of the container. Thus, pressure in the plenum chamber near the wall 15 will necessarily be higher than that near the wall 19, and similarly for the off-take chamber 25.

In the collecting compartment it is undesirable to have any pressure differential or flow of the gas. The pressure in these compartments should not be substantially higher nor less than that in the plenum chamber as otherwise gas would flow back and forth, and the pressure in the collecting compartments should not be sufficiently above the pressure in the off-take chamber to cause a flow of gas upwardly through the off-take pipes. If such flow occurred suspended particles delivered into the collecting compartments would be carried by the flow of gas into the off-take chamber and through the outlet, thus decreasing the efficiency of separation.

In an apparatus of the type shown in the drawings, where the distance from the inlet end of the plenum chamber to the outlet end is beyond that normally usable, the drop in pressure of gas from the inlet end of the plenum chamber to the outlet end of the off-take chamber would be sufficient to cause a flow of gas downwardly through the tubes 40 adjacent the inlet end to the tubes adjacent the outlet end and thence upwardly through the off-take pipe 42 at the outlet end into the off-take chamber thus carrying with it separated particles into the off-take chamber and into the outlet. This would decrease the effectiveness of the apparatus, as well as efficiency.

Applicant's invention overcomes this flow of gas and enables longer containers to be used by dividing the collecting chamber into the compartments 26-28, for in this arrangement the flow of gas in any compartment would be limited to the length of the compartment in an axial direction, which length may be so selected by a sufficient number of compartments as to maintain the pressure differential along the path of flow within any desired usable limit, thus to prevent circulation through the collecting compartments. This enables the container 10, and with it the plenum chamber 24 and off-take chamber 25, to be made longer than would be otherwise possible, and to combine in a single unit the capacity possible in several shorter units. This greatly reduces the cost by reducing the number of units and also reducing the pipe connections and valves for distribution of the gas to several units, as the piping equipment must be of massive construction and expensive.

The division of the apparatus by means of the partition or partitions 43 enables the capacity of the apparatus to be adjusted to demand without requiring separate or a number of separating units.

What is claimed is:

1. Apparatus for separating suspended particles from gases which comprises

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(a) a horizontal closed cylindrical container (10) of substantial length having an inlet (13) at one end and an outlet (14) at the other end,

(b) a first horizontal tube sheet (21) extending from said inlet to said outlet and sealed at its outer edges to said container and disposed in said cylinder to form a collecting chamber (26, 27, 28) below said tube sheet,

(c) vertical partitions (29, 30) transverse to the longitudinal axis of said container below said first tube sheet sealed at their edges to said container and to said first tube sheet and spaced to divide the collecting chamber into separate collector compartments (26, 27, 28) spaced along the longitudinal axis of the container,

(d) a second tube sheet (22) spaced above said first tube sheet and sealed to the wall of the container to divide the space above said first tube sheet into a single plenum chamber (24) below said second tube sheet open to said inlet and closed to said outlet, and a single off-take chamber (25) above said second tube sheet closed to said inlet and open to said outlet,

(e) a plurality of centrifugal separator elements (39-42) in said plenum chamber (24) communicating with each respective one of said collecting compartments (26, 27, 28), each said centrifugal separator element comprising an open-ended tube (40) in said first tube sheet and an open-ended off-take pipe (42) in said second tube sheet extending downwardly coaxially into one of said tubes,

(f) said second tube sheet (22) being inclined downwardly from the inlet end (18) to the outlet end (23) of said container and, in a direction transverse to the container axis, being shaped to form a stepped cross-section for said plenum chamber (24).

2. The apparatus of claim 1 wherein each of said collector compartments (26, 27, 28) includes a separate drain outlet (34, 35, 36) and a funnel-shaped bottom delivering to its respective outlet.

3. The apparatus of claim 1 wherein said container has at least one longitudinal vertical partition (43) extending through said collector and plenum chambers and said collector compartments to divide said chambers and compartments into side-by-side divisions, piston and cylinder means (47-50) arranged to close at least one of said divisions including a sliding seal (44) movable upwardly to close a selected division of said plenum chamber, said sliding seal being pivoted on a horizontal axis at the inlet end of said plenum chamber.

4. The apparatus of claim 3 wherein said sliding seal is a sector shaped plate (44) at the entrance end of said plenum chamber, means for pivotally mounting said sector shaped plate at its point on the axis (45) of said container to swing from a position below said first tube sheet to a position to close the entrance to one division of said plenum chamber and said piston and cylinder means (47-50) being arranged for swinging said plate from a position below said first tube sheet to a position above said first tube sheet.

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