

July 7, 1953

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2,644,397

PROJECTILE CONTROL SYSTEM

Filed Jan. 6, 1945

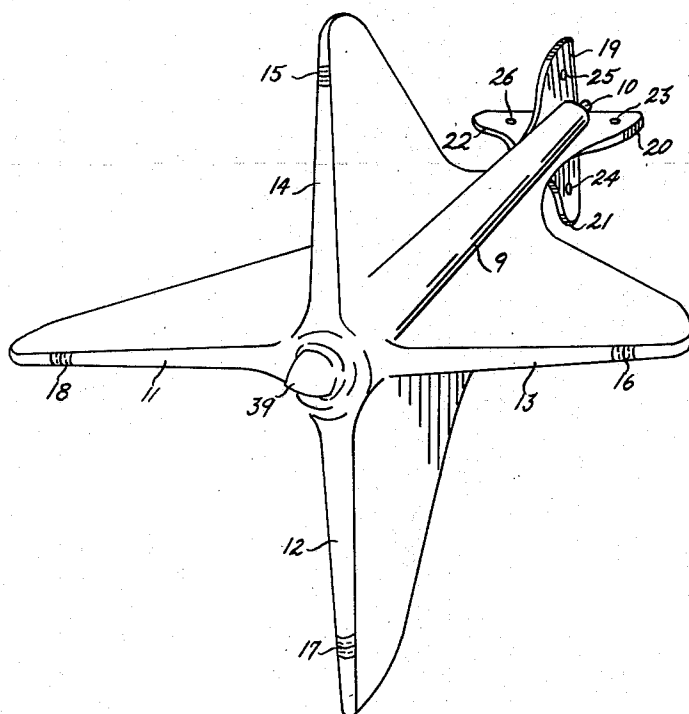


FIG. 1

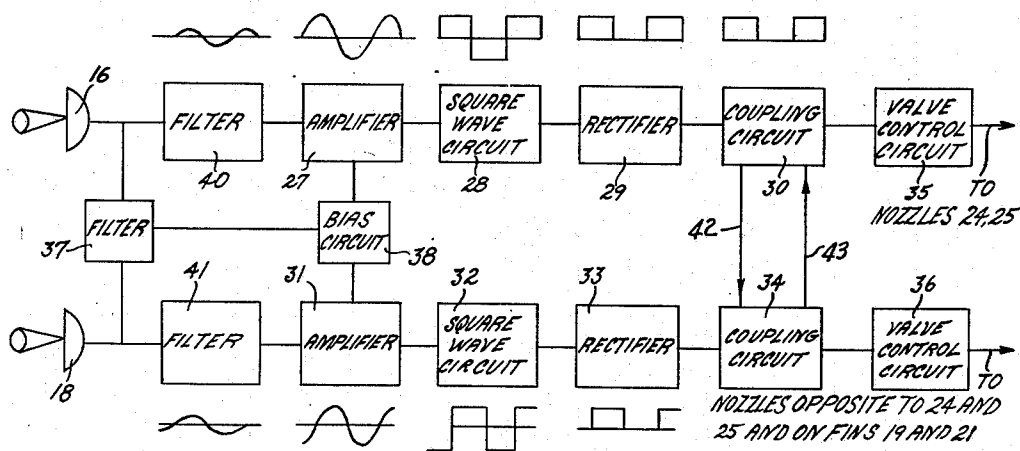


FIG. 2

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2,644,397

PROJECTILE CONTROL SYSTEM

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Application January 6, 1945, Serial No. 571,644

8 Claims. (Cl. 102-50)

(Granted under Title 35, U. S. Code (1952),
sec. 266)

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The invention described herein may be manufactured and used by or for the Government for governmental purposes, without the payment to me of any royalty thereon.

This invention relates to self-guided projectiles and, more particularly to projectiles that operate in response to sonic waves that are emitted by a target.

Numerous systems have been proposed heretofore for the automatic guidance of projectiles such as torpedoes that are self-propelled toward a target, and the like. Such systems usually comprise projectiles incorporating steering control means in cooperation with direction finders which spot the target and influence the control means in a manner and to a degree that are necessary to bring the projectile in line with the target. The nature of the direction finder is such that it reacts to a distinctive form of energy emanated by the target toward which the projectile is directed.

Direction finders are in general responsive to a feature which is unique in a target, otherwise the projectile might be led to an unintended destination. When the target is a power driven vessel, aircraft, flying bomb or the like, the distinguishable feature which lends itself most effectively for direction finding purposes is the sound emanating from the target and propagated in air or through water. Inasmuch as sounds generated by aircraft or vessels are of a high order of intensity, their detection and location are feasible from remote locations.

The objects of the present invention comprise the provision of a self-propelled projectile that contains a direction finder for determining the position of a source of sonic radiation; a projectile containing a direction finder which functions in cooperation with steering control means to direct the projectile to a sound emitting target; and a projectile containing a safety means that functions in conjunction with the automatically directed projectile for rendering the direction finder inoperative in the presence of a sound emitting target that is friendly.

With the above and other objects in view which will be apparent to those who are informed in the field of air borne equipment from the following description, an illustrative embodiment of the present invention is shown in the accompanying drawing, wherein:

Fig. 1 is a perspective view of an aerial torpedo that embodies the present invention; and

Fig. 2 is a block diagram of a circuit arrangement that forms a part of the present invention as applied to the torpedo that is shown in Fig. 1.

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A power driven vessel, aircraft or flying bomb in general generates a spectrum of sonic waves of diverse frequencies, of which certain specific frequencies are predominant. In the orientation of the projectile device that forms a part of the present invention, a small region of this spectrum is utilized with the result that the incoming wave after passing through a filter can be substantially treated as a sine wave.

In intercepting sound waves it must be borne in mind that these waves are of a longitudinal nature and that the wave front emanating from a sound source is substantially a sphere. If the sound source is fixed with respect to the transmission medium and an observation post, the apparent frequency will remain the same no matter how far the wave travels. At the observation post the wave front may be viewed as a plane perpendicular to the direction of its motion. It will be evident that if a pair of observation posts are both intercepting a sound wave from a given source, the observation posts will both receive the same frequency, irrespective of differences in their distances from the source of sound. If two observation posts lie in planes that are spaced from each other and that are both parallel to a wave front travelling from a sound source of a given frequency, and the spaced planes are less than a wavelength of that frequency apart, a sound pressure differential or phase difference will exist between the two observation posts as a function of the spacing between their respective planes. This phase difference will be zero when the observation posts lie in the same plane and will be 360° when the planes are a wavelength apart.

This phenomenon affords the basis for the present invention and is utilized by fitting a projectile with four sound detectors, each arranged at 90° points along the circumference of a circle concentric with the longitudinal axis of the projectile and lying in a plane perpendicular thereto. The diameter of the circle is less than a half wavelength long for a given sound frequency that is emitted by the source of the sound or the objective for which the projectile is intended. Two detectors at opposite ends of a common diameter are associated with the steering control of the projectile governing the angular orientation of the projectile in flight in a first or azimuthal plane, whereas the other two detectors at 90° to the first pair of detectors are associated with the steering control means of the projectile governing the angular orientation thereof in an elevational plane normally disposed to said first plane. When the detectors are oriented with respect to

the sound emitting source so that their outputs are in phase, the steering controls are maintained at a center or null point. When one detector is advanced in phase with respect to the other, the associated steering control is operated to left or right, up or down, as required to effect a correction in the course of the projectile, bringing it into line with the sound-emitting target.

A projectile in the form of an anti-aircraft torpedo that is propelled and steered by the forces of reaction that originate with the spontaneous combustion of gases which are ejected at high speed from the tail of the torpedo is illustrated in Fig. 1 of the accompanying drawing. Although the invention will be described in connection with a projectile of the aforementioned type for purposes of illustration, it is not intended to be limited thereto and may be adapted to function in an equally effective manner with other types of projectiles. The combustible gases preferably are separately maintained under pressure in tanks housed within the projectile in commonly known manner, and, after firing in a mixing chamber, are ejected through an exhaust nozzle 10 opening outwardly from the rear of the projectile and substantially axially thereof to propel the projectile straight ahead on a continuous course.

Four projectile supporting wings 11, 12, 13 and 14, extend radially from and preferably are integral with and extend longitudinally of the body 9 of the torpedo. Adjacent wings are substantially perpendicular with respect to each other. A corresponding number of sound detecting devices such as the microphones 18, 17, 16, and 15, or other suitable type of electrical detector that is responsive to sonic impulses, are individually mounted at radially equidistant points radially outwardly of the leading edges of the wings 11, 12, 13 and 14, respectively. The projectile is provided with tail fins 19, 20, 21, and 22 that preferably are coplanar with the wings 14, 13, 12 and 11 respectively and that provide rudder and elevator surfaces for maintaining a flight course that is normally continuous straight ahead and level where the four microphones 15, 16, 17 and 18 receive the same sound impulse at the same time. The torpedo is steered by the ejection of gases from nozzles 23, 24, 25, and 26 that open selectively thru one side of the faces of the fins 20, 21, 19 and 22 respectively and correspondingly disposed nozzles, not shown, that open oppositely thereto. These steering nozzles 23, 24, 25, and 26 and the corresponding nozzles on the opposite sides of the fins 20, 21, 19, and 22 eject gases in streams, the axes of which are perpendicular to the direction in which propelling gas is ejected from the nozzle 10. The course that is assumed by the projectile is the resultant of the forces of reaction that are created by the discharge of gases that are ejected thru the main driving jet from the nozzle 10 and from the jets in the fins 19, 20, 21 and 22.

A charge that is disposed within the body 9 of the torpedo explodes when the nose 39 thereof impinges upon a target. Electrically operated valves, not shown, are provided in the pipe lines on the steering jets 23, 24, 25, and 26, and the jets that are opposite thereto, for individually controlling the gas flow in the jets, thereby controlling the direction of flight of the projectile in azimuth and in elevation. Each microphone 15, 16, 17 and 18, is associated thru valve controls with its particular jet valve in a fin correspond-

ingly positioned relative to the wing carrying the particular microphone.

The distances between the pair of microphones 15 and 17, and the pair of microphones 16 and 18 are less than a half wavelength for a given frequency and are well within the range of the sound emitted by the target and passed by the filters 40 and 41 of Fig. 2. When the longitudinal axis of the torpedo is coincident with a line from the projectile to the source of sound, all of the microphones 15, 16, 17, and 18, lie in a plane that is parallel to the assumed plane of the wave front. Where the torpedo axis is not aligned with the radial line emanating from the sound source, the microphone currents will be out of phase to a degree that is contingent upon the extent of the deviation. The microphone 16 controls the gas jets from the nozzles 24 and 25 in the vertical fins 21 and 19, respectively, to thrust the tail of the projectile in one lateral direction, and the microphone 18 controls gas jets from corresponding nozzles, not shown, on the opposite side of the vertical fins 21 and 19 to thrust the tail of the projectile in the opposite lateral direction.

If the projectile is approaching a wave front that is not normal to the axis of the projectile body portion 9 and the microphone 16 is incident to the wave front before the microphone 18 is incident thereto, then the nozzles 24 and 25 are caused to emit gas jets to veer the projectile so that the axis of the projectile body portion 9 becomes normal to the plane of the sound wave and until both microphone 16 and 18 receive sound waves which are in phase, whereupon the pair of gas jets is cut off.

In a similar manner, if the microphone 18 strikes the wave front before the microphone 16 does, then gas jets are started from the pair of nozzles, not shown, on the sides of the fins 21 and 19 that are opposite to the sides carrying the nozzles 24 and 25, respectively, so that the nose 39 of the projectile is turned toward the source of sound, or the axis of the body portion 9 is directed toward a normal position with respect to the plane of the sound wave. The ejected gas compels the torpedo to shift position until both microphones receive sound waves which are in phase resulting in the laterally directing jets being cut off.

The microphones 15 and 17 cooperate in a similar manner to cause the projectile to either climb or dive by emitting gas from the nozzles 23 and 26 or from the nozzles opposite thereto, not shown, respectively. The action of the valves controlling the various gas jets in the projectile fins 19, 20, 21 and 22 is positive and will open when there is any phase difference existing between the microphones 15, 16, 17, and 18, irrespective of the degree of such phase difference. Thus, by the combined functioning of the radio channels from the microphones 15, 16, 17, and 18, the torpedo is brought into line with and is maintained on a course straight to the target.

The microphones 16 and 18 open into individual electric energy conducting channels, as shown in Fig. 2. A sound wave that strikes either or both of the microphones 16 and 18 is converted into an audio electric signal that travels along its individual channel and at the end of the channel causes the emission of gas jets laterally of the particular pair of projectile fins that are associated with the microphone that receives the sound wave.

The audio signals into which the microphones

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16 and 18 convert the sound waves that are intercepted thereby, are passed from the microphones 16 and 18 to the pretuned filters 40 and 41, respectively, that are shown in Fig. 2 and that function in the usual manner to clarify the audio signals and to resolve them into preferably sine waves such as those shown above the filter 40 and below the filter 41. The filters 40 and 41 pass their respective audio signals to amplifiers 27 and 31, respectively. Each microphone 15 to 18 inclusive, is associated with a correspondingly positioned jet, through an amplifier which under certain conditions operates an electrical valve when a sound is intercepted by the microphone. The amplifying channels of the microphones 16 and 18 are cooperatively arranged in a manner whereby the microphone nearer the source of sound, opens its associated nozzle and simultaneously causes the other microphone channel to be inoperative.

A preferred block diagram circuit for controlling the operation of the jet jets that are emitted from the fins 19, 20, 21 and 22 from the microphones 15, 16, 17, and 18, is shown in Fig. 2 of the accompanying drawing. The circuit arrangements for the microphones 16 and 18 are shown in block form. The microphones 15 and 17 are associated with a substantially duplicate circuit and hence need not be shown. The output of the microphone 16 is impressed upon the input circuit of the vacuum tube amplifier 27 after having been fed through the pretuned filter 40.

The output of the microphone 18 is impressed thru the filter 41 upon the amplifier 31.

The filters 40 and 41 are designed to select a single harmonic of the sound emanating from the target so that their outputs are substantially sine waves of a common frequency.

The outputs of the amplifiers 27 and 31, as illustrated above the amplifier 27 and below the amplifier 31, are applied to square wave circuits 28 and 32 which level off the top portion of the sine waves so that the waves assume substantially the form of square waves, as shown above the square wave circuit 28, and below the square wave circuit 32. This may be accomplished by conventional limiter circuits that employ vacuum tubes operating in the saturation portion of the plate characteristic curves. Although the initial sound wave may not be of pure sinusoidal form, this factor is of no importance because of the action of the filters 40 and 41. The negative going portions of the square wave output of the square wave circuits 28 and 32 are removed by half wave rectifiers 29 and 33, as shown thereabove and therebelow, respectively. The output of the rectifiers 29 and 33 are fed to coupling circuits 30 and 34 respectively.

The output of microphone 18, as shown below amplifier 31, in a similar manner, is amplified after having gone through a filter 41. It is then converted into a square wave pulse by the amplifier 31 and the square wave circuit 32. The half wave rectifier 33 removes the negative going portion of the wave as indicated below the rectifier 33 in the block diagram. The output of rectifier 33 is applied to a coupling circuit 34 that is substantially a duplicate of coupling circuit 30.

The individual coupling circuits 30 and 34 comprise a vacuum tube amplifier, not shown. The amplifiers in the coupling circuits 30 and 34 are mutually connected by connectors 42 and 43 in such a manner that the plate of the amplifier in the coupling circuit 30 is connected

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through suitable circuit elements to the grid of the amplifier in the coupling circuit 34 and vice versa with this triggering arrangement, the first coupling circuit to receive a square wave pulse from its associated rectifier 29 or 33 generating a biasing voltage which blocks the other coupling circuit for a limited period. The period extending beyond the application of the pulse, commencing with the application of one square wave pulse, lasts until shortly before the appearance of the next square wave pulse. This result is accomplished by initially biasing each coupling circuit 30 and 34 almost to the point of cut-off and associating the output of each coupling circuit with the biasing circuit of the other, so that the first coupling circuit 30 or 34 to receive a square wave pulse in the input circuit thereof imposes a bias upon the other coupling circuit to a point greatly below cut-off. The incoming square wave pulse that is fed to the more heavily cut-off biased coupling circuit is unable to overcome this bias as long as it is imposed. The cut-off bias is maintained for a period that extends beyond the duration of the square wave pulse by any suitable known storing network, such as a resistance-capacitance network or the like. It should be noted that this operation will only be consistent when the phase difference is smaller than 90°. In general this steering control is intended to correct the projectile's course after it has been launched in the direction of the target. The output of the coupling circuit 30 is fed to a valve control circuit 35, preferably in the form of a conventional electronic relay which opens the particular nozzle valves 24 and 25 that are associated with the microphone 16, as long as the coupling circuit 30 is operative. The output of the coupling circuit 34 in a like manner is associated with a valve control circuit 36 that operates the valves of the nozzles that are associated with the microphone 18 and that are disposed on the sides of the fins 19 and 21 that are opposite to the sides thereof upon which the nozzles 24 and 25 are disposed.

When the projectile is oriented on a line with the target, both microphones 16 and 18 are caused to generate in-phase currents that cause the coupling circuits 30 and 34 to be rendered inoperative and to return the valve control circuits 35 and 36 to their normally closed condition. While the projectile is so oriented its course remains unchanged. If, however, the phase of the current that is generated in the microphone 16 is advanced by a small amount with respect to that of the microphone 18 because of the angular orientation of the torpedo from the target line, the pair of nozzles 24 and 25 that are associated with the microphone 16 will be actuated, thereby causing the torpedo to swerve to a position in line with the target. When this occurs the currents of the microphones 16 and 18 are again in phase and neither valve control circuit 35 or 36 is operated.

The microphones 15 and 17 operate in association with their respective set of nozzles in substantially the same manner in which the microphones 16 and 18 operate but in a plane perpendicular thereto. This association provides for the angular correction of the flight path of the projectile both in elevation and in azimuth, and maintains the flight course of the torpedo directly toward the target.

A safety device for inactivating the torpedo control in the presence of a friendly plane is provided by inserting a peaked filter network in the

outputs of the microphones 16 and 18 in known manner. The friendly plane is provided with a sound generator whose frequency is equal to the resonant frequency of the peaked filter 37, so that when the microphones 16 and 18 intercept this signal, the currents that are generated in the microphones are passed through the peaked filter 37 and are fed to an amplifier biasing circuit 38 which serves to impress a cut-off bias on the amplifiers 27 and 31, thereby rendering both microphone channels inoperative. The filter 37 discriminates against all frequencies other than the frequency of the friendly sound generator and since the safety circuit is operated only by the sound generator on a friendly plane. The frequency of the friendly sound generator preferably is chosen to be below that ordinarily initiated in air by plane propellers.

The distance between the microphones 15 and 17 and the distance between the microphones 16 and 18 are preferably equal and are chosen so that they are less than one quarter of the frequency passed by filters 40 and 41. The Doppler effect which causes the apparent frequency to change if the relative velocity between target and torpedo changes will be small if the torpedo is launched in the general direction in which the target is travelling. The torpedo will normally describe a "follower curve." The Doppler effect will be minimized as long as the angle between the direction of flight of the target and the direction of flight of the torpedo remains smaller than 90°.

It is to be understood that the self-propelled projectile and the circuit therefor that have been shown and described herein have been submitted for the purposes of illustrating and explaining one embodiment of the present invention and that various modifications and improvements may be made therein without departing from the scope of the present invention, as defined by the appended claims.

What I claim is:

1. A projectile of the character described, comprising a body portion, four wings radiating from and adjacent the lead end of said body portion and coplanar with each other in pairs, sound detectors in the lead edges of coplanar pairs of said wings, four fins adjacent the trailing end of said body portion and each of said fins being substantially coplanar respectively with one of said wings, gas jet emitting means forming a part of each of said fins for directing the flight course of the projectile, phase difference control means operating said gas jet emitting means from said sound detectors, and means for blocking the operation of said phase difference control means upon reception of a predetermined signal by said sound detectors.

2. A projectile of the character described, comprising a body portion, four wings radiating from and adjacent the lead end of said body portion and coplanar with each other in pairs, sound detectors in the lead edges of coplanar pairs of said wings, four fins adjacent the trailing end of said body portion and each of said fins being substantially coplanar respectively with one of said wings, gas jet emitting means forming a part of each of said fins for directing the flight course of the projectile, means responsive to phase difference between signals from a first pair of said sound detectors for effecting from said fins a steering operation in a direction bringing said signals into phase coincidence, means responsive to phase difference between signals

in a second pair of detectors for effecting a steering operation in a direction bringing the signals into phase coincidence, and means blocking the steering operation upon the reception of predetermined signal at said sound detectors.

3. A projectile of the character described, comprising a body portion, a plurality of wings arranged in coplanar pairs and radiating from and adjacent to the lead end of said body portion, detector means in the lead edges of each of said wings, an equal plurality of fins adjacent to the trailing end of said body portion, each of said fins being coplanar, respectively, with one of said wings, jet means forming a part of each of said fins for directing the flight course of the projectile, means responsive to phase difference between signals from a first pair of said detector means for effecting from said fins a steering operation in a direction bringing said signals into phase coincidence, means responsive to phase difference between signals in a second pair of detector means for effecting a steering operation in a direction bringing the signals into phase coincidence, and means blocking the steering operation upon the reception of a predetermined signal at said detector means.

4. A projectile of the character described, comprising a body portion, a plurality of wings arranged in coplanar pairs at one end of said body portion, sound detector means in the lead edges of each of said wings, an equal plurality of fins at the other end of said body portion, each of said fins being coplanar, respectively, with one of said wings, jet means forming a part of each of said fins for directing the flight course of said projectile, a plurality of channels, each responsive to a given frequency and each respectively connected to the output from one of said detector means, for activating said jet means in response to the output of said detector means, means interconnecting each pair of said channels respectively associated with each of said coplanar pairs of wings, one of each of said pairs of channels serving to remove its associated channel from the circuit in response to a phase difference in the input to said detector means so as to effect a steering operation of said projectile which will bring said input into each of said pairs of detector means into phase coincidence.

5. The projectile of claim 4, further including means for blocking the operation of all of said channels upon the reception of a predetermined signal frequency at said detector means.

6. A projectile of the character described, comprising a body portion, a plurality of wings arranged in coplanar pairs at one end of said body portion, sound detector means in the lead edges of each of said wings, an equal plurality of fins at the other end of said body portion, each of said fins being coplanar, respectively, with one of said wings, jet means forming a part of each of said fins for directing the flight course of said projectile, a plurality of channels, each responsive to a given frequency and each respectively connected to the output from one of said detector means, for activating said jet means in response to the output of said detector means, each of said channels respectively comprising filter means connected to the output of said detector means and means connected to the output of said filter means and responsive thereto for activating the corresponding jet means, each pair of said last-named means, associated with each of said coplanar pairs of wings, being coupled together in order that a phase difference in the output of

said detector means will deactivate the channel associated with the lagging signal so as to effect a steering operation of said projectile and bring the outputs of each pair of said detector means into phase coincidence, and means adapted to become operative upon the reception of a predetermined signal frequency at said detector means and coupled to all of said channels for blocking the operation thereof.

7. In a directional system including at least two channels for receiving wave energy generated by a moving source, wherein the phase of the received energy in one of said channels differs with respect to the phase of received energy in the other of said channels due to the direction of reception of said energy: means in each of said channels for squaring said wave energy, means interconnecting said channels for enabling the first one of said channels receiving said energy to deactivate the other of said channels in response to and for at least the duration of each square wave in said first channel, and utilization means connected to the square wave outputs of said channels and responsive thereto.

8. In a directional system including at least two channels for receiving wave energy generated by a moving source, wherein the phase of the received energy in one of said channels differs with respect to the phase of the received energy in the other of said channels due to the direction of reception of said energy by said channel: means in each of said channels for squar-

ing said wave energy, means interconnecting said channels for enabling the first one of said channels receiving said energy to deactivate the other of said channels in response to and for at least the duration of each square wave in said first channel, utilization means connected to the square wave outputs of said channels and responsive thereto, and means connected to said channels and responsive to energy of a given frequency for completely deactivating all of said channels and preventing any energy from passing therethrough.

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