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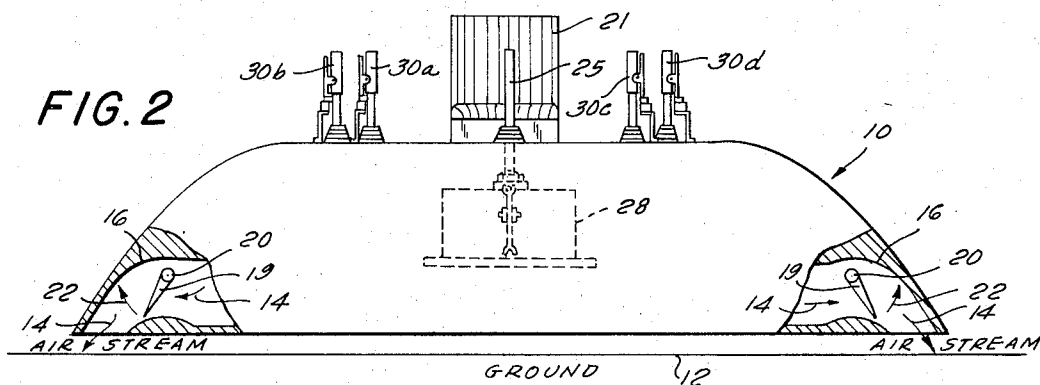
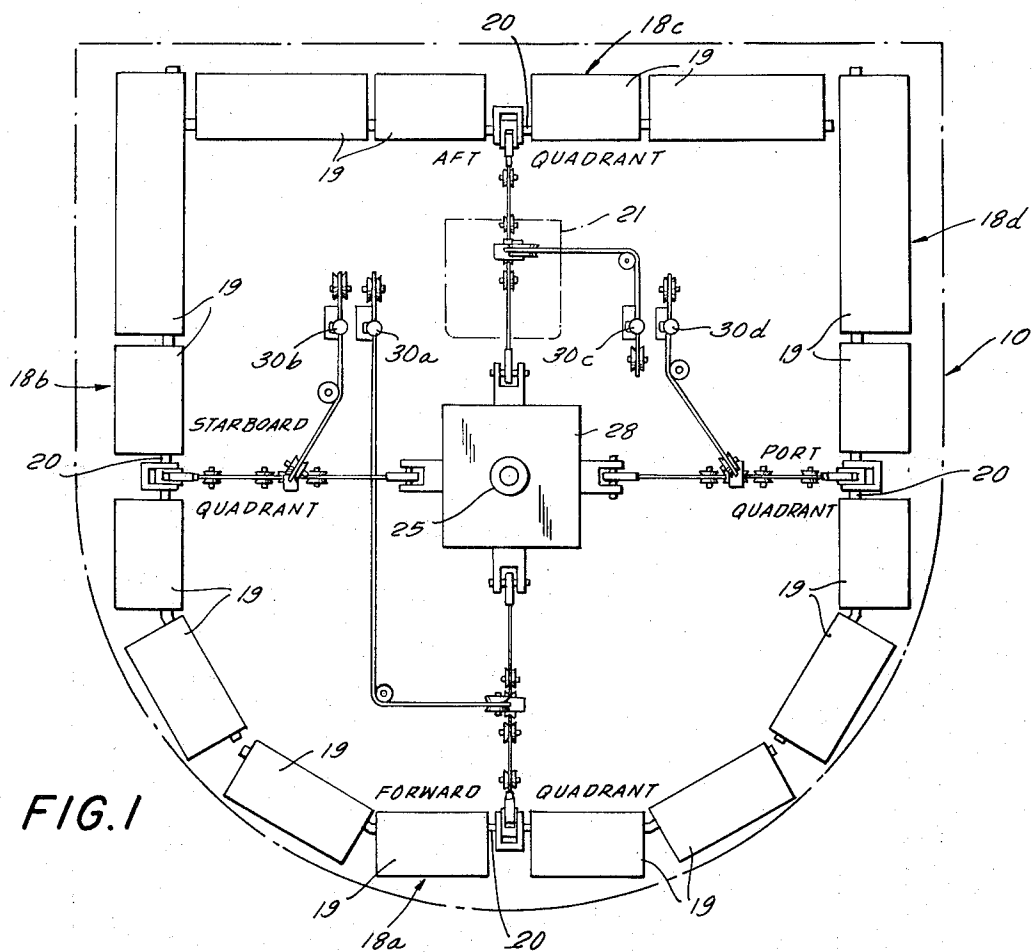
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CONTROL SYSTEM FOR GROUND EFFECT MACHINES

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2 Sheets-Sheet 1



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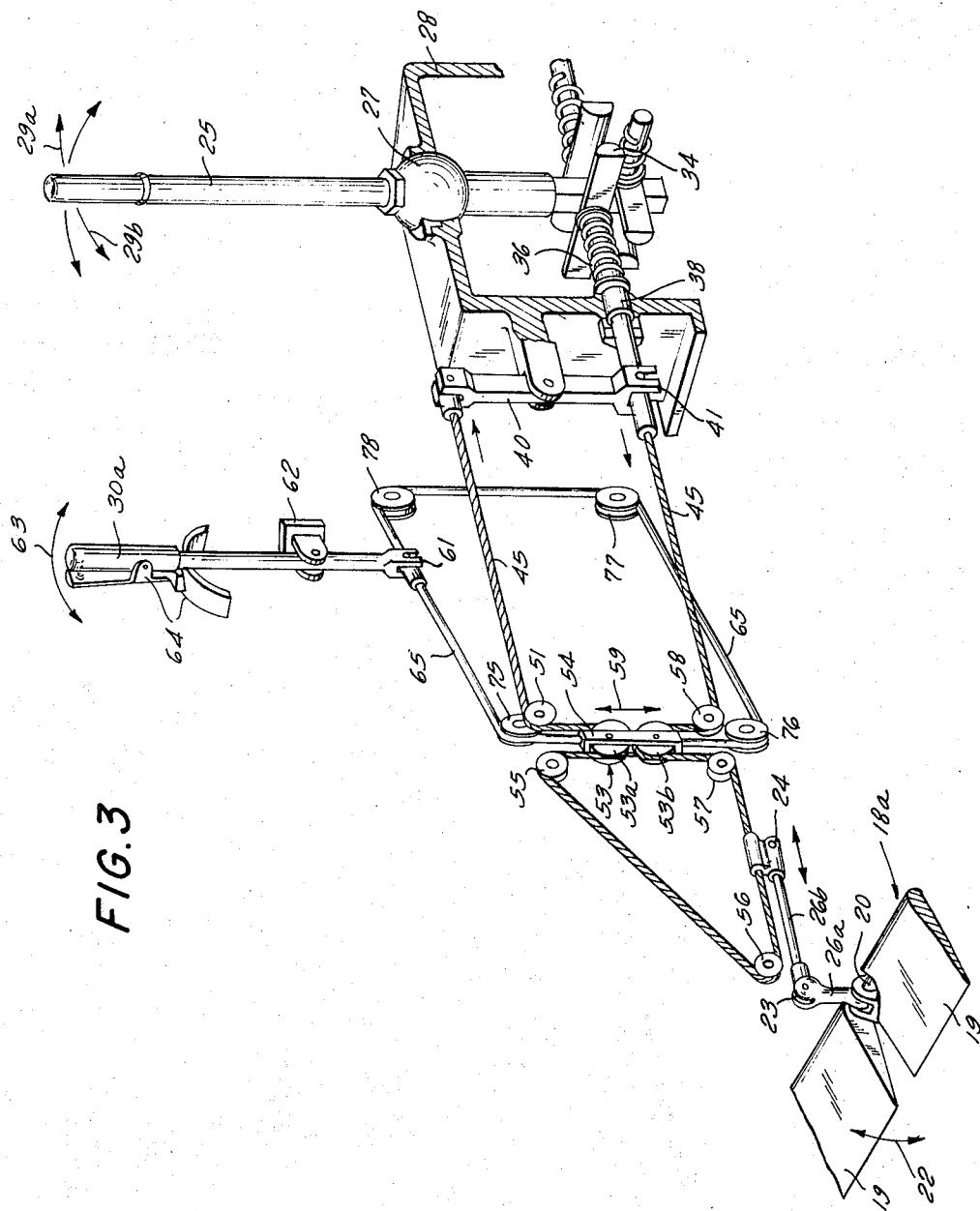
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CONTROL SYSTEM FOR GROUND EFFECT MACHINES

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8 Claims. (Cl. 180—7)

This invention relates to a control mechanism for operating the flaps or dampers which govern the flying and hovering attitude of so-called ground effect machines (GEM's), also referred to as air cushion vehicles (ACV's), which travel along a few inches above the ground supported on a cushion of air. More particularly, the present invention provides a cable-and-roller linkage arrangement for effecting both multi-directional control of the attitude of a GEM vehicle and, in addition, separate and independent adjustment of the trim setting of the dampers either before or during flight of the vehicle.

In known prior art arrangements, direct connections from the operator's control stick to the dampers of the GEM vehicle have been provided, using cable-and-roller linkages, solenoid coils, or combinations of both; however, none of these conventional arrangements have provided a means for adjusting the trim of the flaps without disturbing the calibrated setting of the main control mechanism.

It will be readily appreciated that any control system which permits the operator, either before or during flight, to introduce a predetermined amount of pre-trim or bias setting to each of the several dampers arranged about the GEM vehicle, without thereby affecting the setting of the main control stick, is highly desirable, since such a system would permit the dampers to be adjusted at the required trim positions for stable and level movement of the vehicle with the control stick in the "neutral" position. In prior known arrangements, a change in the trim setting of any one of the dampers would affect not only the trim setting of all the other dampers, but in addition would alter the calibration of the main control stick by which the operator controls the vehicle in flight.

Through the medium of the present invention, a highly reliable and entirely mechanical control system is provided which accomplishes the foregoing objectives in a novel manner. In addition, the disclosed control system possesses certain novel features and advantages, all of which will be more readily understood upon consideration of the following detailed description of the invention, taken in conjunction with the accompanying drawings.

FIG. 1 is a top plan view of an illustrative embodiment of the control system of the present invention arranged in the environment of a typical GEM vehicle. (The body shell of the GEM vehicle, shown in phantom lines, has been removed from this view, for the sake of clarity.)

FIG. 2 is a front view of the control system of FIG. 1.

FIG. 3 is a perspective detail view of a quadrant portion of the control system of FIG. 1, the mechanical arrangement of the other three quadrant portions being identical thereto.

Referring to the drawings, there is shown in FIGS. 1 and 2 a GEM vehicle, designated generally by 10, which operates by means of ground effect, that is, the creation of a pressure below the vehicle greater than the surrounding or ambient pressure so that the vehicle floats a few inches above the ground surface 12 supported on a cushion of air. By means of a fan, turbine, or other suitable means not shown, a highly pressurized air flow stream, represented by the arrows 14, is projected downward against the ground through a plurality of outlets 16 provided along the peripheral undersurface of the vehicle. The

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direction, and thus the thrust, of the air stream 14 against the ground surface 12 is regulated by a system of four quadrant damper assemblies, 18a, 18b, 18c, and 18d, arranged respectively at the forward, starboard, aft, and port quadrants of the vehicle 10.

Each of the four quadrant damper assemblies 18a . . . d is comprised of a series of flaps or vanes 19 fitted along a respective common shaft 20 so that the movement within a quadrant is coordinated. In the illustrative embodiment shown, each of the four damper assemblies 18a . . . d has four such vanes 19 which serve to regulate the flow of the air stream 14 in their respective quadrant.

As is illustrated in somewhat diagrammatic form in FIG. 2, rotational displacement of the vanes 19 by movement of their associated shaft 20 controls the air stream 14 passing through the outlets 16 in the corresponding quadrant of the vehicle. As is well understood in the operation of such ground effect machines, through the medium of the abovedescribed mechanism control of the flying and hovering attitude of the vehicle may thereby be effected. Means for propelling the vehicle 10 in the forward direction, braking its thrust, and other conventional elements which comprise a typical GEM vehicle but which form no part of the present invention, have been excluded from this description for purposes of simplifying and clarifying the disclosure.

In the proposed construction of the present invention the pilot or operator, positioned on a seat 21 centrally-located on the vehicle 10, arranges the trim setting and controls the operation of the four sets of quadrant dampers 18a, 18b, 18c, and 18d, by means of a multi-directional control stick 25 and a set of four corresponding quadrant trim setting controls 30a, 30b, 30c, and 30d, all of which are arranged conveniently within his reach while he is in the seated position. The control system, formed of control stick 25 and the trim setting controls 30a . . . d, is mechanically linked to the four damper assemblies 18a . . . d by means of a cable-and-roller arrangement, the details of which are shown in detail in FIG. 3. In FIG. 3, however, only the linkage for the forward quadrant damper assembly 18a is shown, it being understood that the linkage arrangement for the damper assemblies of the other three quadrants are substantially identical to the one shown, as the mechanics of operation of all four of the damper assemblies 18a, 18b, 18c, 18d through the control system are the same.

As shown in FIG. 3, the universally-movable main control stick 25 is pivotally supported by a ball joint 27 which is carried within a housing 28 secured inside the vehicle. Movement of the control stick 25 in any direction about its fulcrum 27 causes a differential rotation of the damper assemblies 18a . . . d, proportional to the degree of movement in that direction, by means of a cable linkage arrangement which will now be described for the forward quadrant damper assembly 18a, it being understood that the operation of the other quadrant damper assemblies will be similar.

The lower end of the vertically-positioned control stick 25 acts on a horizontal pressure T-bar 34 which is constantly urged thereagainst by an associated spring return member 36. The center leg of the T-bar 34 is slidably supported within bushing 38 mounted in the side of the housing 28. Lateral displacement of the T-bar 34 due to movement of the control stick 25 is transmitted to a cable linkage via a 1:1 lever member 40 which is pivotally supported at its center by a fulcrum element 42 mounted on the side of the housing 25.

As shown in FIG. 3, a loop of control cable 45 is secured at one end to the upper arm of the lever member 40 and at the other end to the base of the T-bar 34 which is coupled in a yoke 41 to the lower arm of the lever

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member. The control stick 25 is coupled via the control cable loop 45 to the damper assembly 18a in the following manner: Starting from the termination of the control cable 45 on the upper arm of the lever member arm 40, the cable is fed over a first fixed roller 51 and over the upper one 53a of a two-roller movable pulley 53 mounted on a tie bar 54, thence over a second fixed roller 55 out to the extremity of the quadrant where the cable passes over a third fixed roller 56, next returning inwardly where the cable passes over a fourth fixed roller 57, again through the movable pulley but this time passing over the lower roller 53b, and then finally over the fifth and last fixed roller 58, after which the control cable 45 terminates at the base of the pressure T-bar 34.

The common shaft 20, on which are mounted the flaps 19 comprising the damper assembly 18a for the forward quadrant portion of the GEM machine, is coupled by linkage rods 26a and 26b through a pivot joint 23 to a shackle 24 which is attached to the control cable 45 at a point between the fourth fixed roller 56 and the fifth roller 57. As will be readily apparent from observation of the mechanical linkages involved, the described cable-and-roller arrangement will operate to transmit any forward or backward movement of the control stick 25 relative to the direction of this particular quadrant (which is the forward quadrant for the portion of the system shown in FIG. 3) and cause a corresponding angular rotation of the common shaft 20 controlling the flaps 19 on the associated damper assembly 18a. Thus, with the control stick 25 pulled in the direction indicated by arrow 29a (i.e., to the right in FIG. 3), the portion of the control cable 45 associated with the upper arm of the lever 40 will move inward, whereas the lower portion of the cable will move outward toward the forward extremity of the vehicle. Accordingly, the shackle 24 and linkage rods 26a, b connected to the control cable will move outward, causing the common shaft 20 of the damper assembly 18a to pivot and the flaps 19 to turn in the downward direction (as indicated by the arrow 22). Correspondingly, in the same manner, forward movement of the main control stick 25, in the direction indicated by the arrow 29b (to the left in FIG. 3), will cause upward rotation of the damper flaps 19.

Attention is now directed, in the diagram of FIG. 3, to the trim override control system which provides a means for independently adjusting the trim of the dampers of the GEM vehicle without disturbing the setting of the main control stick 25. As shown in the figure, the trim setting control stick 30a for the forward quadrant is coupled to a trim cable 65 whose operation is integrated into the control cable loop 45. The trim control stick 30 is pivotally supported by a fixed pivot member 62 and is preferably provided with a friction locking device 64 of conventional design for setting and securing the stick in any position of adjustment. Lateral movement of the trim control stick 30, in either the forward or backward direction as represented by the arrow 63, is coupled by a yoke shackle 61 to the trim cable 55. The trim cable is in the form of a closed loop passed over a set of four fixed rollers 75, 76, 77 and 78 arranged in a general rectangular configuration, and is secured at either end, as shown, to the tie bar 54 carrying the movable pulley 53 through which the control cable 45 passes. (It will be appreciated of course that three fixed rollers instead of the four shown would provide a satisfactory loop arrangement for the trim cable 65.)

Lateral movement of the trim control stick 30 in the direction shown by the arrow 63 will cause a corresponding vertical displacement of the movable pulley 53 in the direction shown by the arrow 59. The movement of the movable pulley 53 will cause some displacement in turn of the control cable 45 as it accommodates the new positioning of the pulley 53 relative to the adjacent set of four fixed rollers 51, 55, 57 and 58. The movement of the control cable 45, in order to accommodate the vertical re-

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positioning of the movable pulley 53, produces a corresponding lateral displacement of the shackle 24 secured to the cable 45, and this in turn, through the linkage rods 26a and 26b in the manner previously described, causes a rotational adjustment of the trim or bias setting of the damper flaps 19 of the damper assembly 18a in this, and only this, particular quadrant.

By the nature of the coupling of the control cable 45 to the spring-pressured T-bar 34 and the lever member 40, no displacement occurs in the lateral position of the main control stick 25 when the above-described trim adjustment is made. Thus, the "neutral" or rest position of the control stick 25 remains unchanged, even though there has been a substantial trim adjustment in the setting of the forward quadrant damper assembly 18a. In similar manner, trim setting control sticks 30b, 30c, and 30d, provide separate control of the trim settings of their respective starboard, aft and port quadrant damper assemblies 18b, 18c and 18d, independent of each other and of the neutral position of the main control stick 25.

As the control system described above consists entirely of mechanical linkages, it is both simple to construct and inherently highly reliable in operation. Furthermore, the direct mechanical coupling of the main and trim control sticks to the various damper assemblies provide the operator of the ground effect machine with an exceptionally good "feel" of the vehicle when altering its attitude or direction of flight.

The terms and expressions which have been employed here are used as terms of description and not of limitation, and there is no intention, in the use of such terms and expressions, of excluding equivalents of the features shown and described, or portions thereof, it being recognized that various modifications are possible within the scope of the invention claimed.

What is claimed is:

1. A control mechanism for operating the damper vanes of a ground effect machine or the like comprising
 - (a) a plurality of damper assemblies independently actuatable and controlling the air flow at respective sectors of said machine,
 - (b) a main control stick pivotally supported for multidirectional movement with respect to a neutral or rest position,
 - (c) first cable linkage means, respectively associated with each of said damper assemblies and coupling said main control stick to each of said respective damper assemblies, for converting motion of said stick in a respective predetermined direction with respect to said neutral position into a corresponding displacement of said respective damper assembly,
 - (d) a plurality of trim control sticks, respectively associated with each of said damper assemblies, movable about one axis, and
 - (e) second cable linkage means, respectively associated with each of said trim control sticks and engaging said respective first cable linkage means, for converting a displacement of said respective trim control stick into a positional adjustment of said respective damper assembly without causing any corresponding displacement in the neutral position of said main control stick.
2. The control mechanism set forth in claim 1 characterized in that at least one of said respective first cable linkage means comprises
 - (a) a spring-urged pressure bar engaging a portion of said main control stick for transmitting motion of the latter in said respective predetermined direction,
 - (b) a lever member having two rigid arms joined at a common base and pivotally supported thereat, one of said arms engaging said pressure bar,
 - (c) a cable loop supported by rollers, one end of said loop being connected to said pressure bar and the other end to said other arm of said lever member, and

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- (d) a shackle member fixedly secured to a point on said cable loop and coupled to said respective damper assembly.
3. The control mechanism set forth in claim 2 further characterized in that said respective damper assembly includes a common rotatable shaft on which the vanes of said damper assembly are mounted, and rod linkage means coupling said shackle member to said shaft whereby movement of the former along the cable loop of said first cable linkage means causes an angular rotation of said shaft.
4. The control mechanism set forth in claim 1 further characterized in that at least one of said respective second cable linkage means comprises
- (a) a cable loop supported on rollers, a point on said cable being connected to a portion of said respective trim control stick and transmitting motion of the latter into a corresponding displacement of the cable along said loop, and
- (b) a movable pulley means connected in said cable loop and having restrained roller elements cooperating with said respective first cable linkage means, whereby displacement of the cable along said loop, resulting from movement of said respective trim control stick, causes a displacement in said respective first cable linkage means.
5. The control mechanism set forth in claim 4 further characterized in that said respective trim control stick is provided with a locking means for setting and securing said stick in any desired position of adjustment within the range of movement thereof.
6. The control mechanism set forth in claim 1 wherein said main control stick is pivotally supported for movement in the forward, starboard, aft and port quadrant directions within a plane, and said plurality of damper assemblies four elements associated, respectively, with said forward, starboard, aft and port quadrant directions of said machine, whereby movement of said main control stick in a direction having a component in any of said quadrants is translated into a corresponding displacement of said respective quadrant damper assembly.
7. The control mechanism set forth in claim 6 wherein pairs of said respective first cable linkage means are mounted in opposition to each other at their points of coupling with said main control stick, whereby movement of said stick in a respective quadrant direction is translated by said respective first cable linkage means into a differential displacement of said opposing quadrant pairs of said respective damper assemblies.
8. A control for operating the damper vanes of a ground effect machine or the like comprising
- (a) a plurality of damper assemblies independently actuatable and controlling the air flow at respective sectors of said machine,

- (b) a main control stick pivotally supported for multidirectional movement with respect to a neutral or rest position,
- (c) a first cable linkage means, respectively associated with each of said damper assemblies and coupling said main control stick to each of said respective damper assemblies, for converting motion of said stick in a respective predetermined direction with respect to said neutral position into a corresponding displacement of said respective damper assembly, said first cable linkage means including
- (i) a spring-urged pressure T-bar engaging a portion of said main control stick for transmitting motion of the latter in said respective predetermined direction,
- (ii) a lever member having two rigid arms joined at a common base and pivotally supported thereat, one of said arms engaging said pressure T-bar,
- (iii) a cable loop supported by rollers, one end of said loop being connected to said pressure T-bar and the other end to said other arm of said lever member, and
- (iv) a shackle fixedly secured to a point on said cable loop and coupled to said respective damper assembly,
- (d) a plurality of trim control sticks, respectively associated with each of said damper assemblies, movable about one axis, and
- (e) second cable linkage means, respectively associated with each of said trim control sticks and engaging said respective first cable linkage means, for converting a displacement of said respective trim control stick into a positional adjustment of said respective damper assembly without causing any corresponding displacement in the neutral position of said main control stick, said second cable linkage means including
- (i) a cable loop supported on rollers, a point on said cable being connected to a portion of said respective trim control stick and transmitting motion of the latter into a corresponding displacement of the cable along said loop, and
- (ii) a movable pulley means connected in said cable loop and having restrained roller elements cooperating with said respective first cable linkage means, whereby displacement of the cable along said loop, resulting from movement of said respective trim control stick, causes a displacement in said respective first cable linkage means.

No references cited.

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