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OFFICE OF NAVAL RESEARCH
Contract N6onr-24428
Project NR 062.087

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FREE-BODY MODELING OF THE STABILITY AND CONTROL OF SUBMARINES

Volume 2 - Figures

Joseph Levy
Donald A. Price, Jr.

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Hydrodynamics Laboratory
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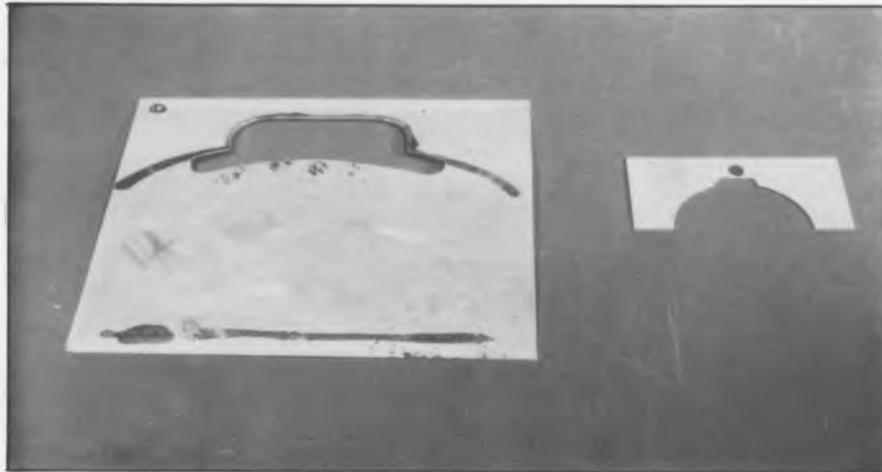
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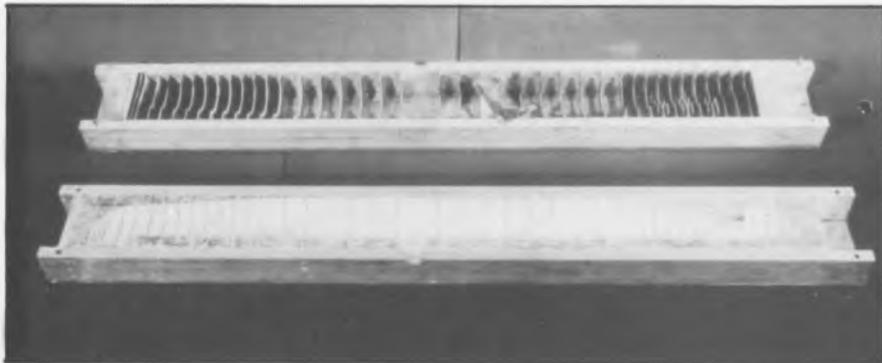
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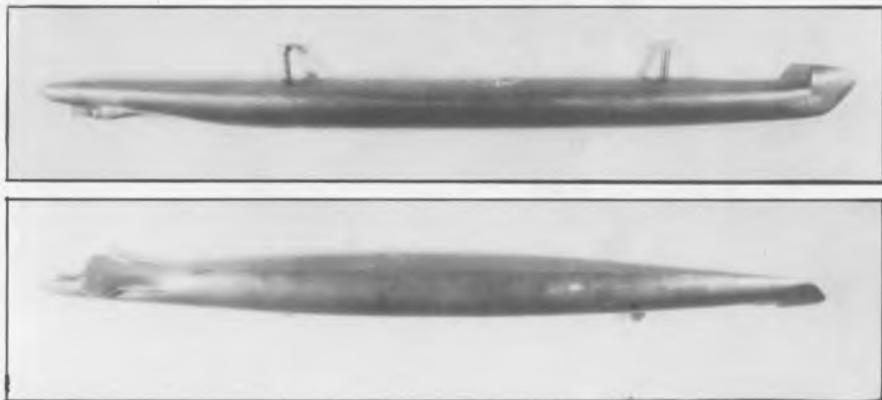
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(a) Template

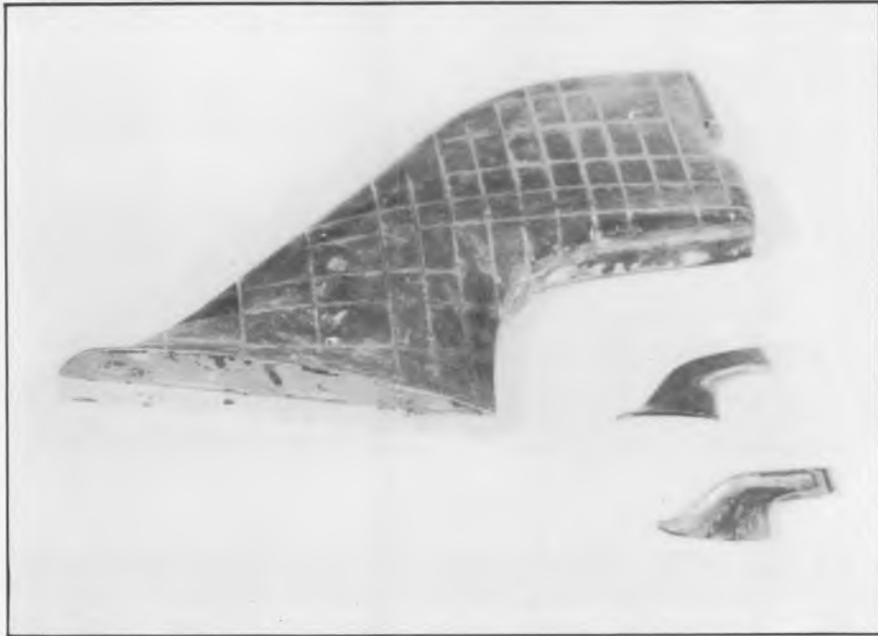


(b) Mold box with templates in place

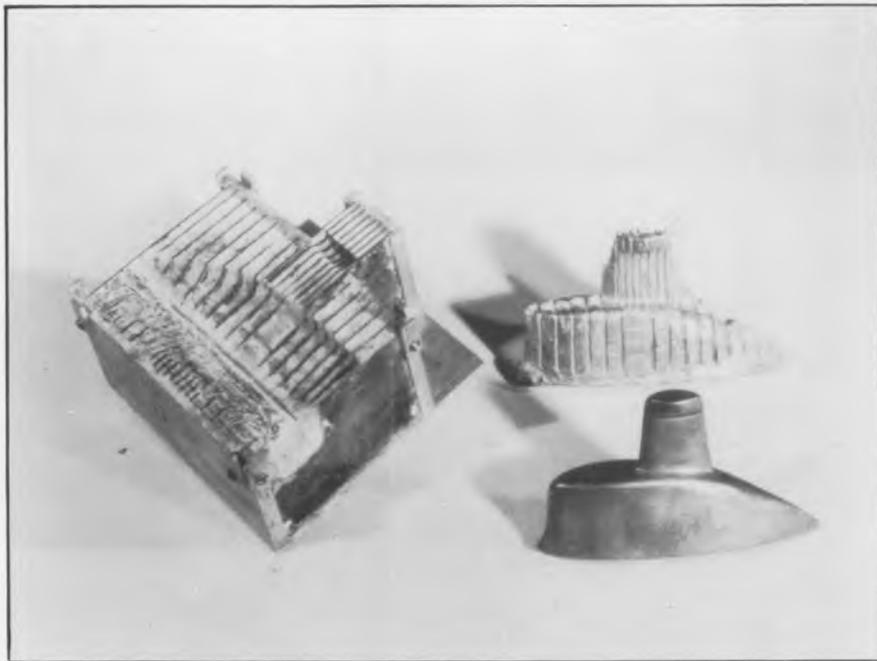


(c) Finished form ready for plating

Fig. 2-1 Steps in making plating forms for model shell.



(a) 5:1 Template for pantograph

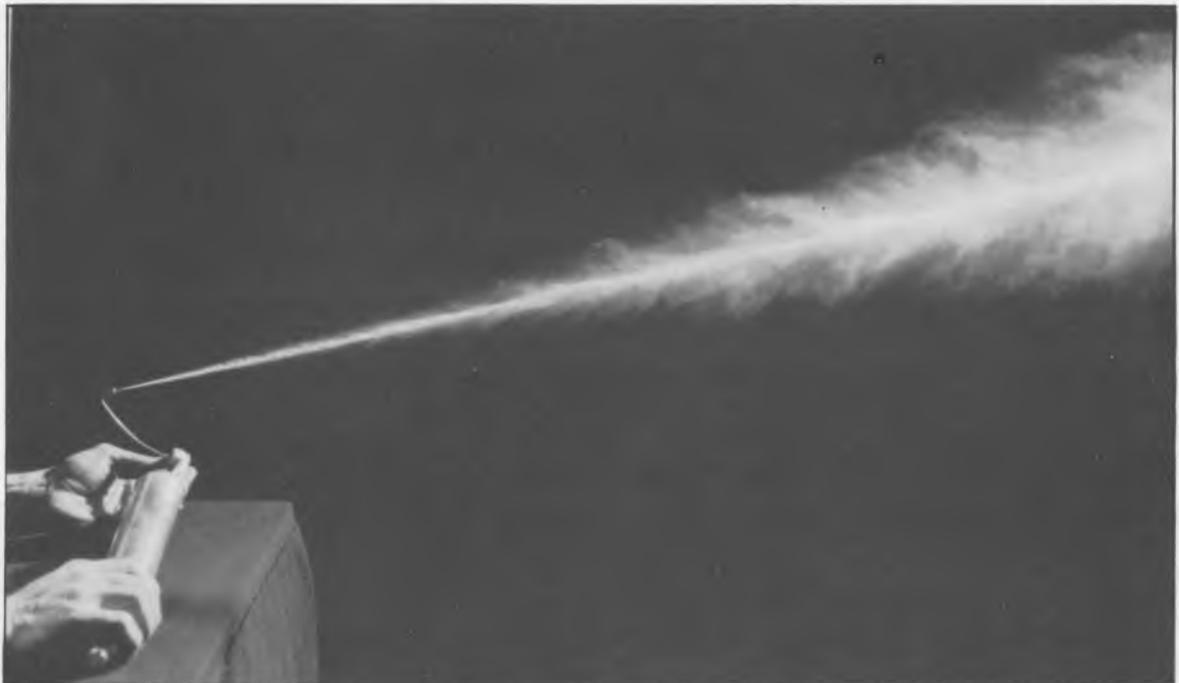


(b) Mold and cast cerrobase conning tower

Fig. 2-2 Templates, molds, and cerrobase forms

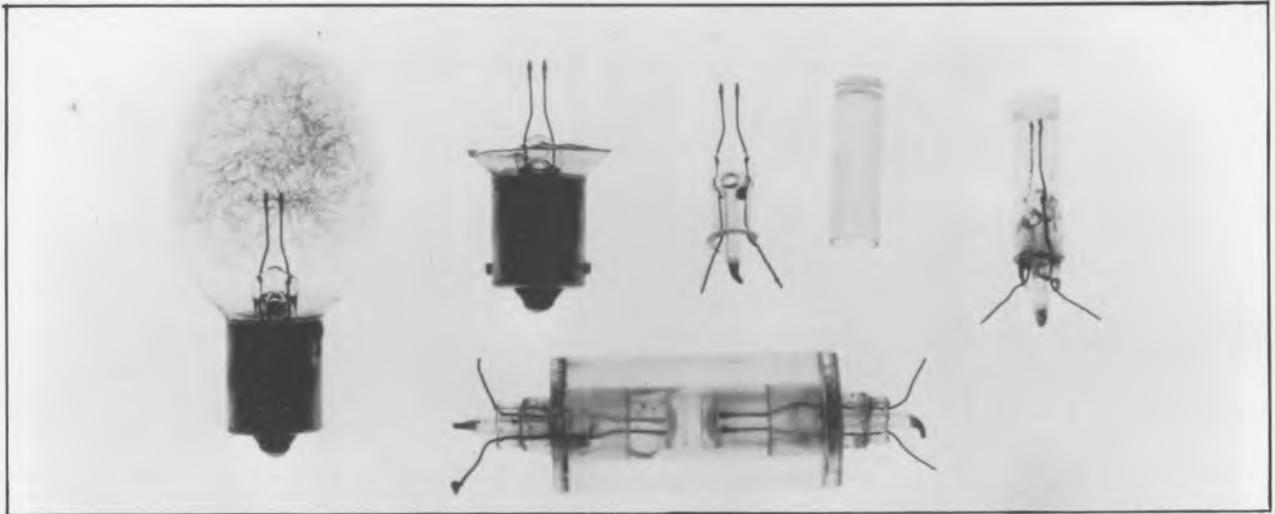


(a) Turbine wheel

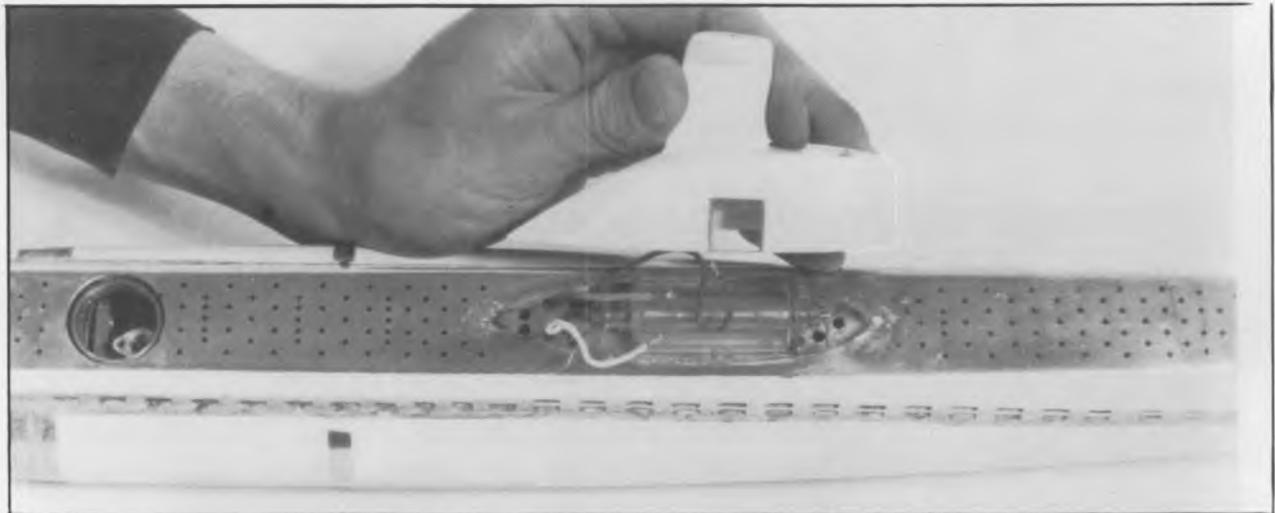


(b) Water jet from 0.013-in. dia. nozzle under pressure of 2200 psi

Fig. 2-3 Trigger valve and jet.



(a) Steps in converting No. 5 flashbulb to cam light



(b) Location of cam lights in conning tower

Fig. 2-4 Program cam position indicators.

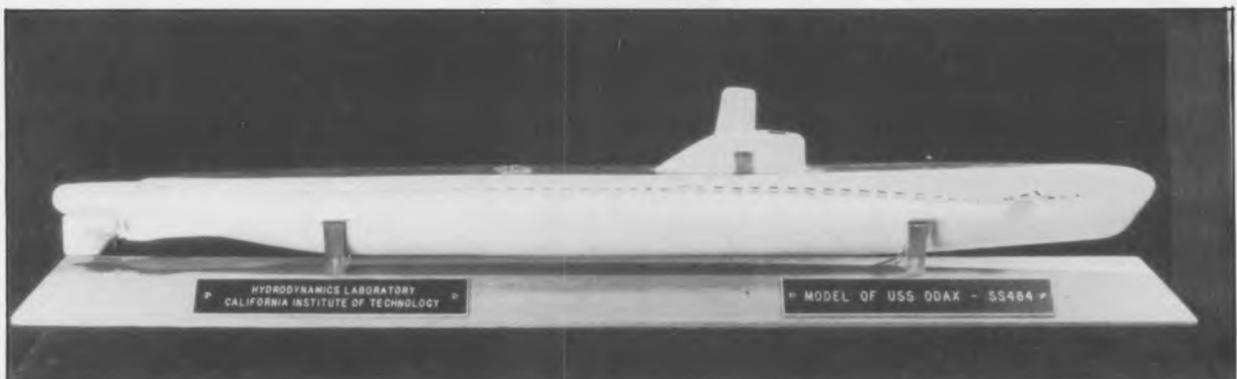
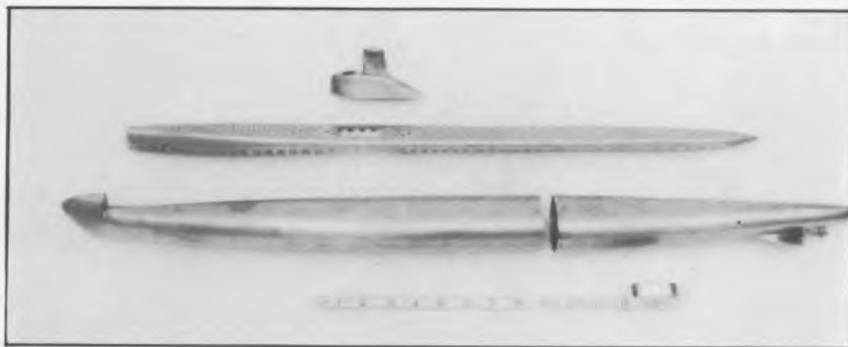
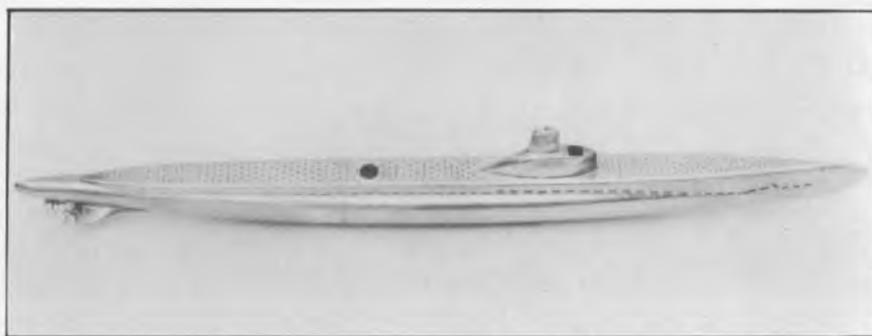


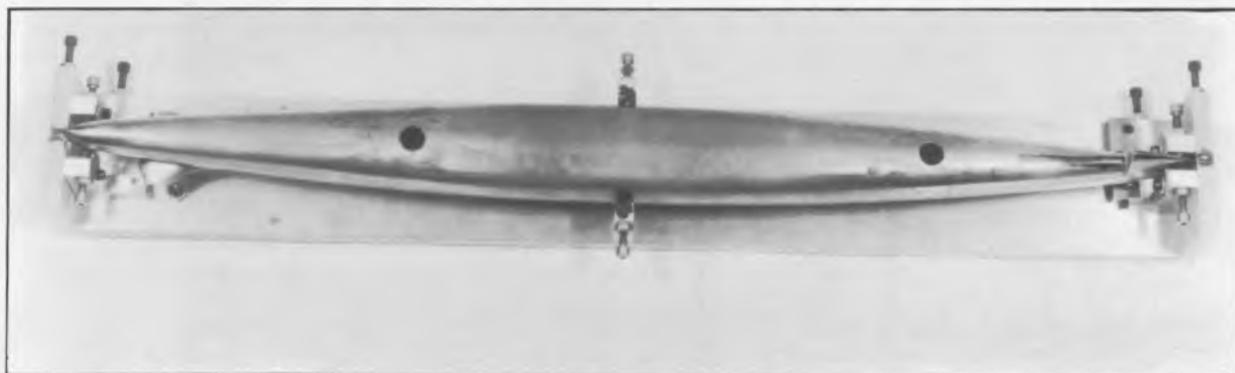
Fig. 2-5 Model of Guppy-type submarine USS Odax-SS484.



(a) Exploded view

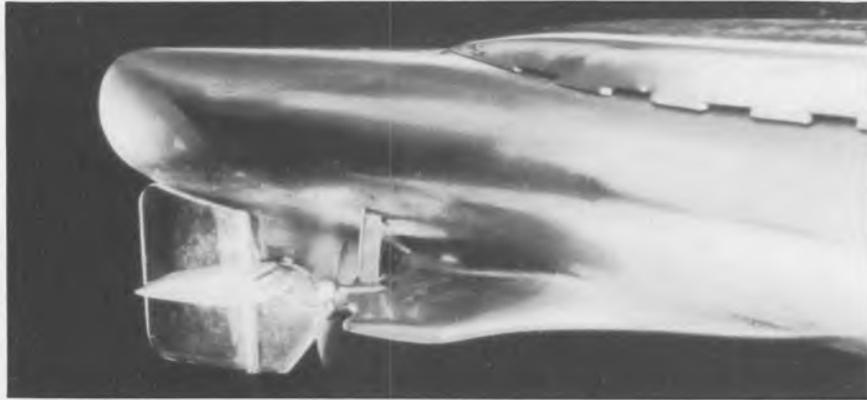
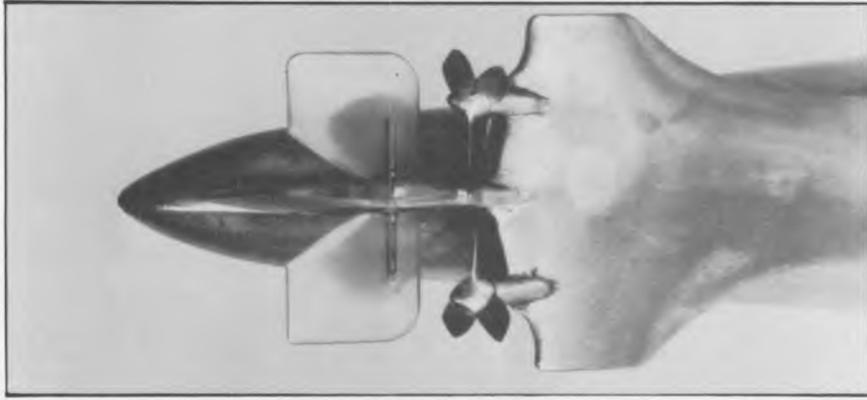


(b) Assembled shell

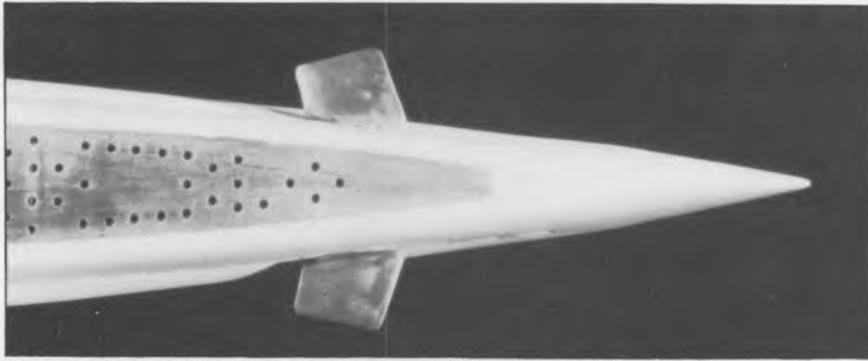


(c) Hull in aligning jig

Fig. 2-6 Model shell.

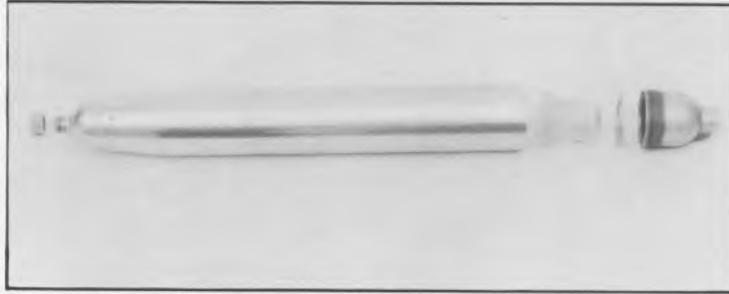


(a) Stabilizers, stern planes, rudder, and propellers



(b) Bow planes

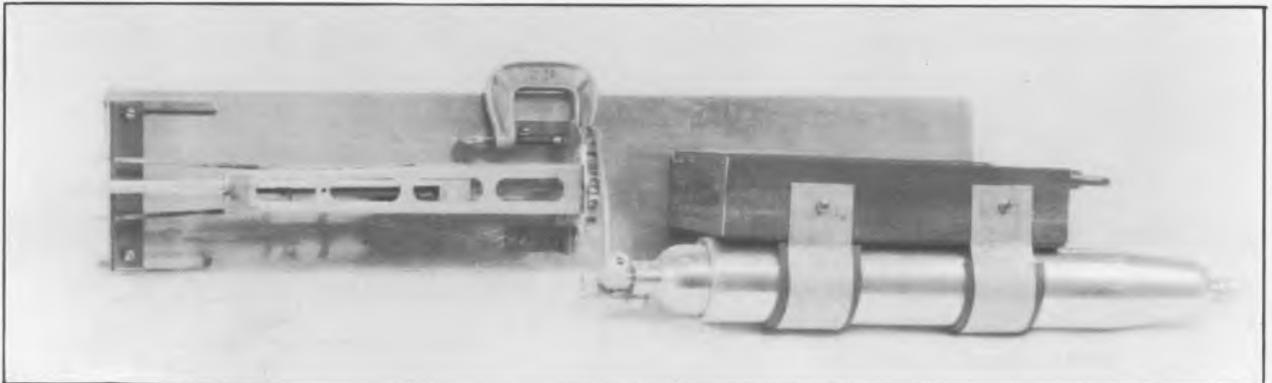
Fig. 2-7 Control surfaces.



(a) Exploded view of accumulator



(b) Plastic diaphragm

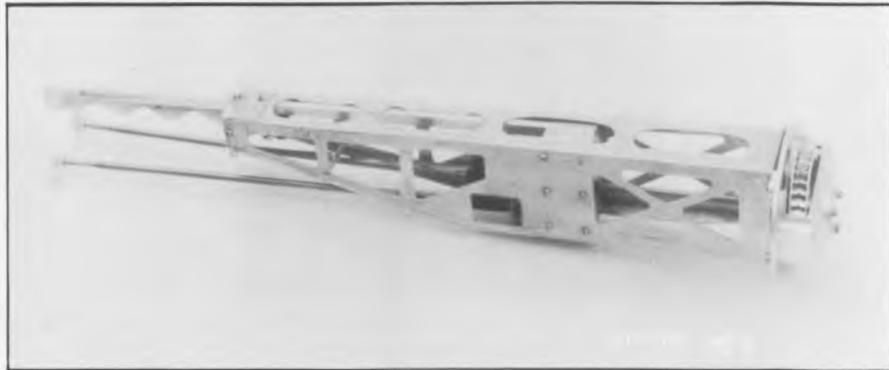


(c) Setup for testing Odax power plant

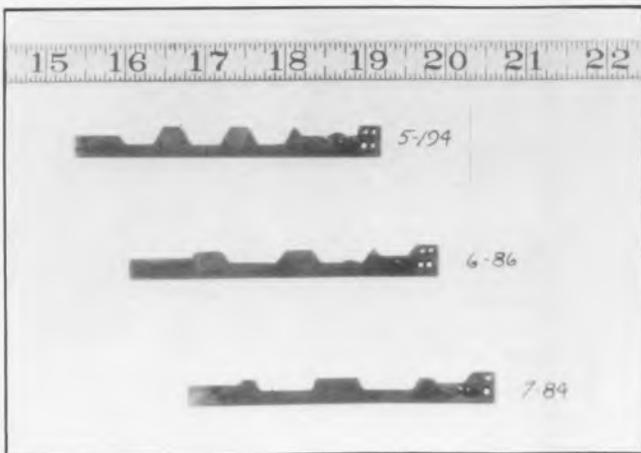
Fig. 2-8 Model power plant.



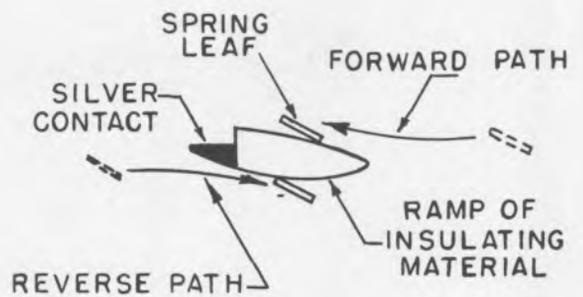
(a) Closeup of turbine arrangement



(b) Propulsion and control mechanism

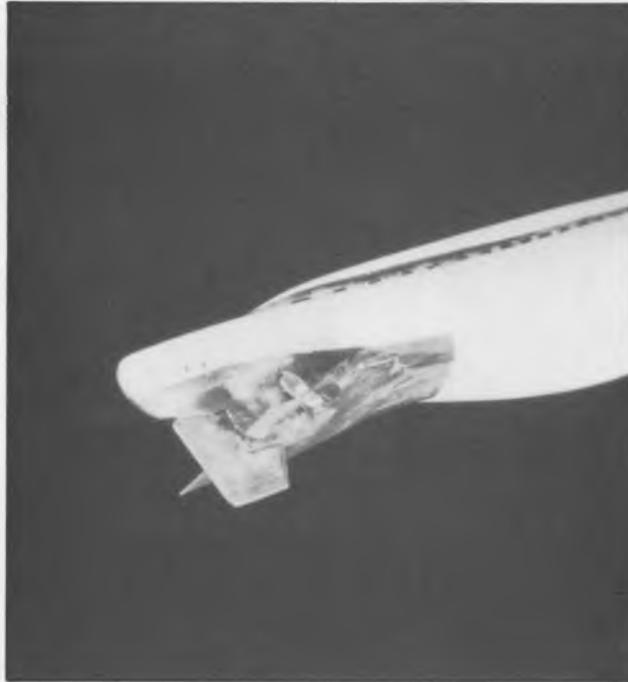


(c) Control program cams



(d) Cam light ramp and contact

Fig. 2-9 Propulsion and control mechanism details.



(a) Stabilizer without fender

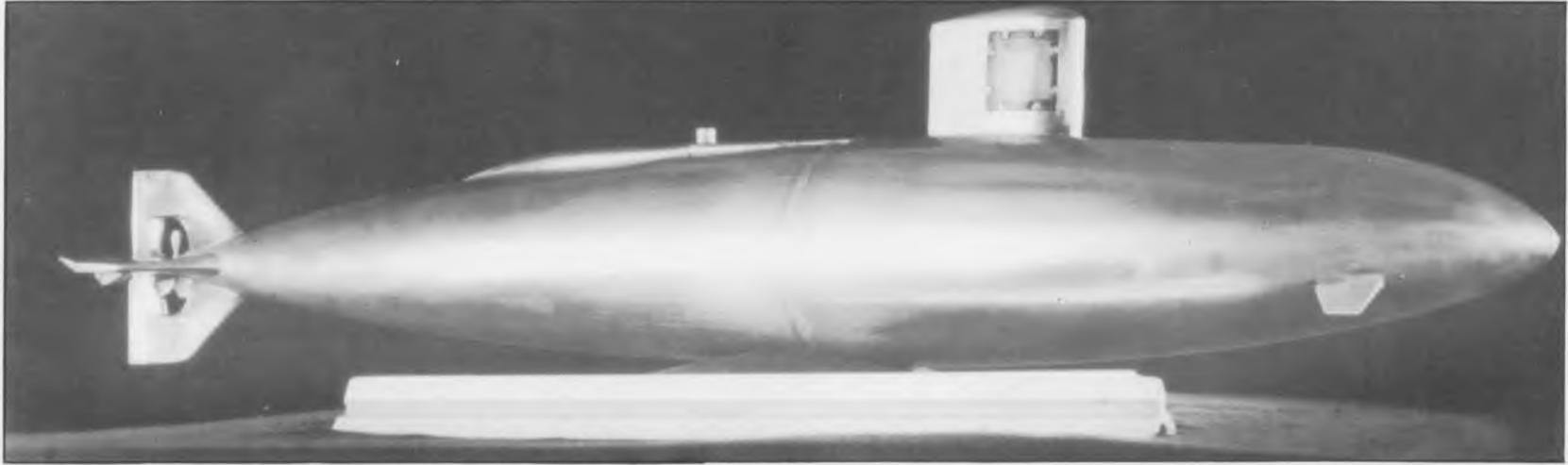


(b) Stabilizer with fender

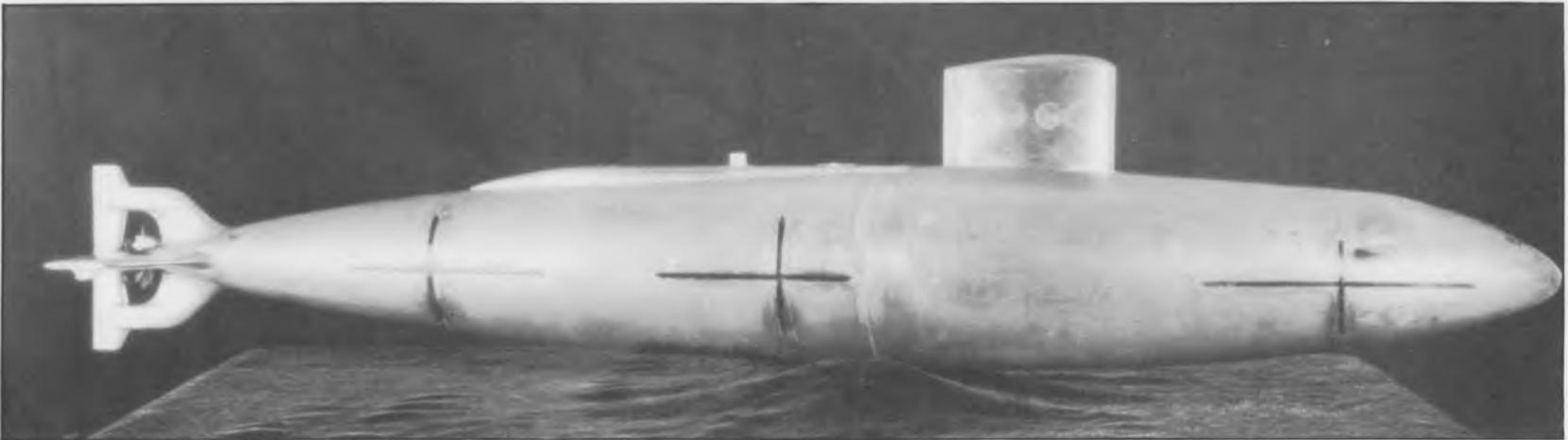
Fig. 2-10 Protective fenders used to keep the propellers from hitting launcher rails.

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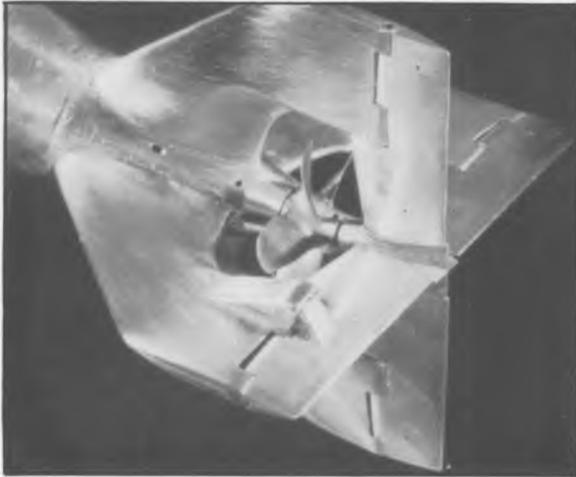


(a) Original configuration

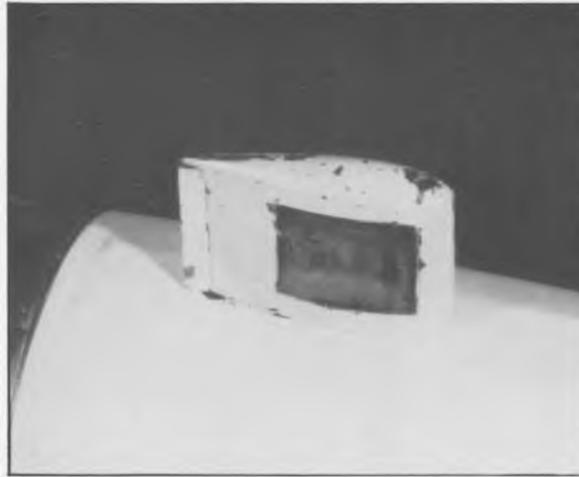


(b) Revised configuration

Fig. 2-11 Model of the USS Albacore AGSS 569, SST Scheme IV, with two configurations of appendages.

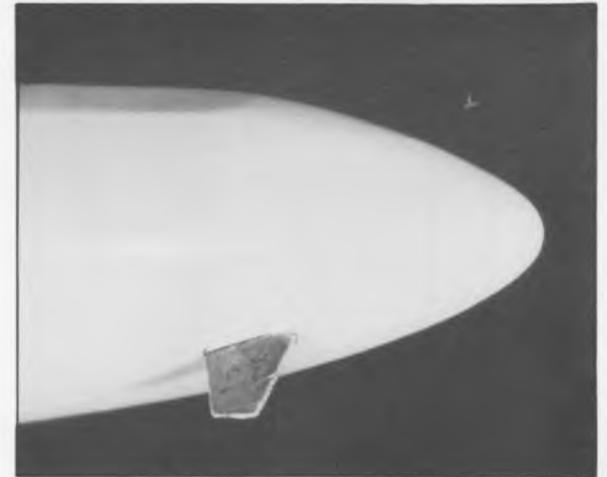


Tail

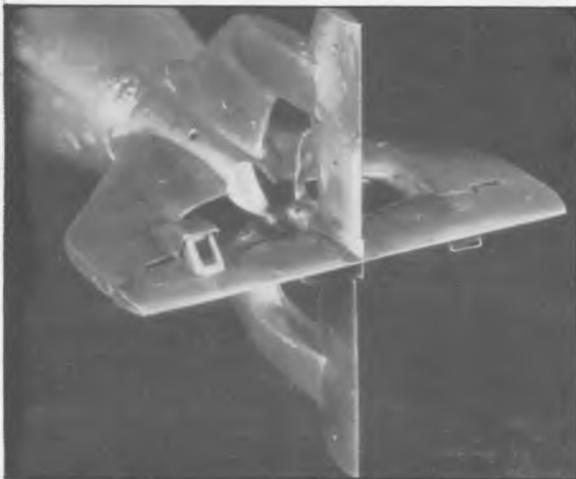


Bridge fairwater

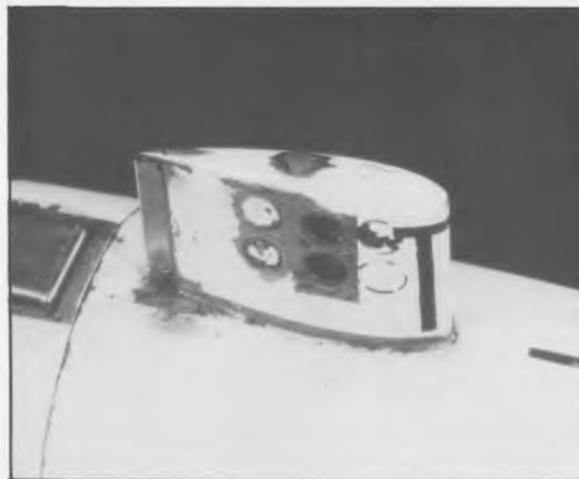
(a) Original configuration



Bow planes



Tail



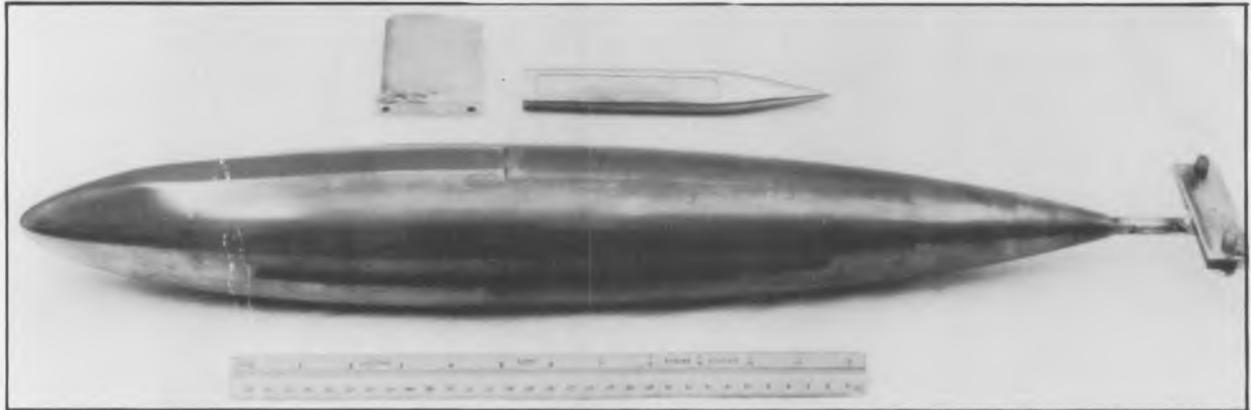
Bridge fairwater

(b) Revised configuration

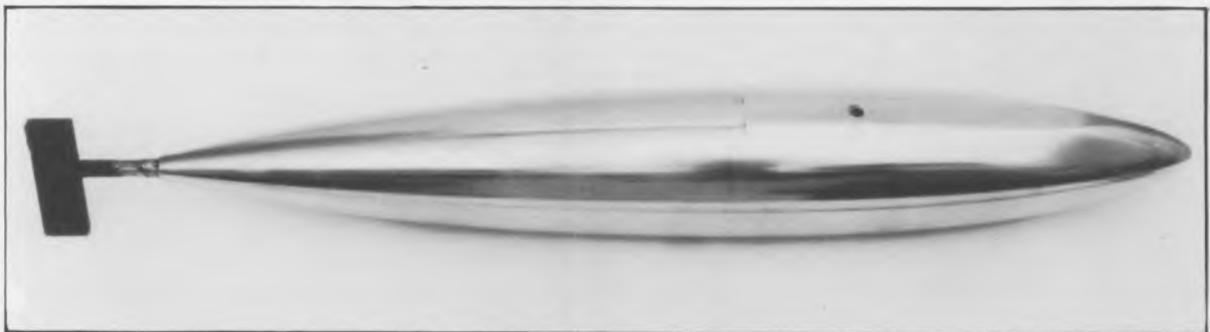


Bow planes

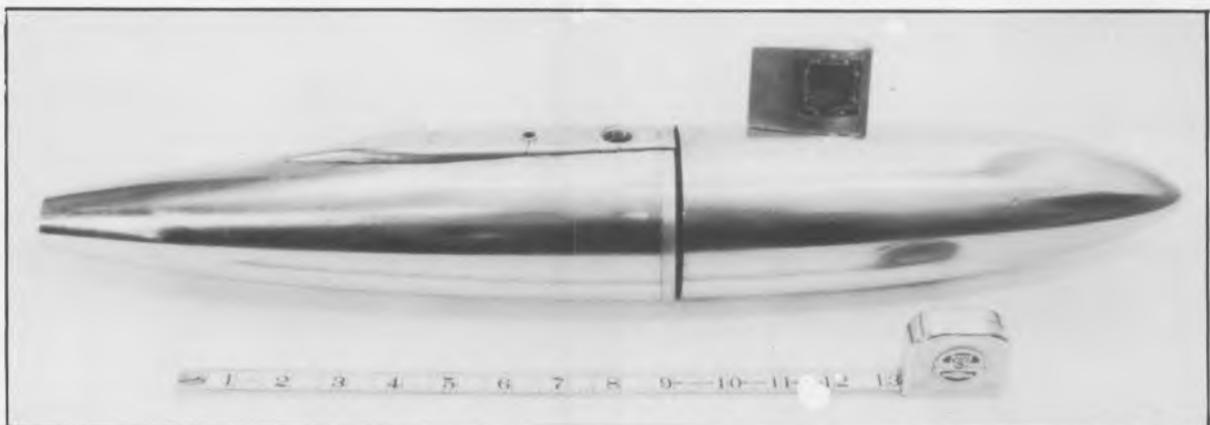
Fig. 2-12 Comparison of model configurations.



(a) Cerrobased forms before plating



(b) Hull shape after plating



(c) Nickel shell with conning tower, deck, and joining ring in place

Fig. 2-13 Steps in forming Albacore model hull.

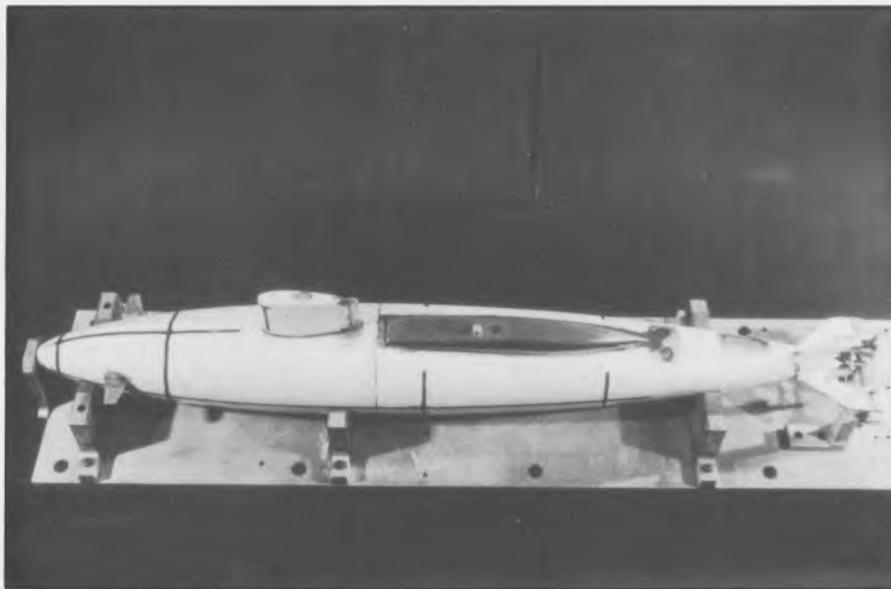
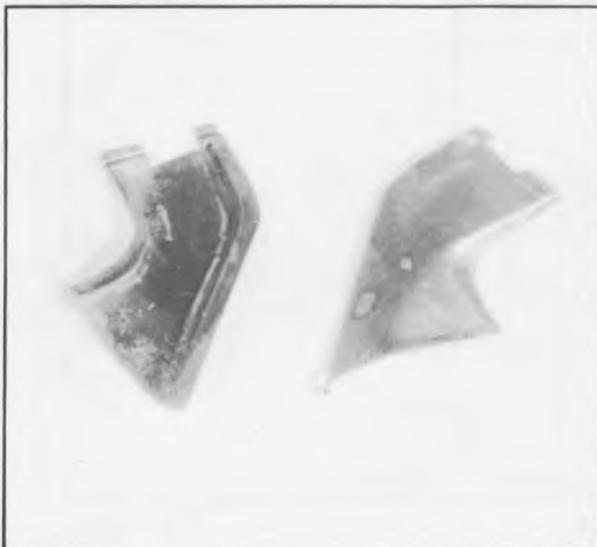


Fig. 2-14 Model in aligning jig.



(a) Plated fins



(b) Machined fins

Fig. 2-15 Comparison of plated and machined stabilizers.

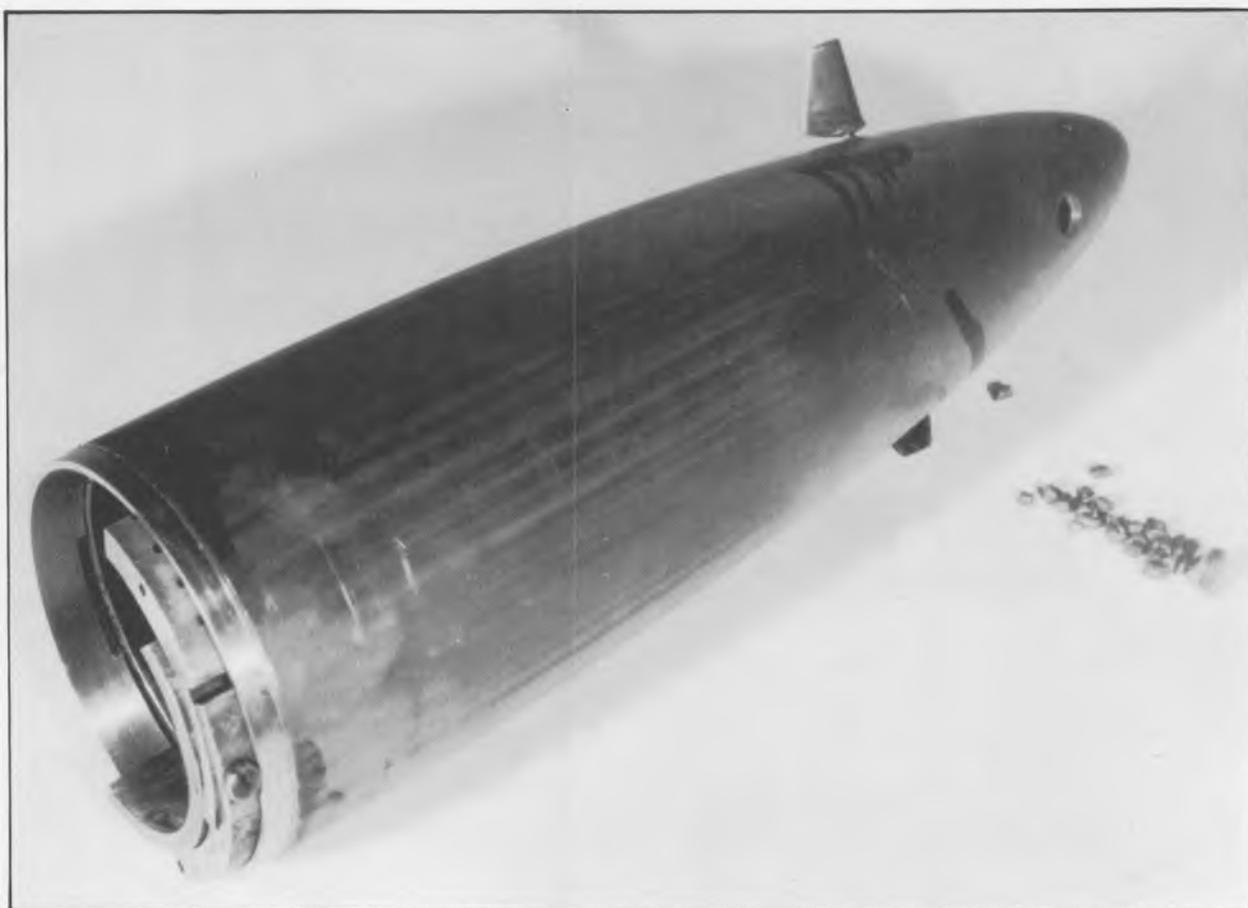


Fig. 2-16 Ballast weight arrangement in forward hull.

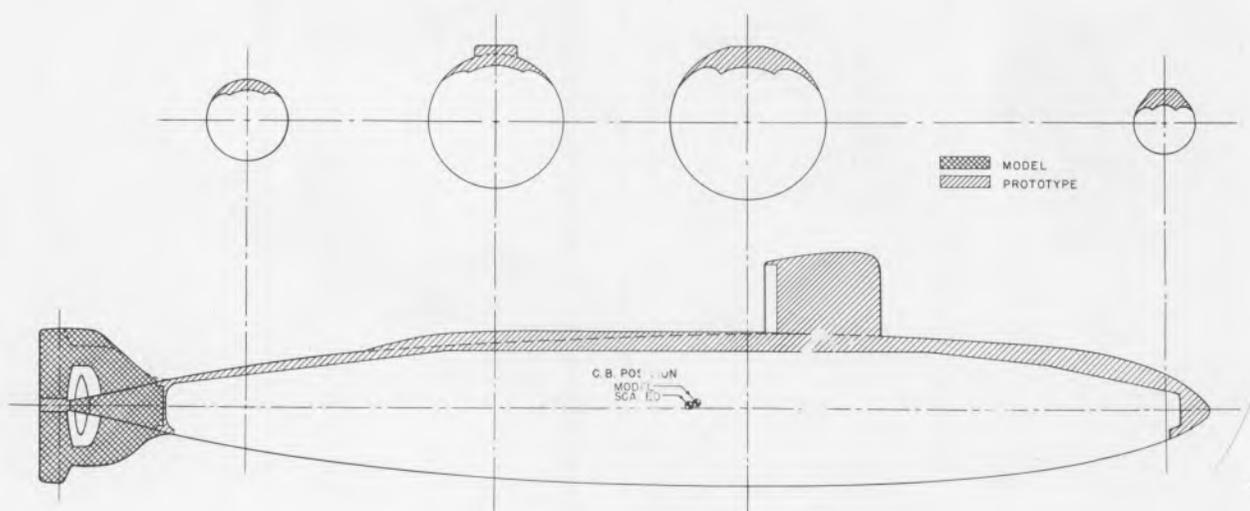
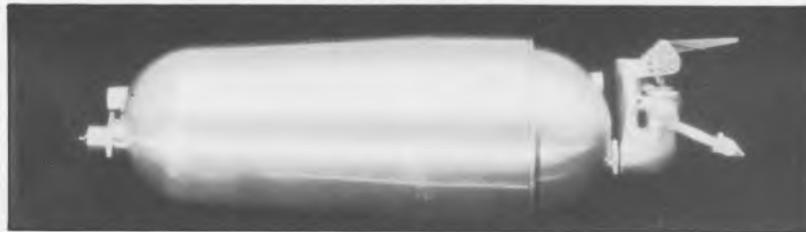


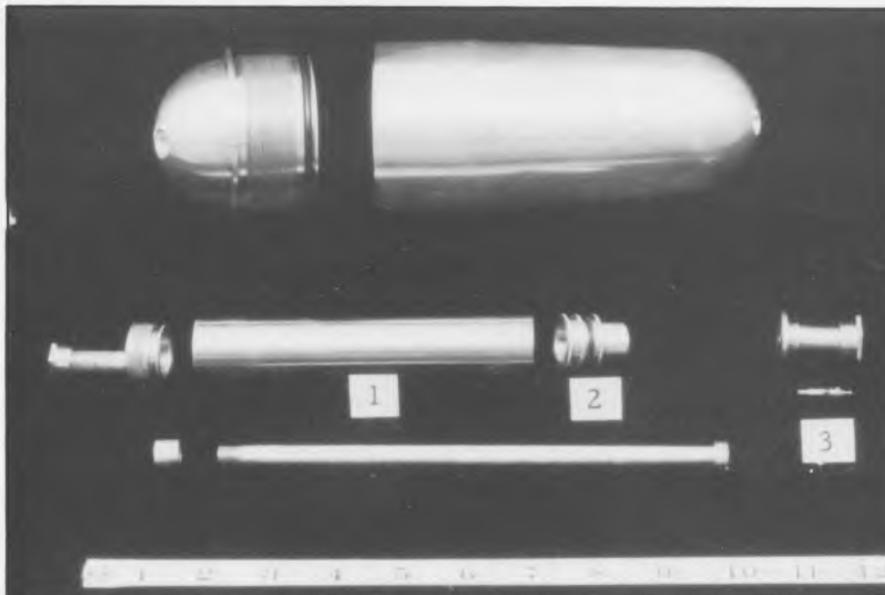
Fig. 2-17 Free flooding volumes of model and prototype.

$\frac{1.5 \times 10^3}{2} = 757$

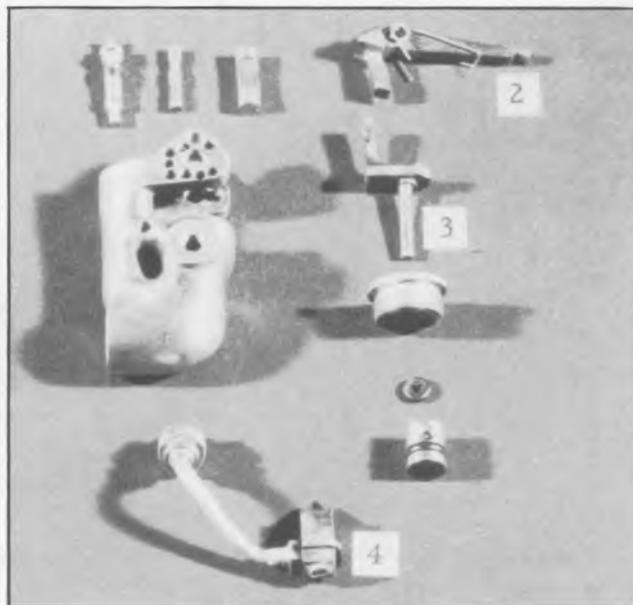
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(a) Accumulator - assembled



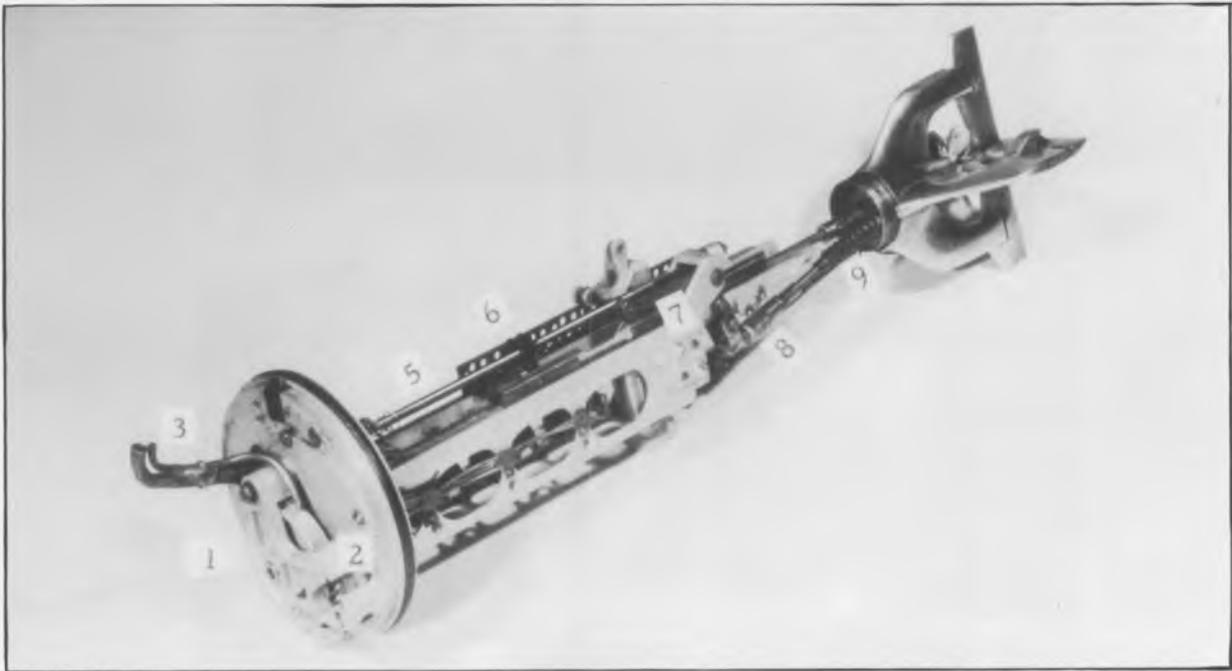
(b) Accumulator - disassembled



(c) Trigger valve - disassembled

Fig. 2-18 Pressure receiver and trigger valve details.
(1) Accumulator, piston and cylinder,
(2) Valve trigger lever,
(3) Valve piston,
(4) Turbine nozzle.

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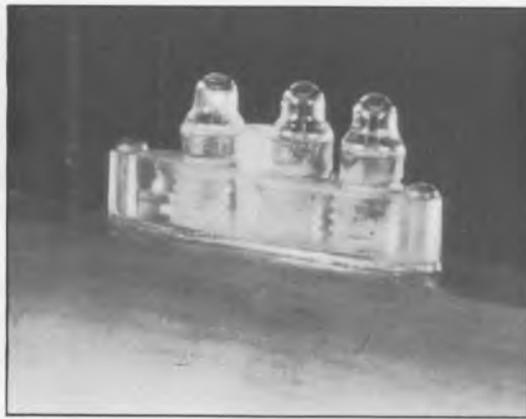


(a) Looking aft

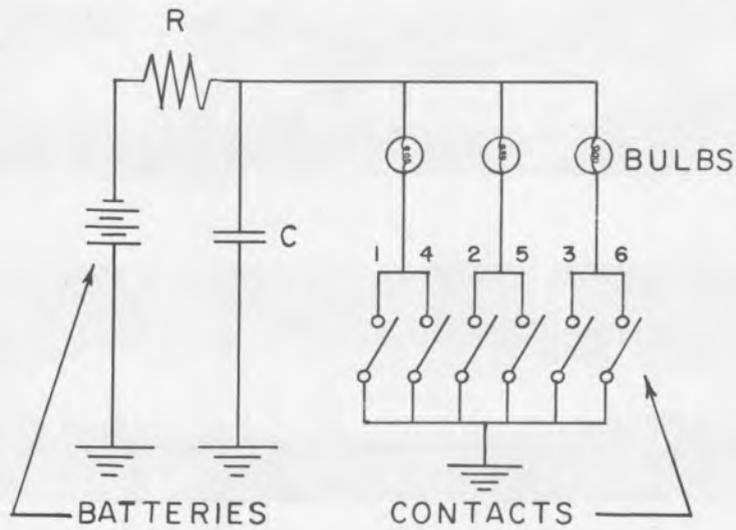


(b) Looking forward

Fig. 2-19 Propulsion and control mechanism.
(1) Turbine, (2) Nozzle socket, (3) Turbine air tubes,
(4) Reduction gears, (5) Cam lead screw, (6) Cam
drive bridge, (7) Cam follower, (8) Connecting rod
turnbuckle, (9) Bellows



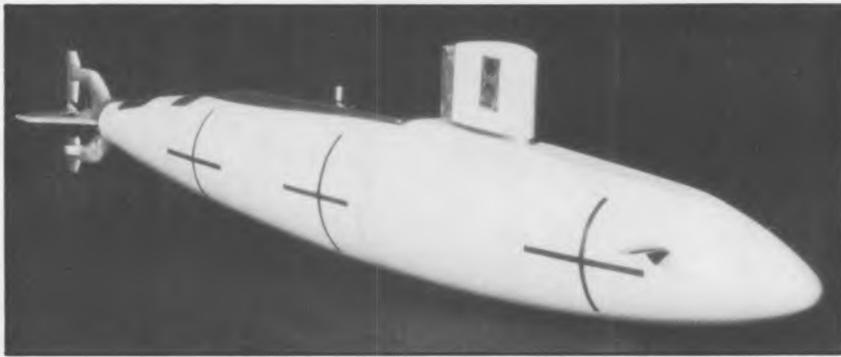
(b) Appearance of cam light streak on film



(c) Electrical circuit

Fig. 2-20 Program cam position indicators.

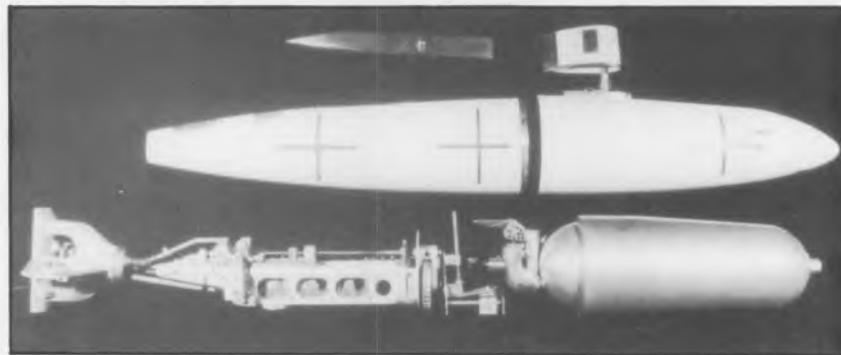
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(a) Starboard view



(b) Port view



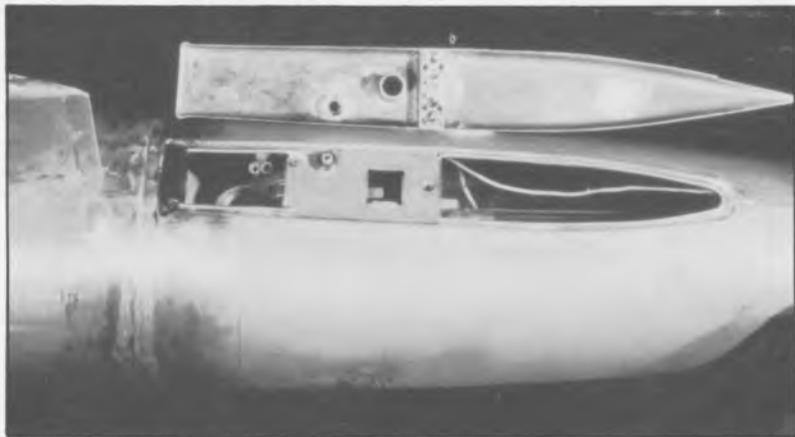
(c) Disassembled



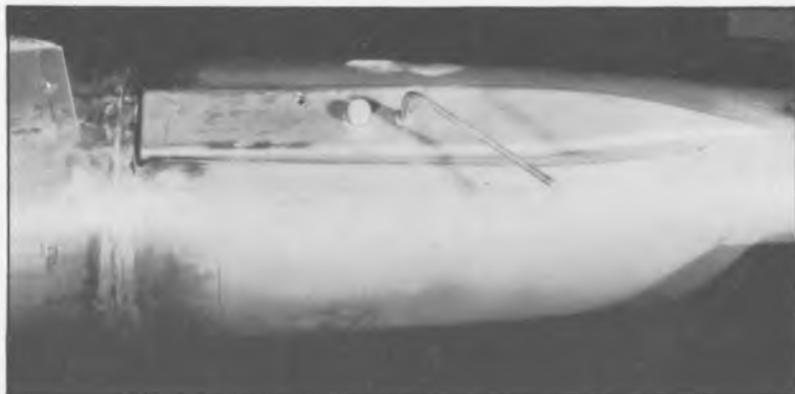
(d) Top starboard view

Fig. 2-21 Views of the C.I.T. free running model of the USS Albacore, AGSS 569, SST Scheme IV submarine with revised control surface configuration.

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(a) Access hatch and deck



(b) Deck in place

Fig. 2-22 Main access hatch arrangement.

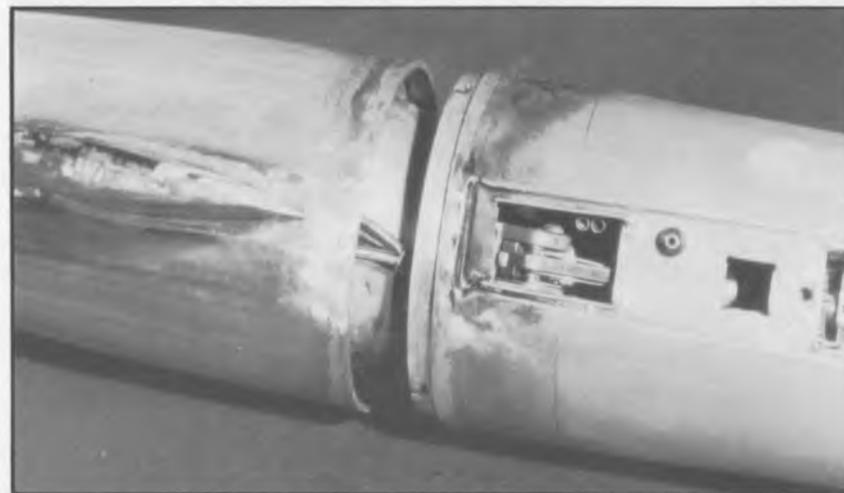
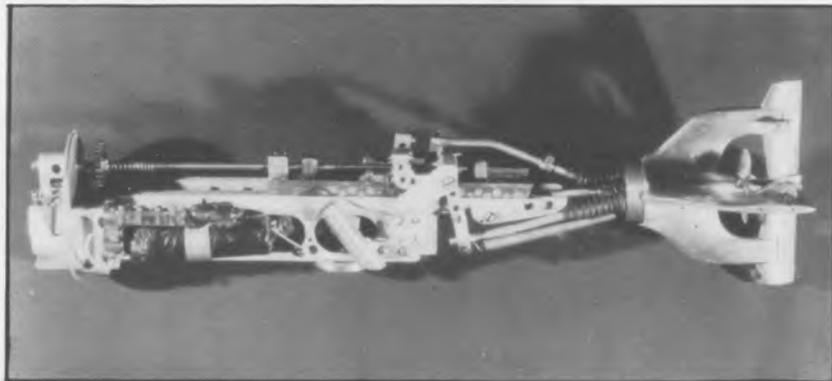


Fig. 2-23 Hull bayonet-type take down arrangement.



(a) Port side



(b) Starboard side

Fig. 2-24 Control mechanism.

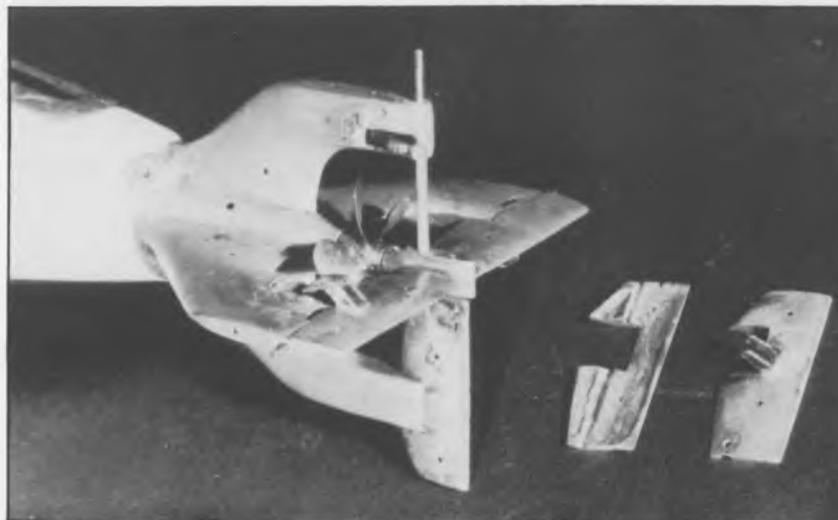


Fig. 2-25 Rudder pivot arrangements

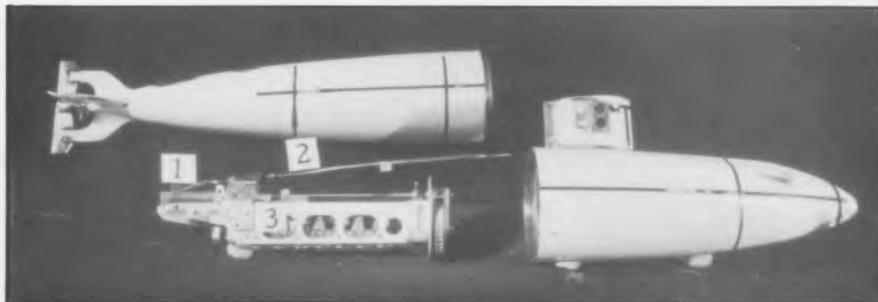


Fig. 2-26 Dorsal rudder control linkage arrangement.
(1) Rudder yoke and rod, (2) Dorsal rudder yoke and rod, (3) Cam follower, (4) Operating tab, (5) Pivot horn, (6) Linkage rod.



Fig. 2-27 Reduced height bridge.
Fairwater molded in wax.

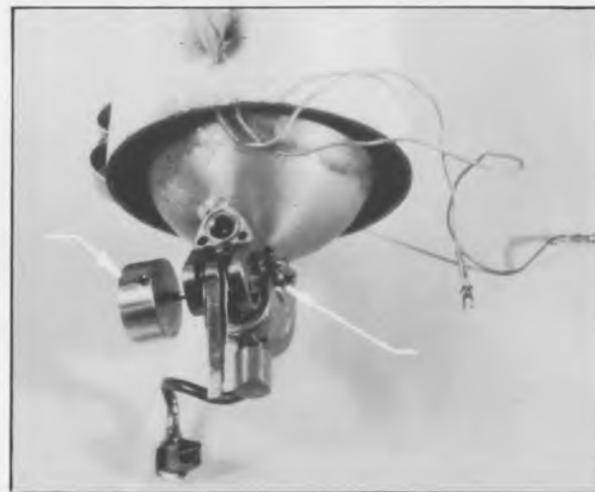
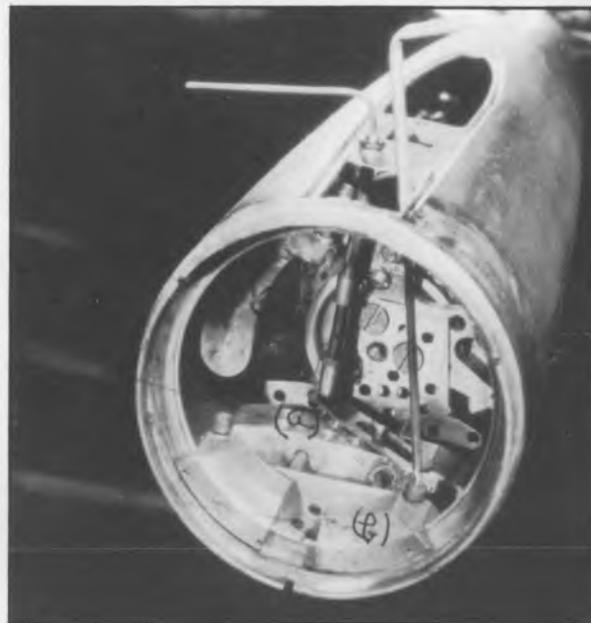
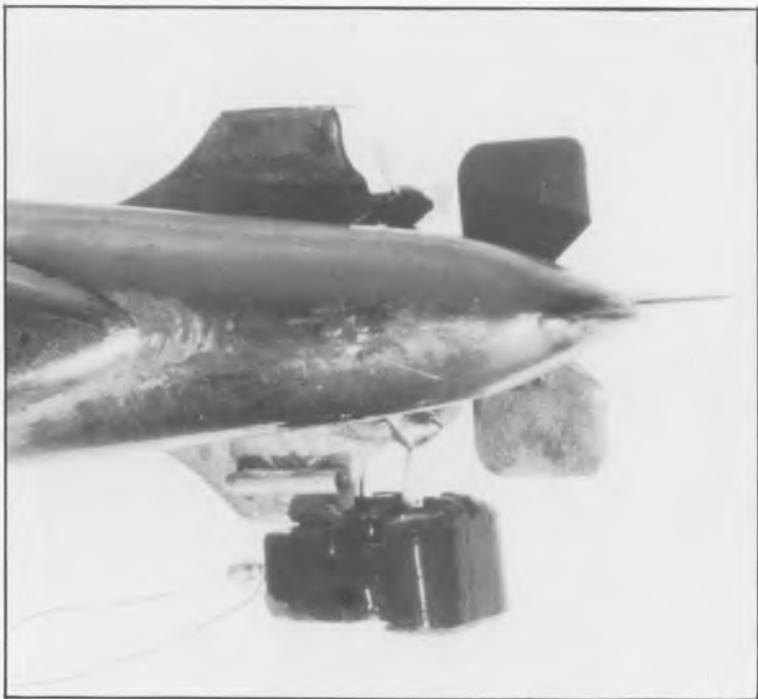
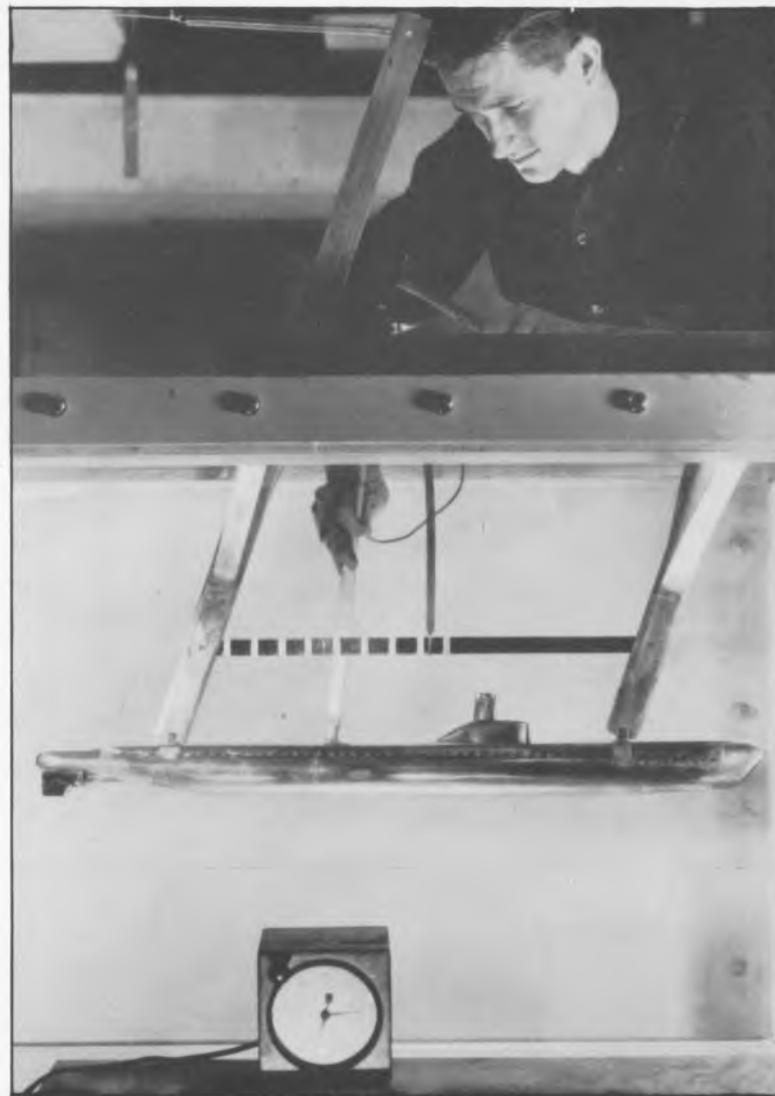


Fig. 2-28 Model trim adjustments.

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(a) Magnetic pickup for measuring propeller speed



(b) Model mounted on free swinging parallelogram support

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Fig. 3-1 Power test setup in Free Surface Water Tunnel.

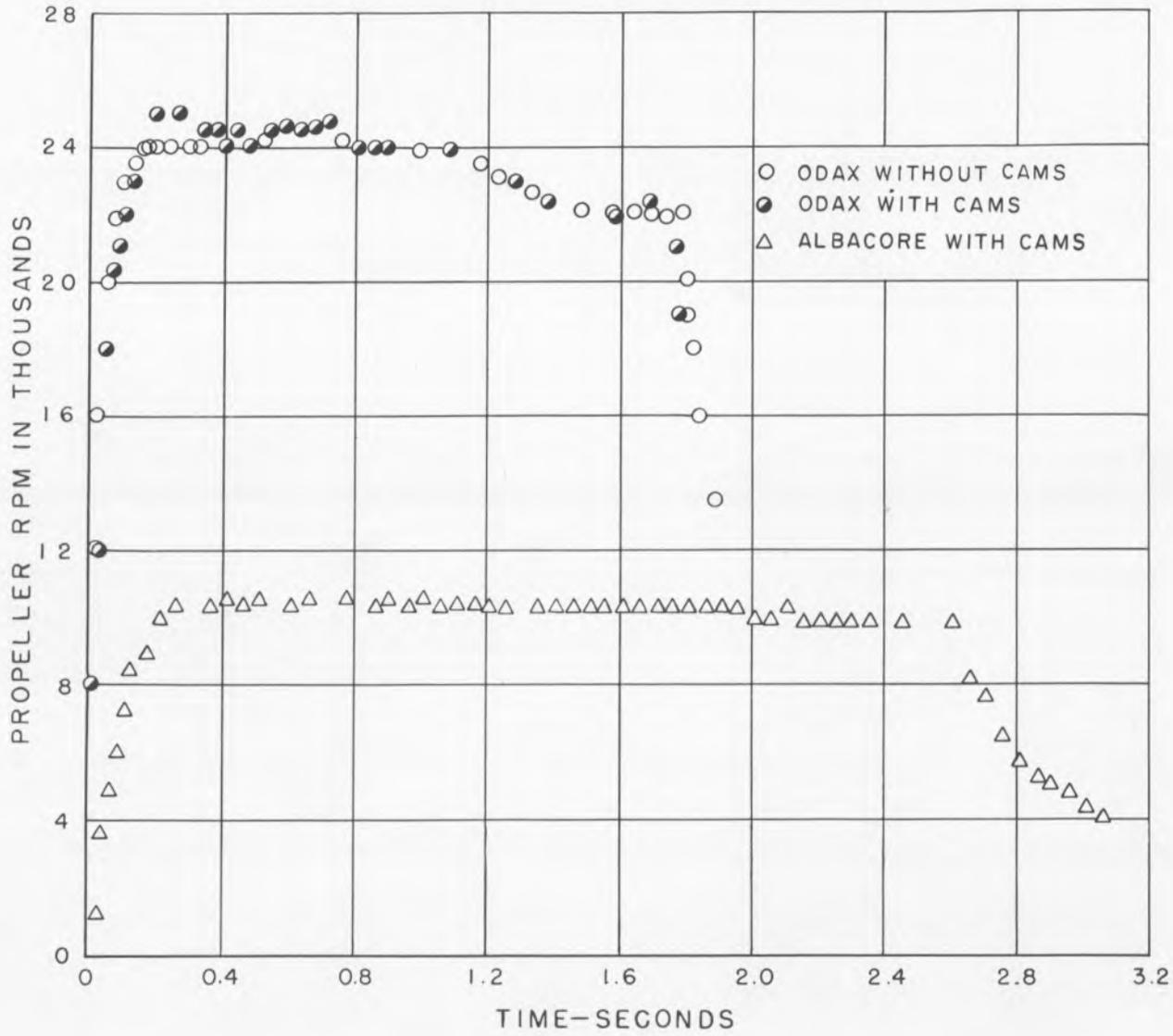


Fig. 3-2 Model propeller speeds in the Free Surface Water Tunnel



(a) Odax model calibration setup



(b) Albacore model calibration setup

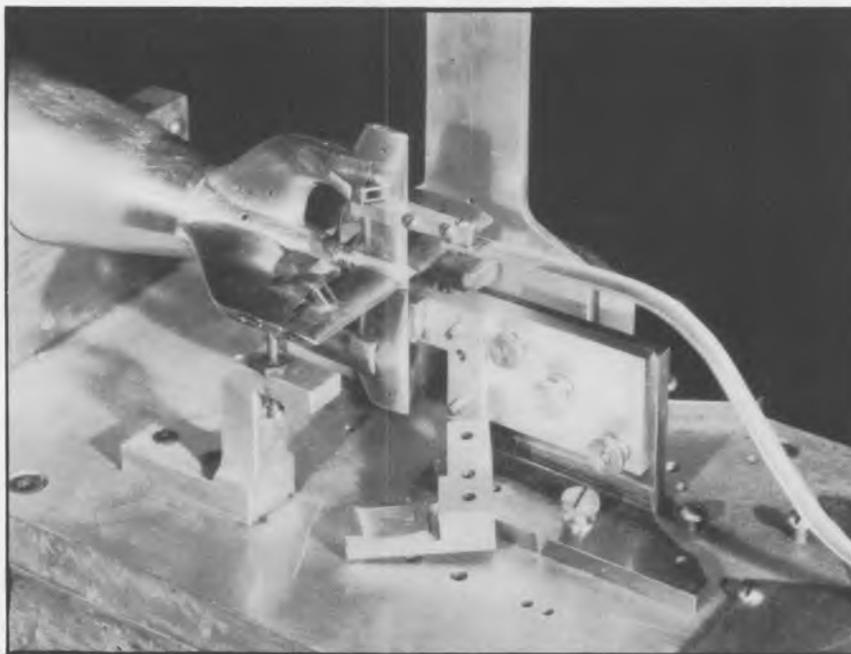


(c) Stern plane and rudder angle measuring setup for Albacore model (vertical maneuvers)

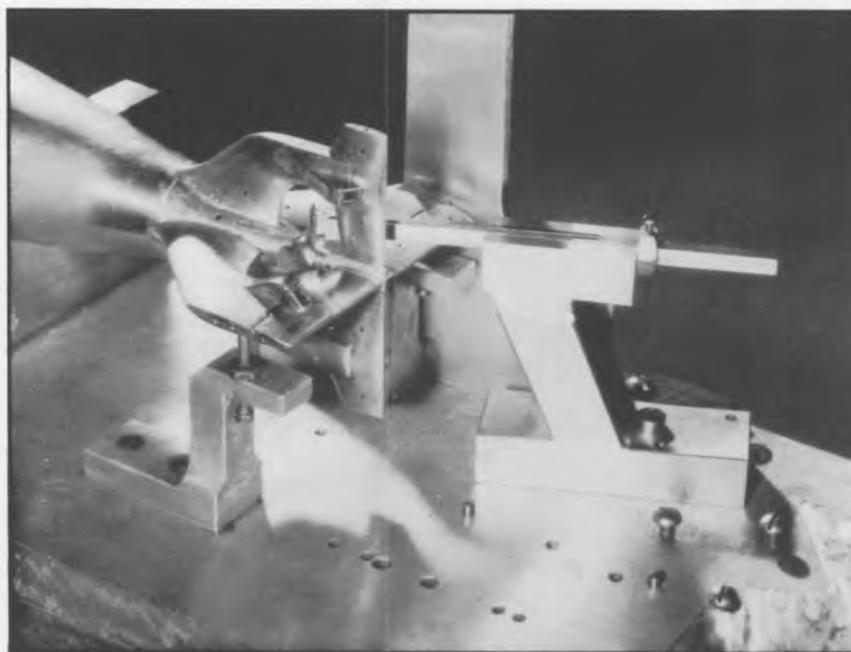
Fig. 3-3 Model measuring fixtures.

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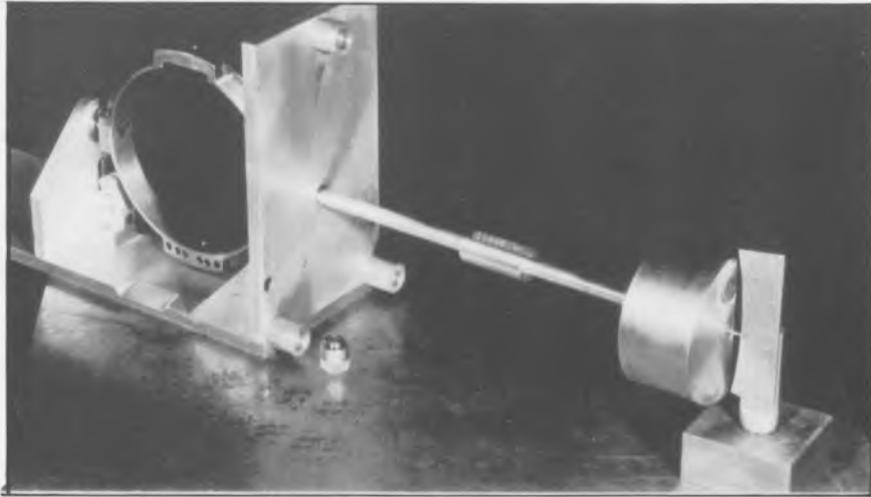


(d) Rudder pointer and zero block for Albacore model (horizontal maneuvers)

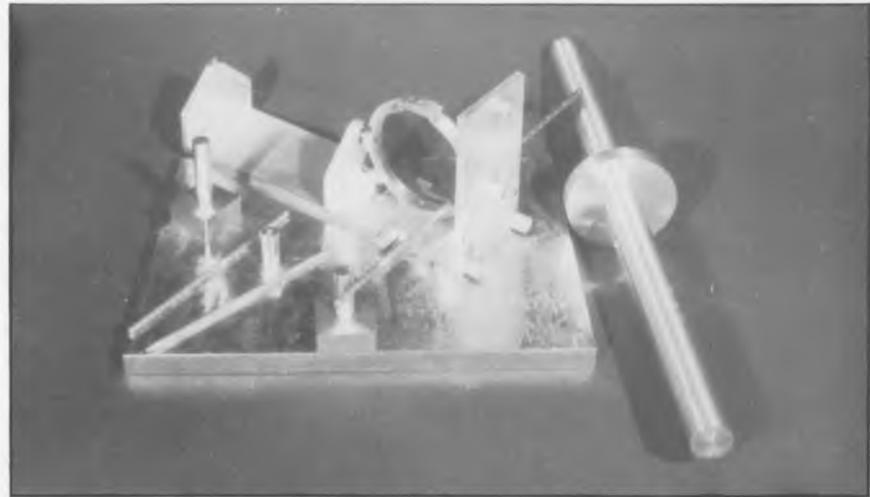


(e) Propeller check gage for Albacore model

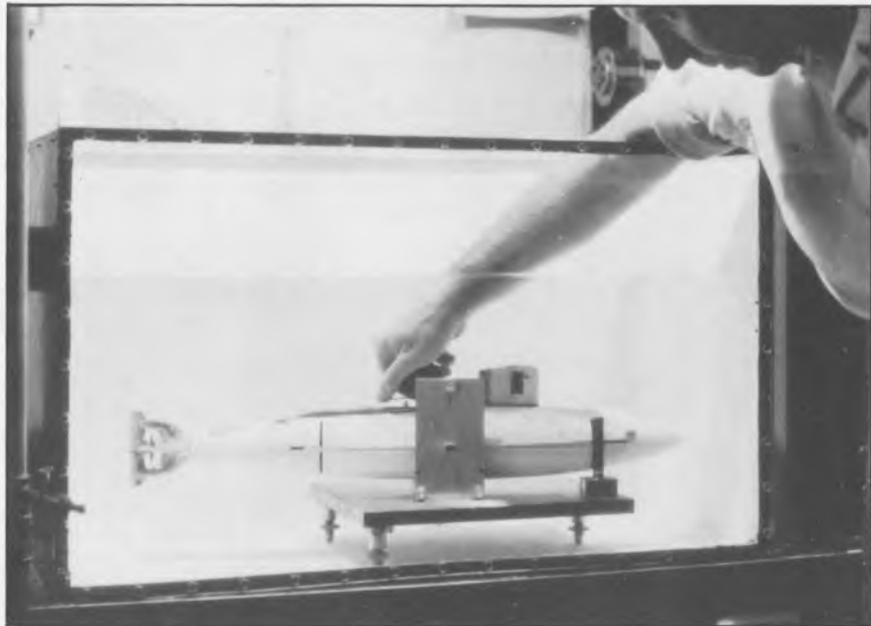
Fig. 3-3 (cont.) Model measuring fixtures



(a) Balance components



(c) Roll measuring attachment



(b) Adjusting longitudinal trim in flotation tank



(d) Measuring vertical C.G. location

Fig. 3-4 Static trim measurements with C.G. -I balance.



Fig. 3-5 Charging accumulator with metering pump.

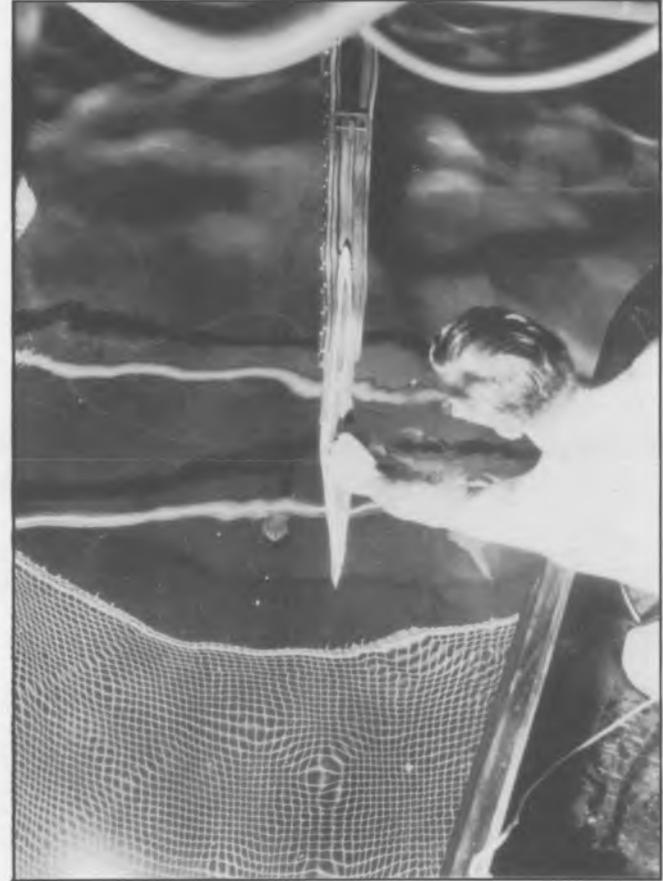


Fig. 3-6 Installing model in launching cradle from wooden boat in tank.

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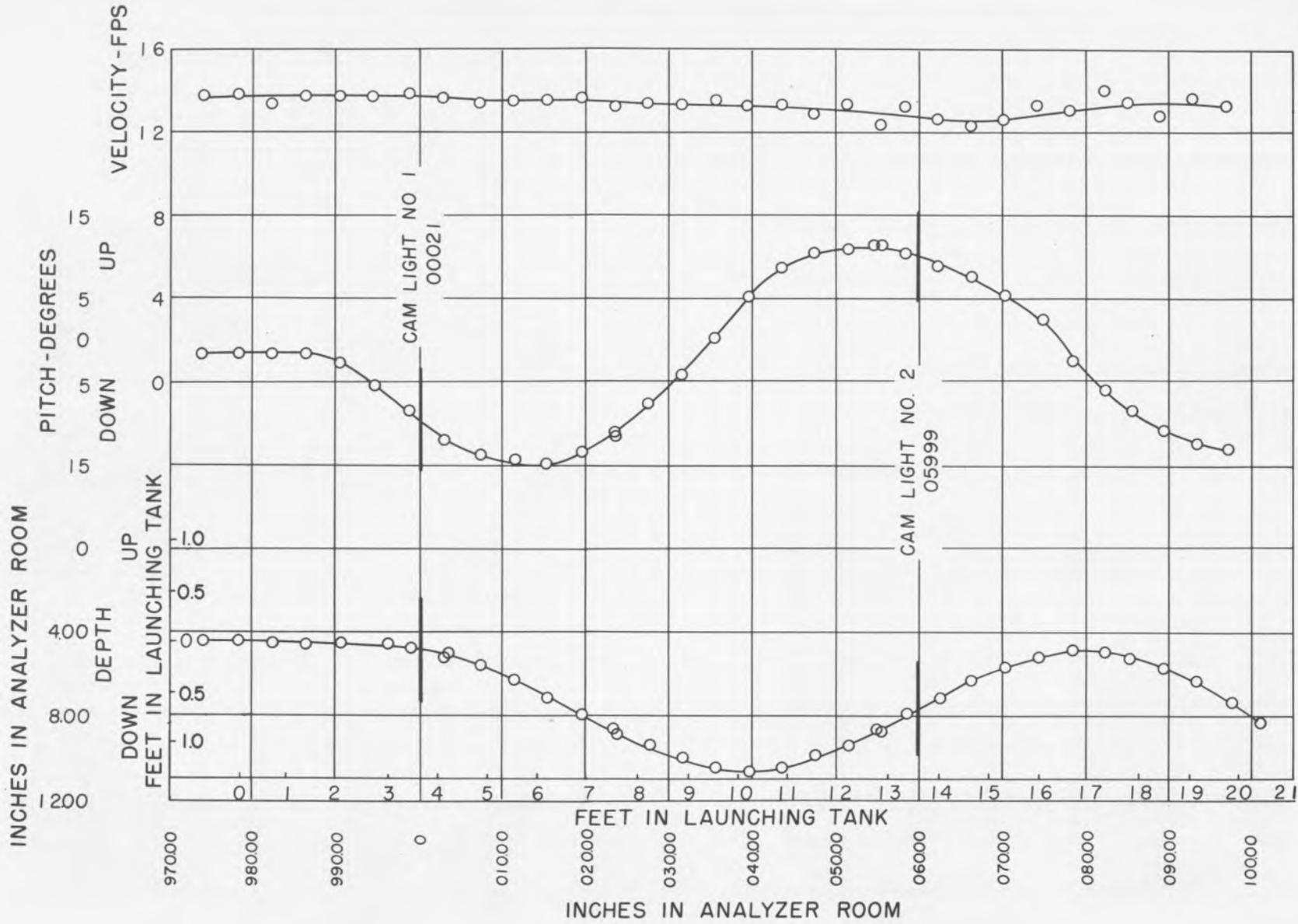
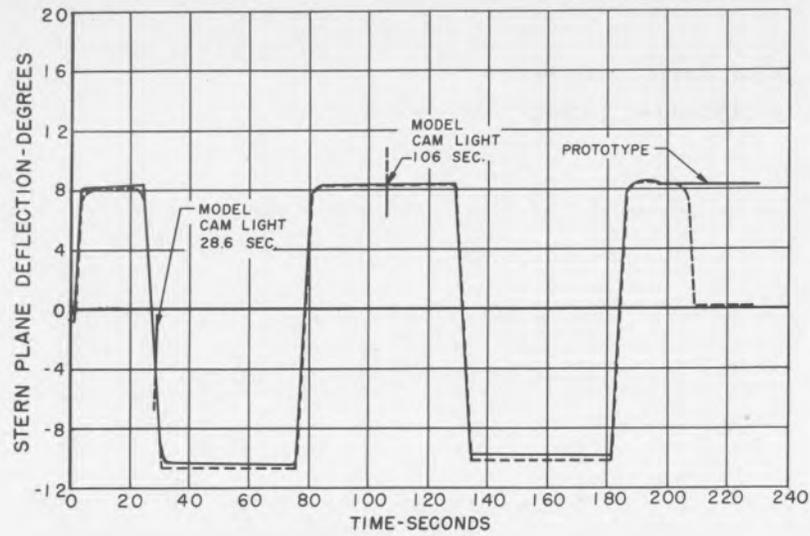
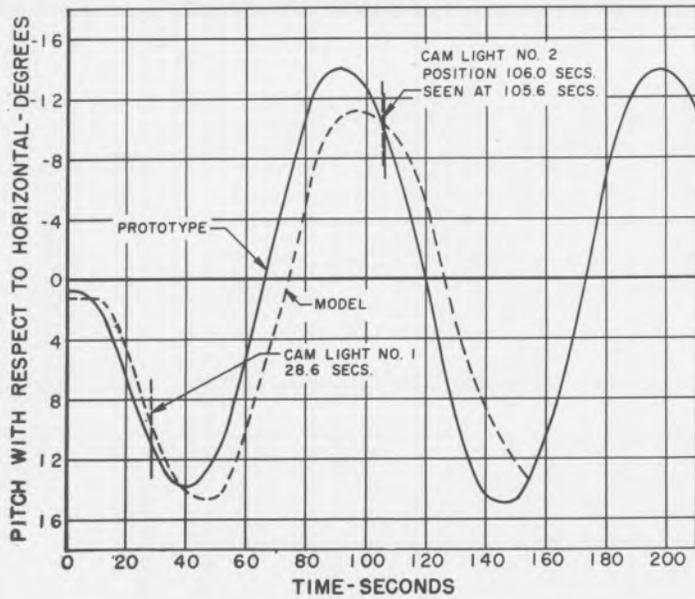


Fig. 4-1a Model test data for run No. 365 with program cam No. 7 representing prototype run No. 84.

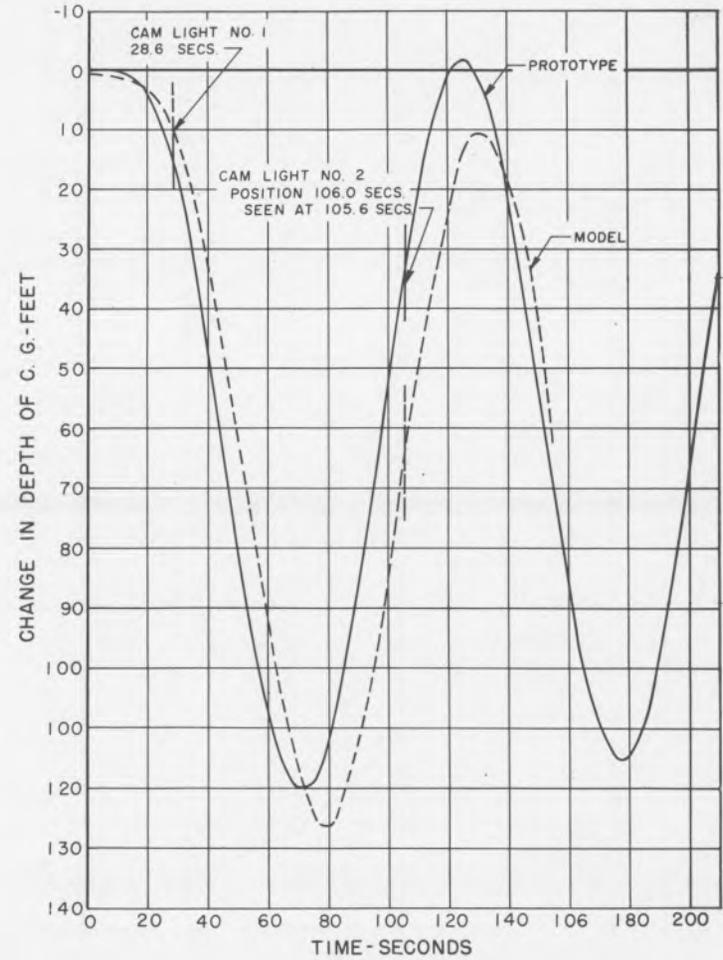
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(1) Comparison of stern plane action.

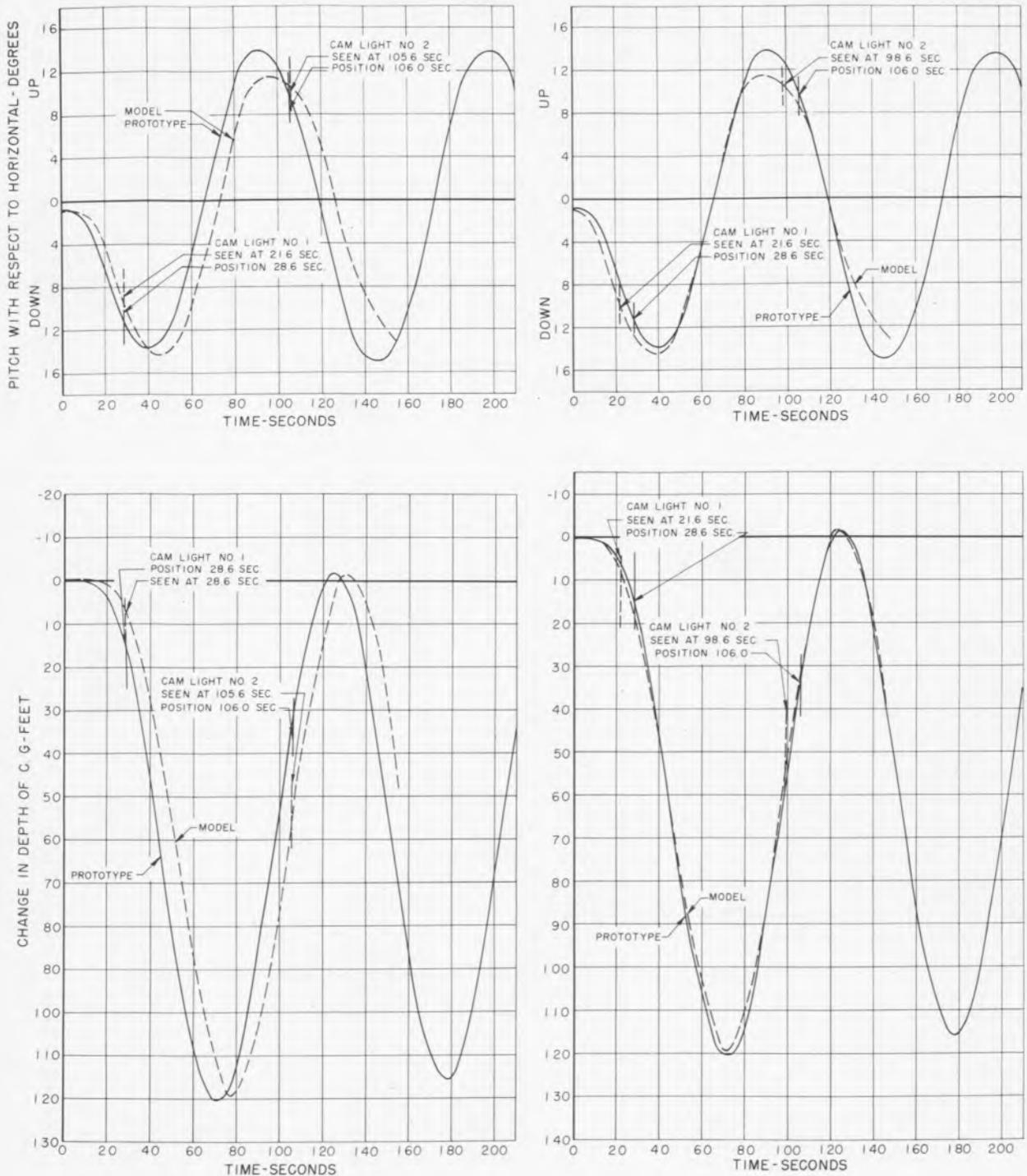


(2) Comparison of pitch response.



(3) Comparison of depth response.

Fig. 4-1b Comparison of results of model test No. 365, before applying corrections, with prototype run No. 84.



(1) Depth curve rotated in plane of paper 0.35° counter clockwise. Pitch curve raised 0.35° .

(2) Both curves shifted toward left 7.0 seconds.

Fig. 4-1c Comparison of model test results of run No. 365, after applying corrections in two steps, with results of prototype run No. 84.

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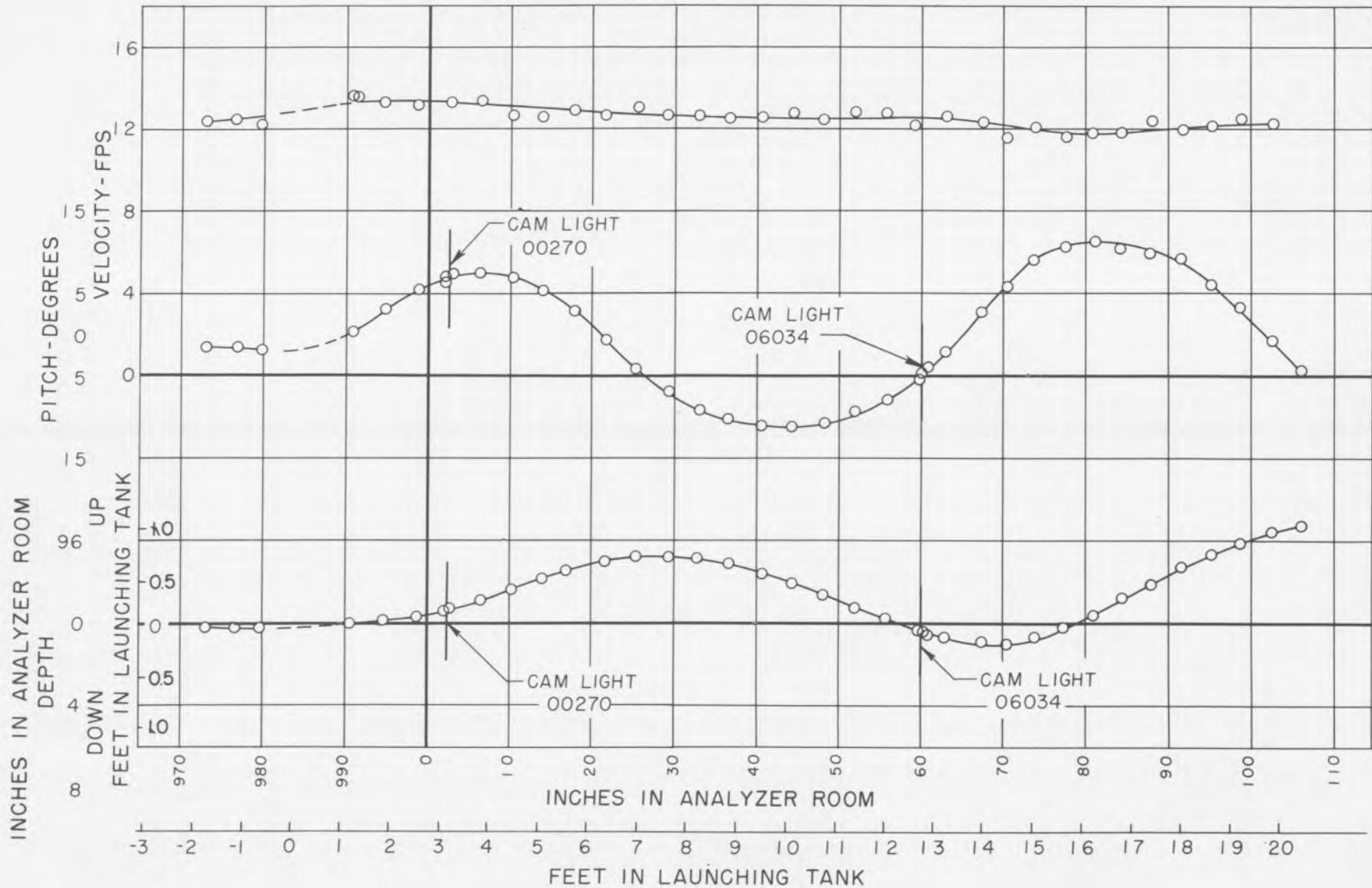


Fig. 4-2a Model test data for run No. 446 with program cam No. 8 representing prototype run No. 87.

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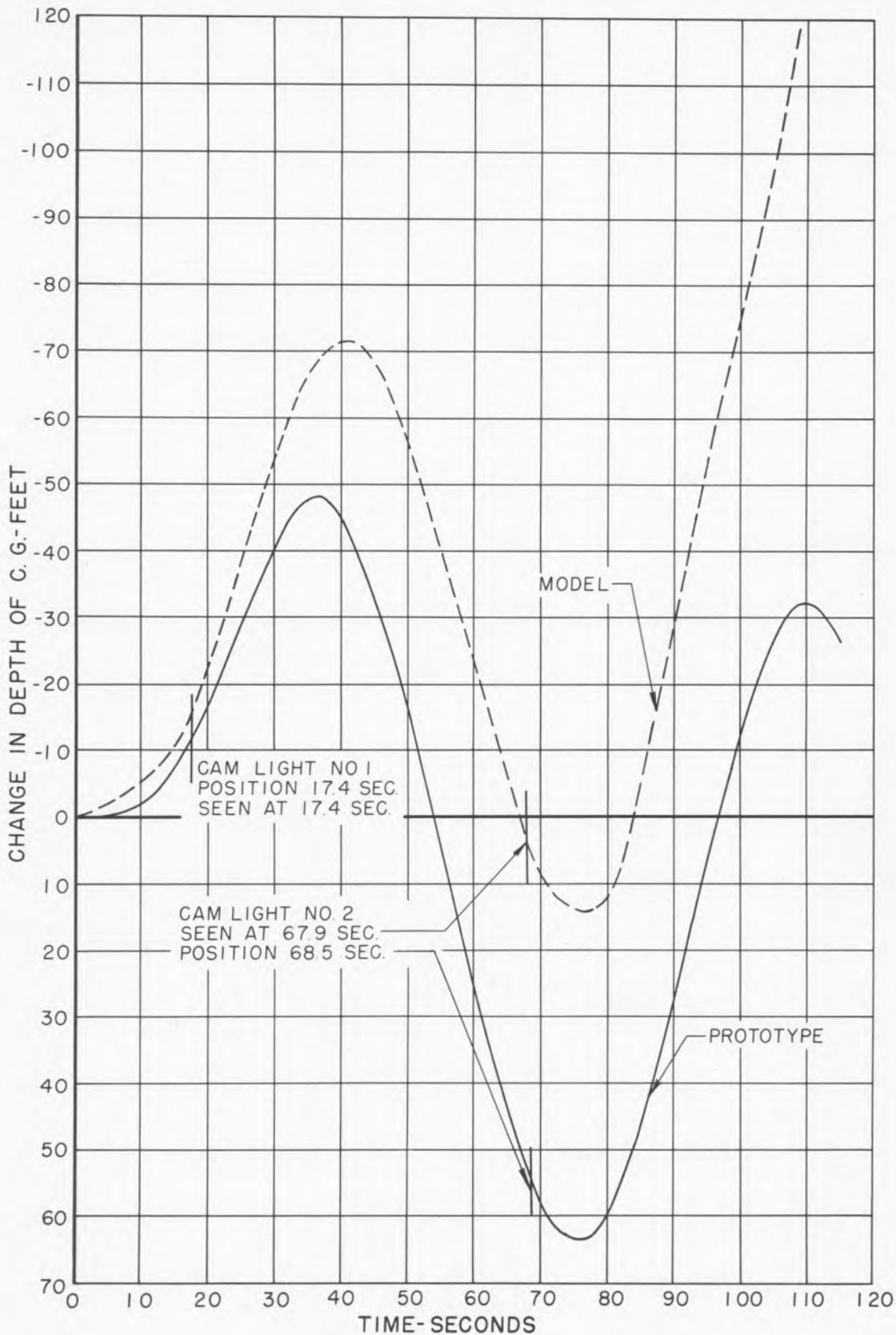


Fig. 4-2b Comparison of depth response of model test run No. 446 with prototype run No. 87 before applying corrections as aligned by cam light.

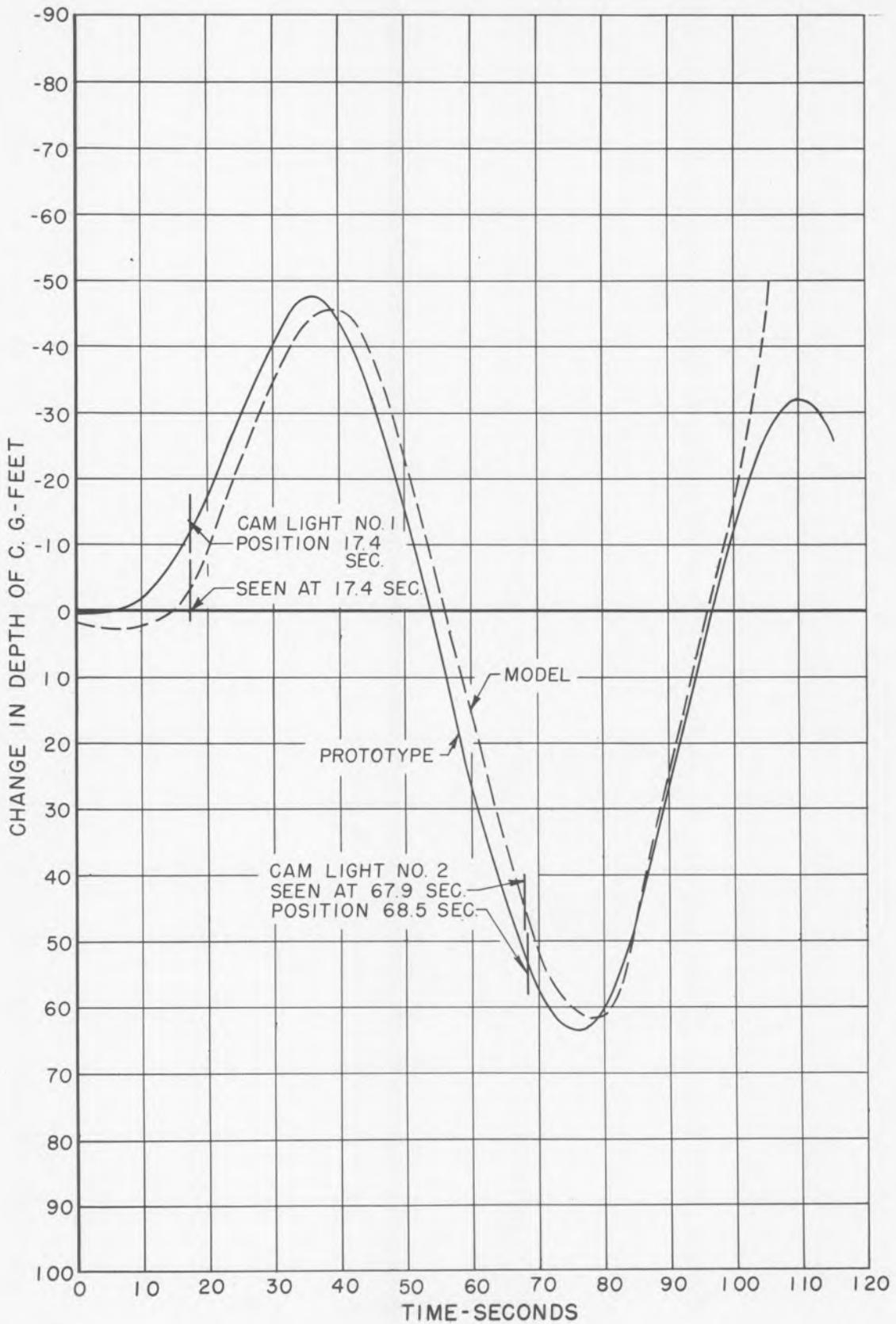


Fig. 4-2c Comparison of depth response of model test run No. 446 with prototype run No. 87 after rotating 1.51° clockwise in the plane of the paper.

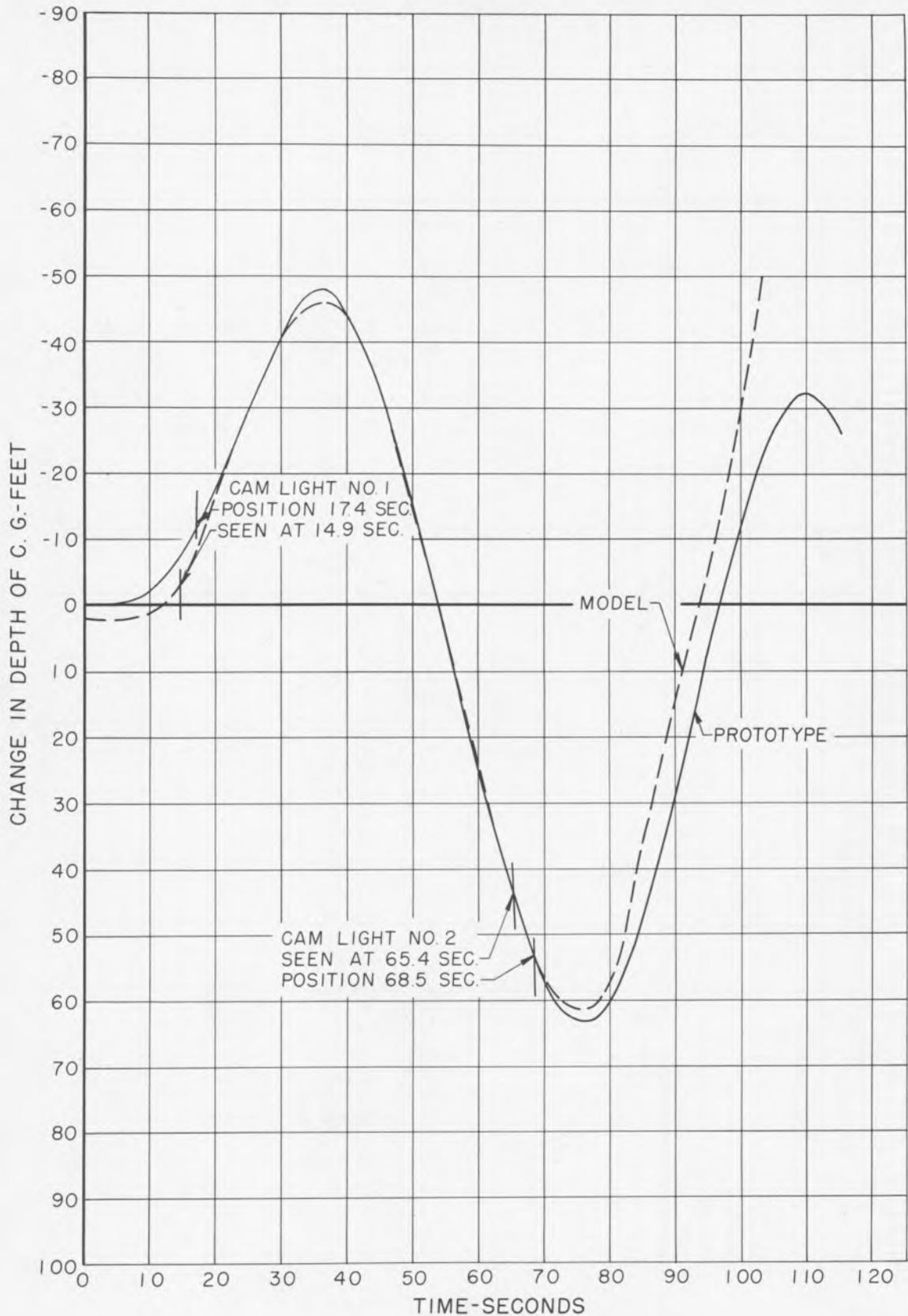
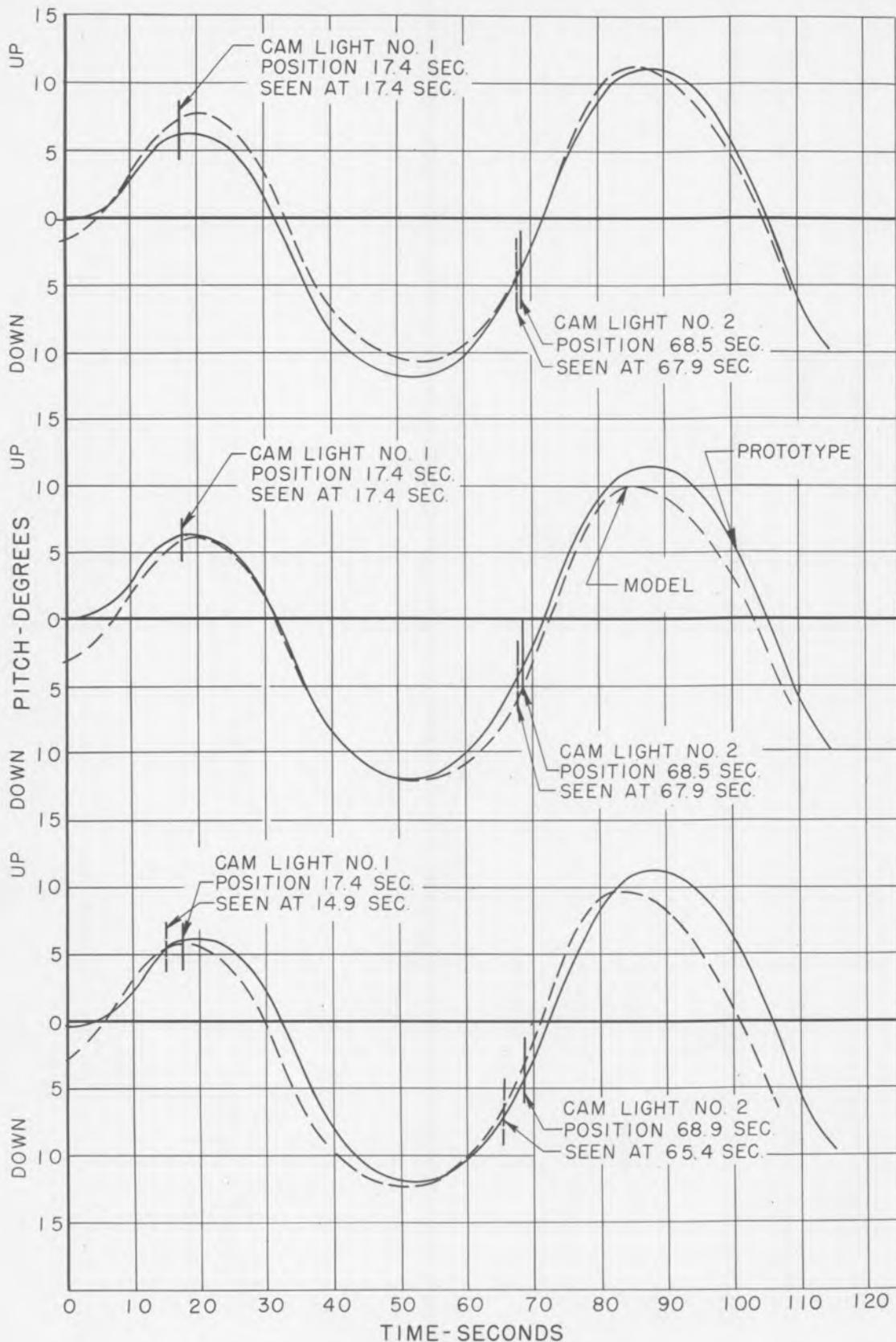
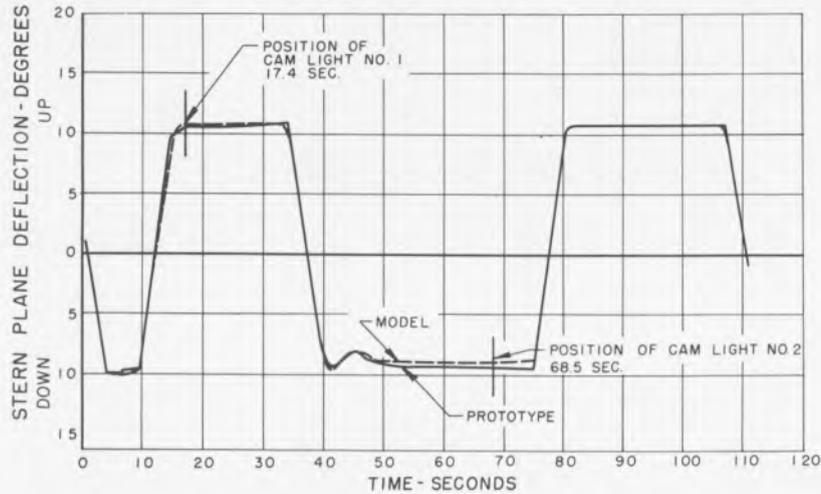


Fig. 4-2d Comparison of depth response of model test run No. 446 with prototype run No. 87 after rotating and shifting 2.5 seconds to the left.

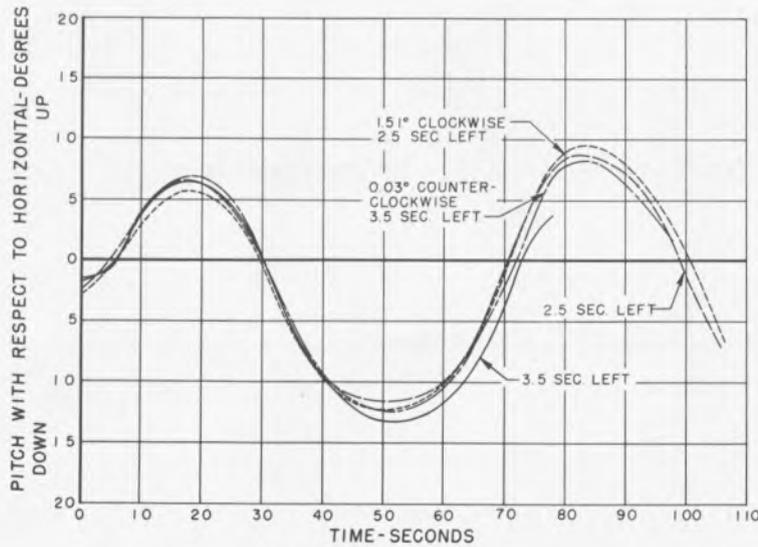


(3) Shifted 2.5 seconds to the left. (2) Rotated 1.51° clockwise. (1) Aligned by cam light No. 1.

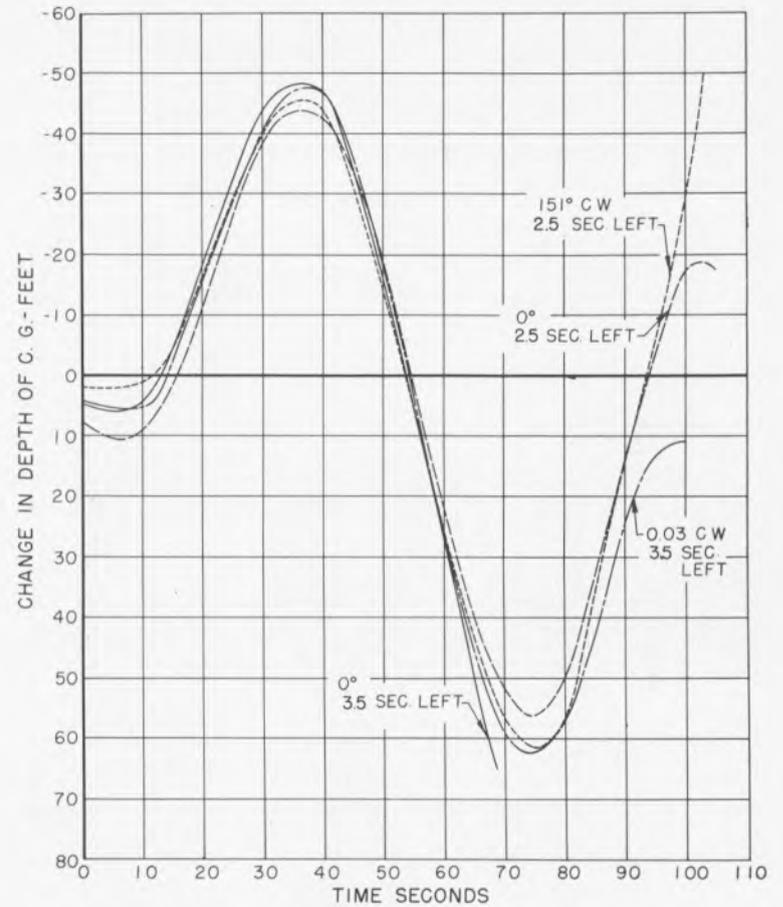
Fig. 4-2e Comparison of pitch response of model test run No. 446 with prototype run No. 87 showing steps in applying corrections.



(1) Comparison of stern plane programs.

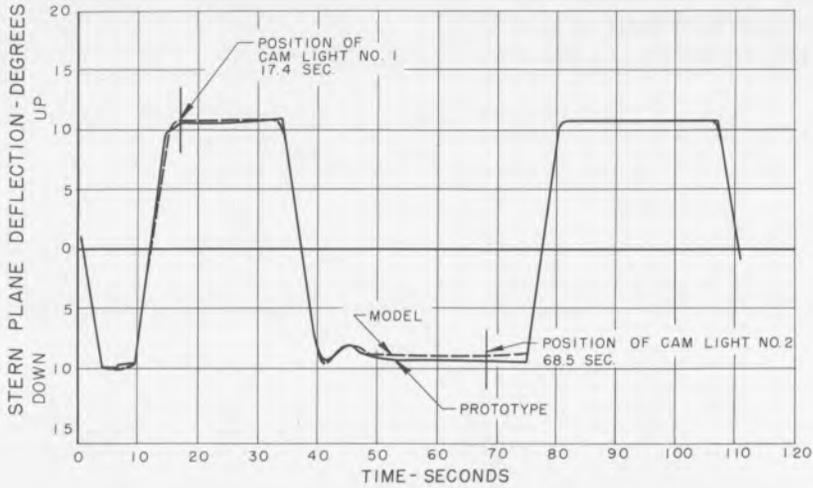


(2) Comparison of pitch response.

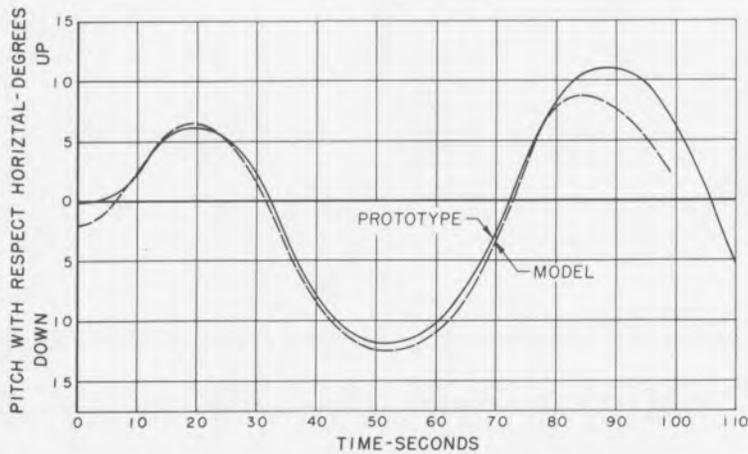


(3) Comparison of depth response.

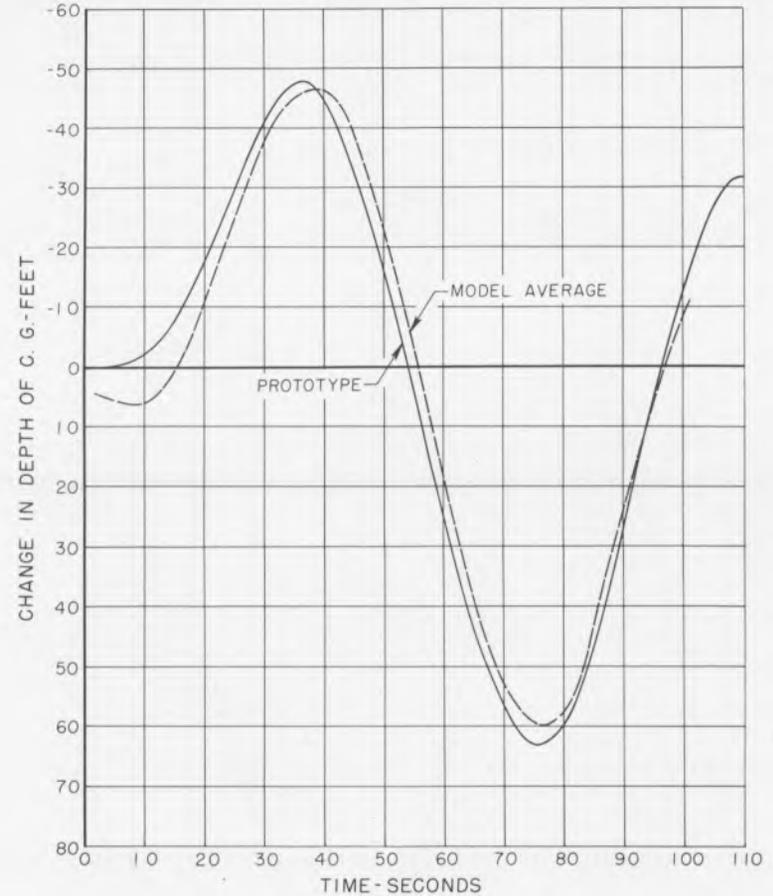
Fig. 4-2f Comparison of four model test runs with program cam No. 8 representing prototype run No. 87 after applying corrections.



(1) Comparison of stern plane programs.

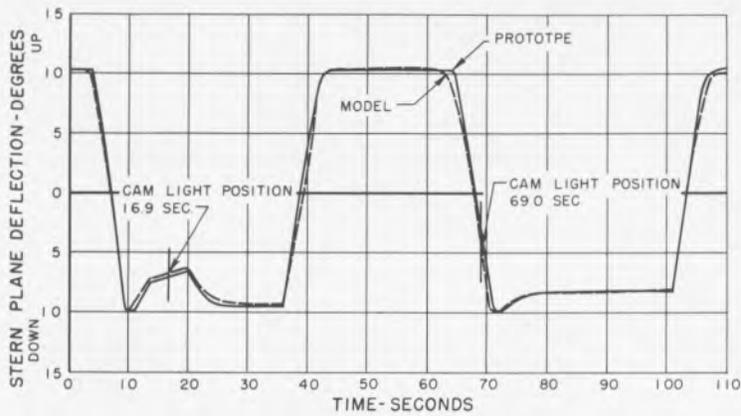


(2) Comparison of pitch response.

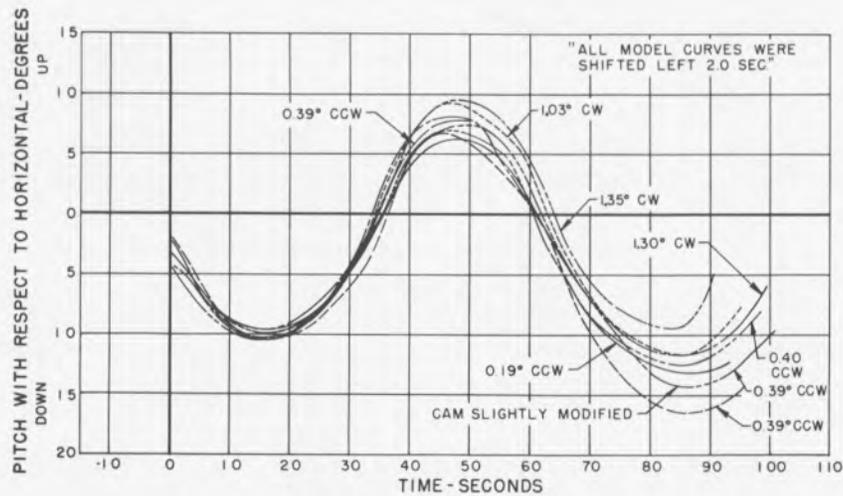


(3) Comparison of depth response.

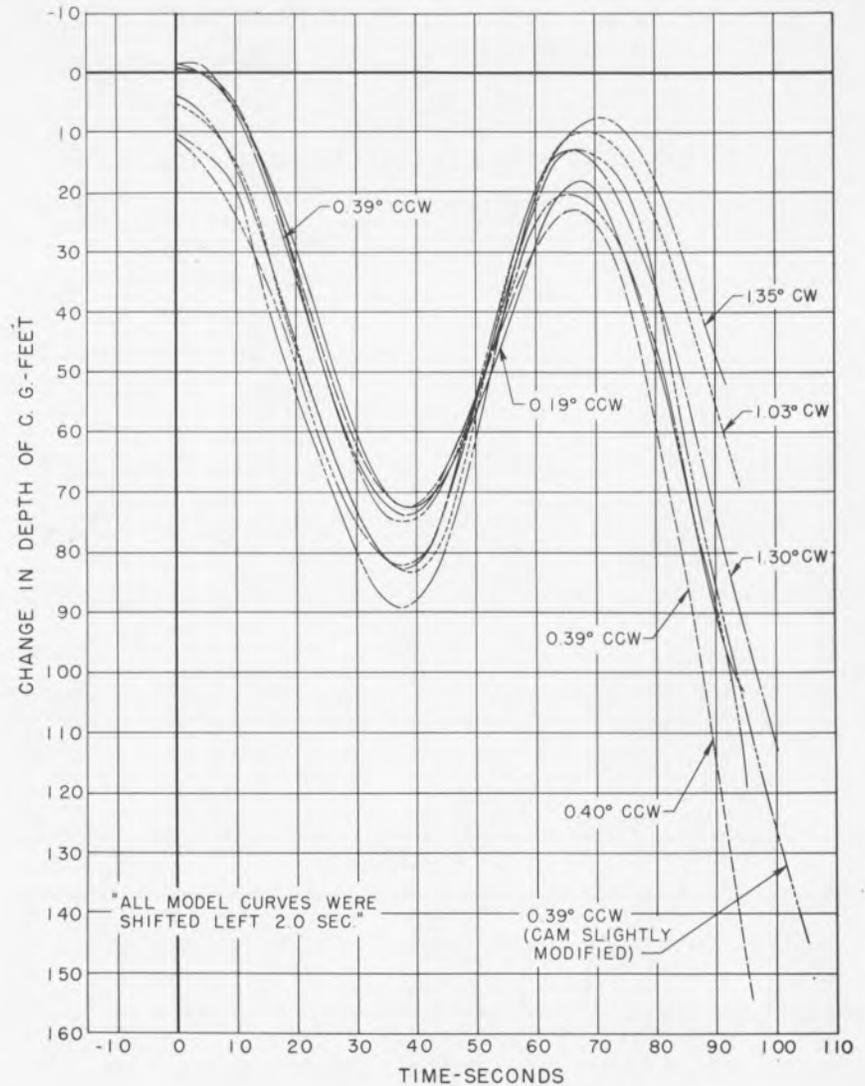
Fig. 4-2g Comparison of average of four model test runs with prototype run No. 87.



(1) Comparison of stern plane programs.

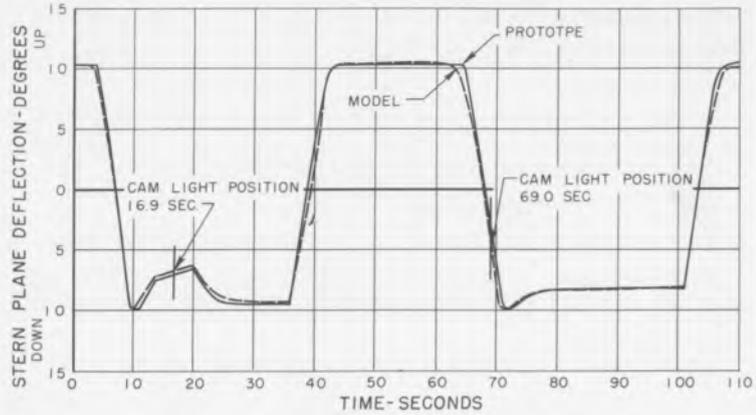


(2) Comparison of pitch response.

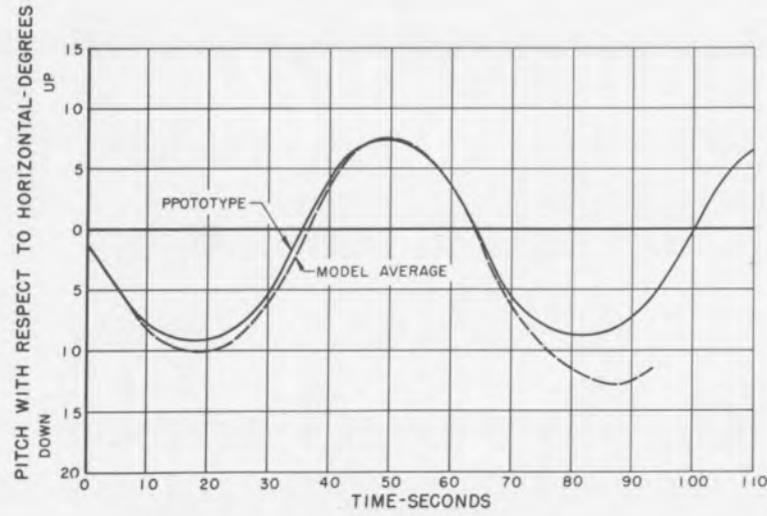


(3) Comparison of depth response.

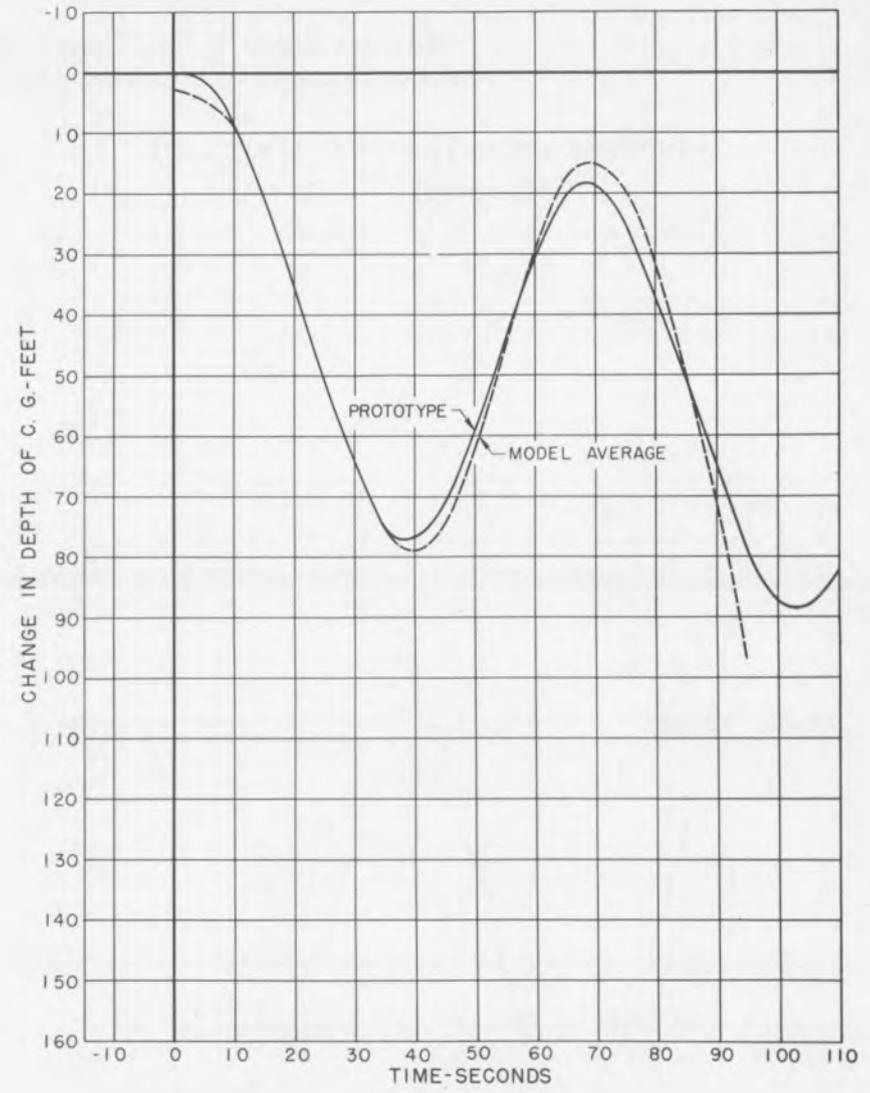
Fig. 4-3a Comparison of eight model test runs, after applying corrections, for program cam No. 6 representing prototype run No. 86.



(1) Comparison of stern plane programs.

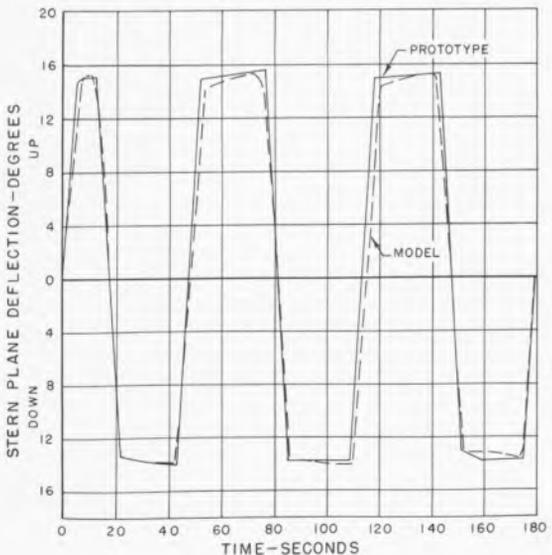
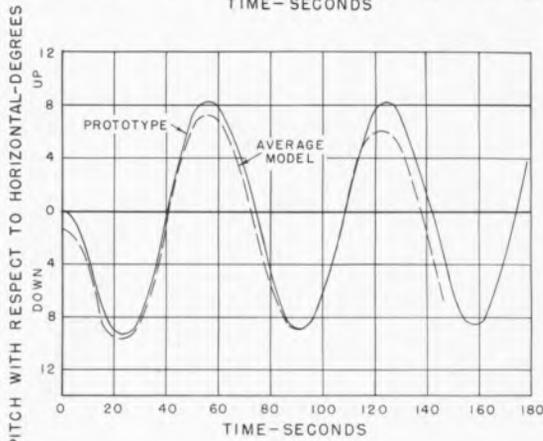
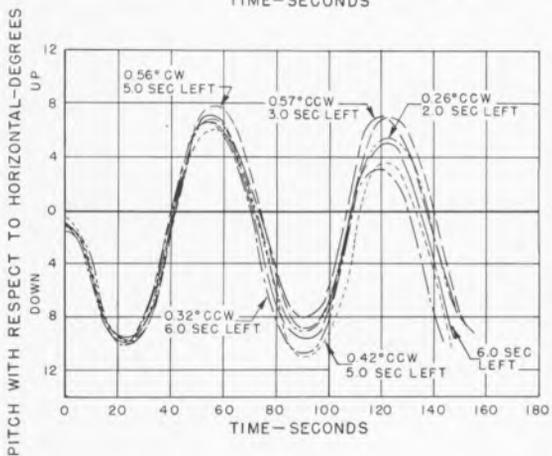
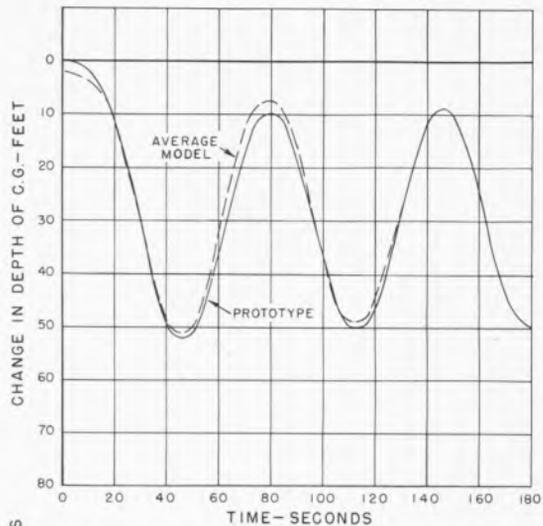
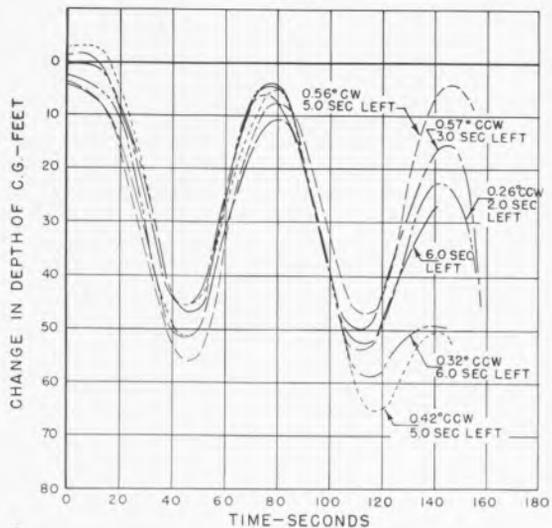


(2) Comparison of pitch response.



(3) Comparison of depth response.

Fig. 4-3b Comparison of average of eight model test runs with prototype run No. 86.



(b) Comparison of average of model test runs with prototype run.

(a) Comparison of model test runs after applying corrections.

Fig. 4-4 Comparison of the results of six model test runs with program cam No. 5 with prototype run No. 194.

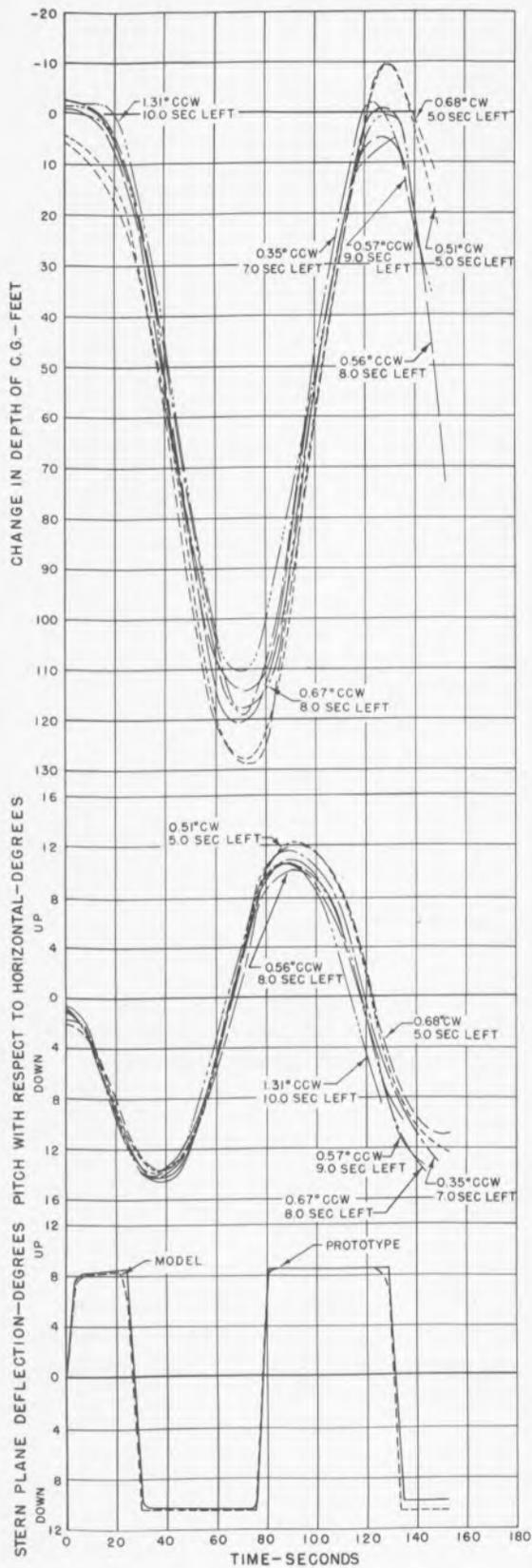


Fig. 4-5a Comparison of first series of model test runs with program cam No. 7 with protective fenders mounted on horizontal stabilizer fins.

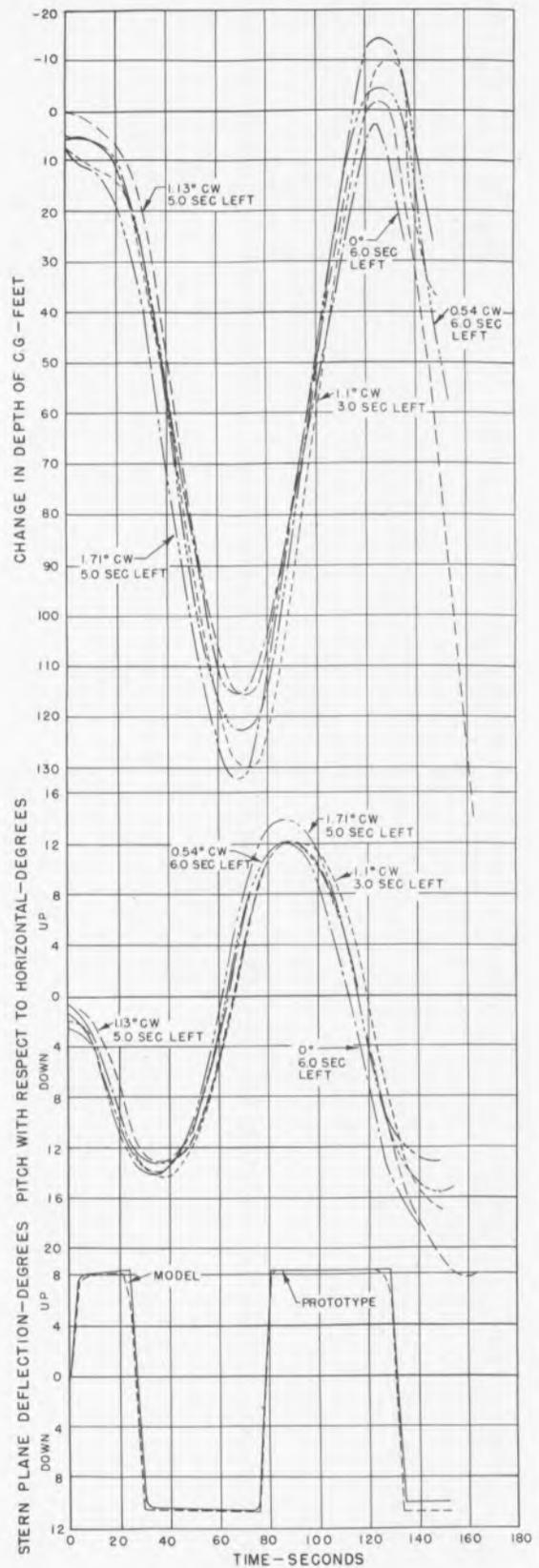
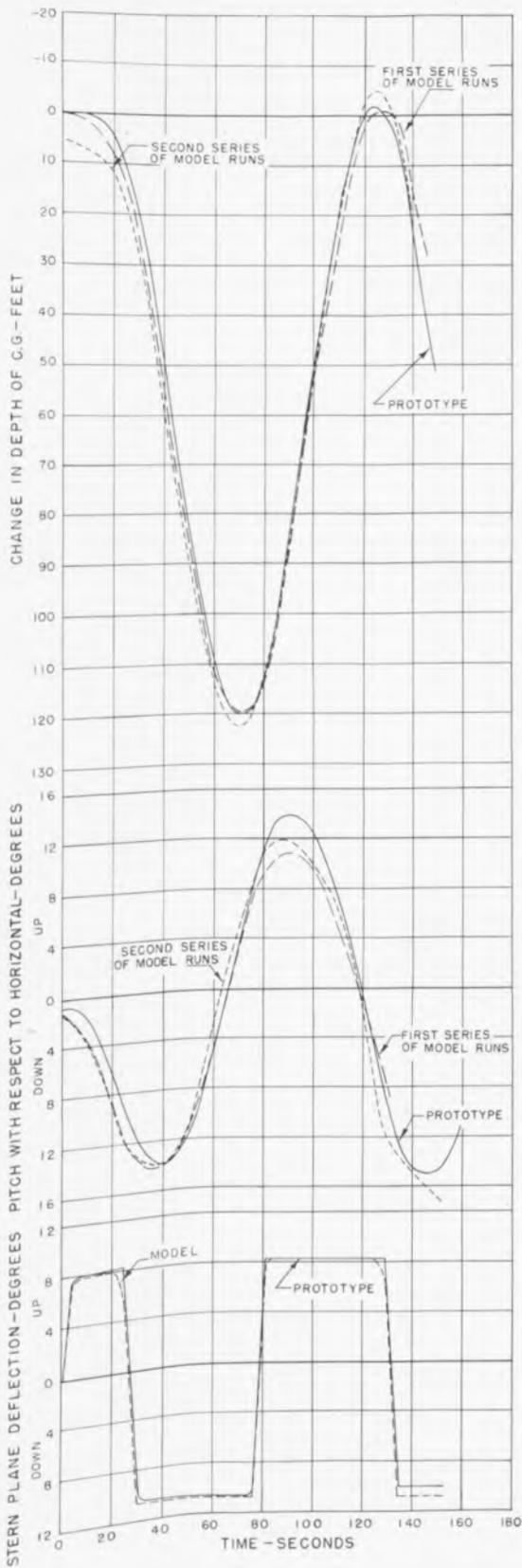


Fig. 4-5b Comparison of second series of model test runs with program cam No. 7 with protective fenders removed.



(3) Comparison of depth response.

(2) Comparison of pitch response.

(1) Comparison of stern plane programs.

Fig. 4-5c Comparison of average of model test runs for first and second series with prototype run No. 84.

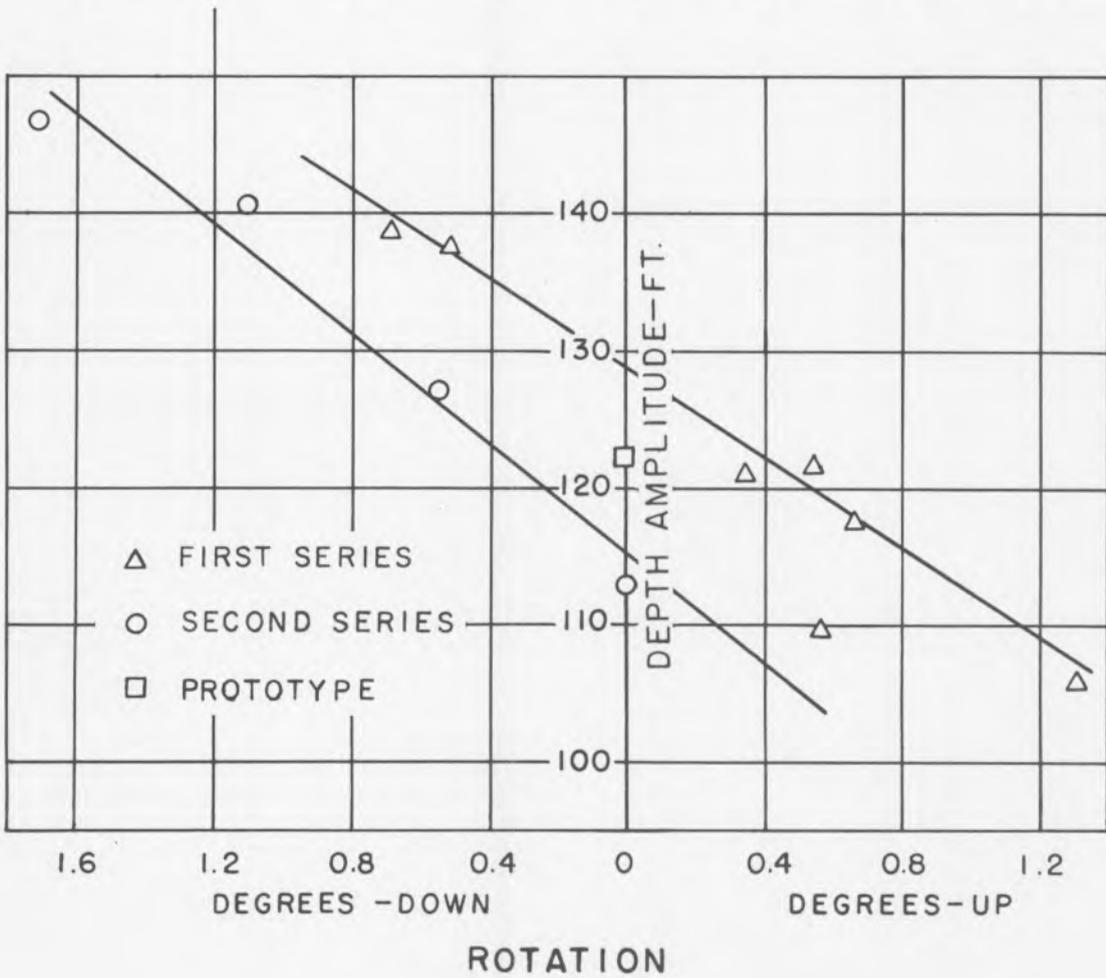
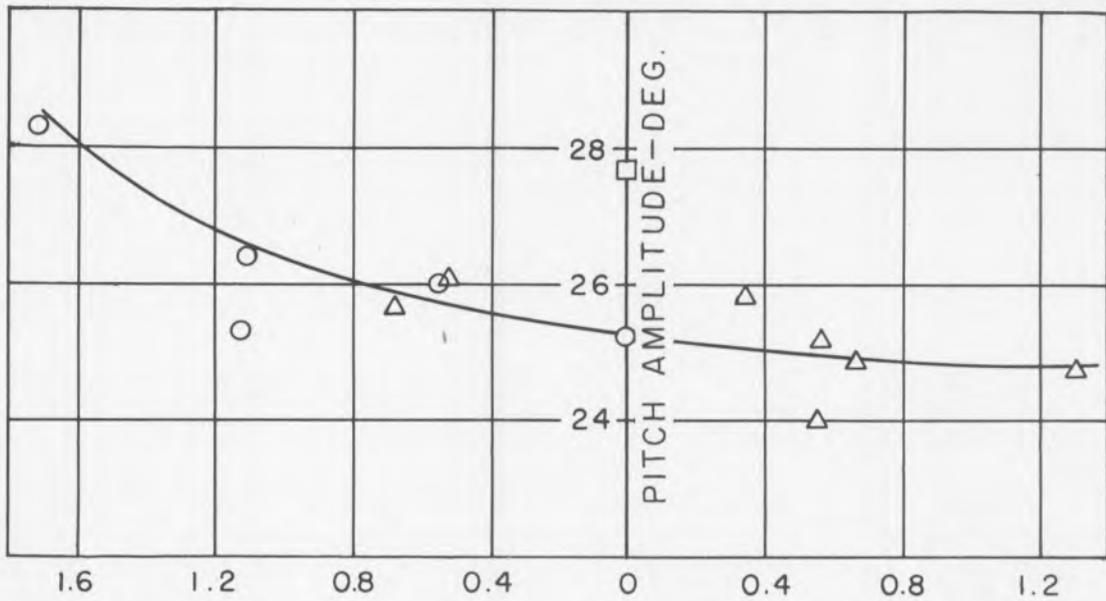


Fig. 4-5d Comparison of amplitudes of oscillation in pitch and depth for first and second series of model tests with program cam No. 7 representing prototype run No. 84.

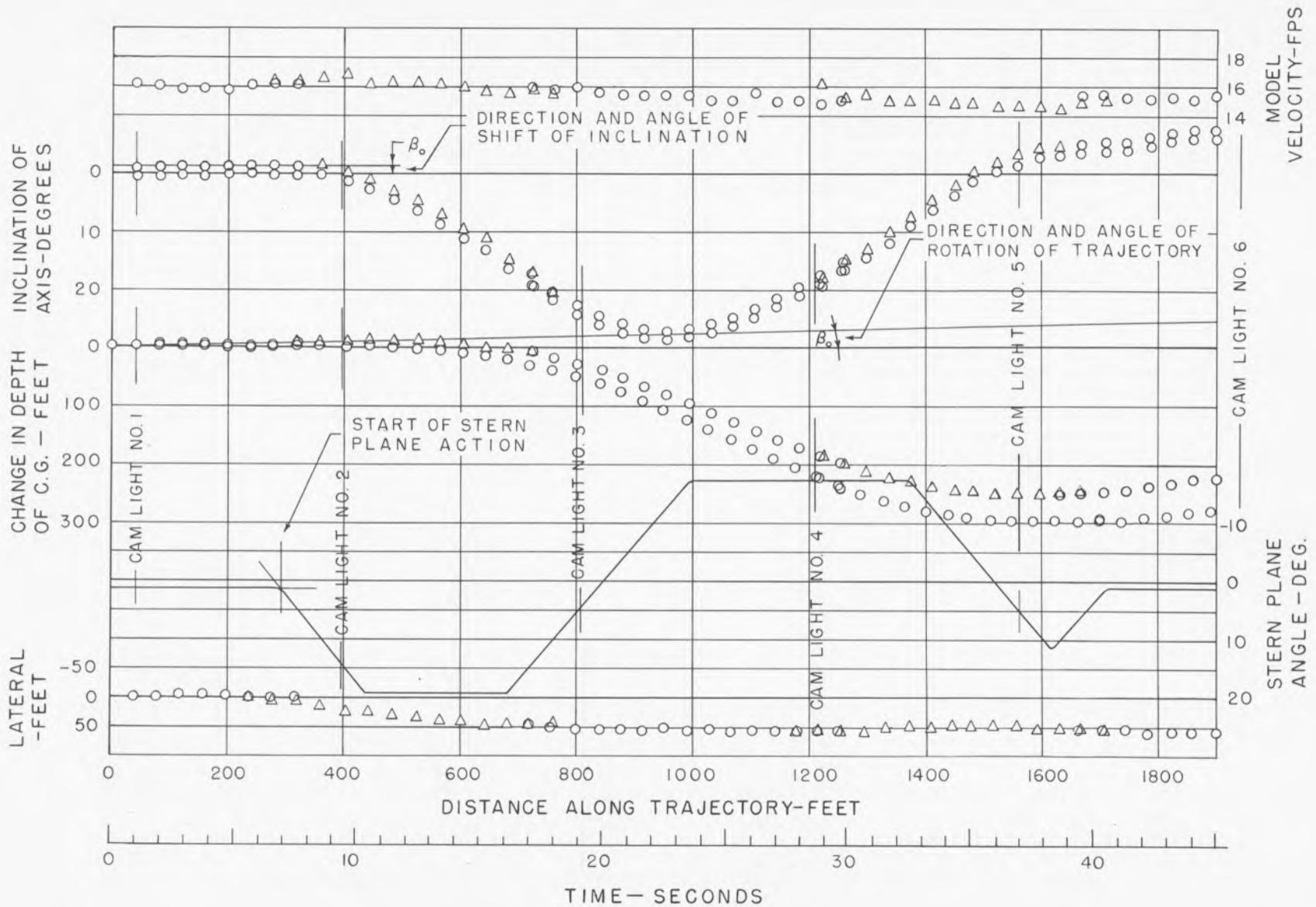


Fig. 5-1a Typical test run expanded to full scale showing rotation technique for trajectory plot.

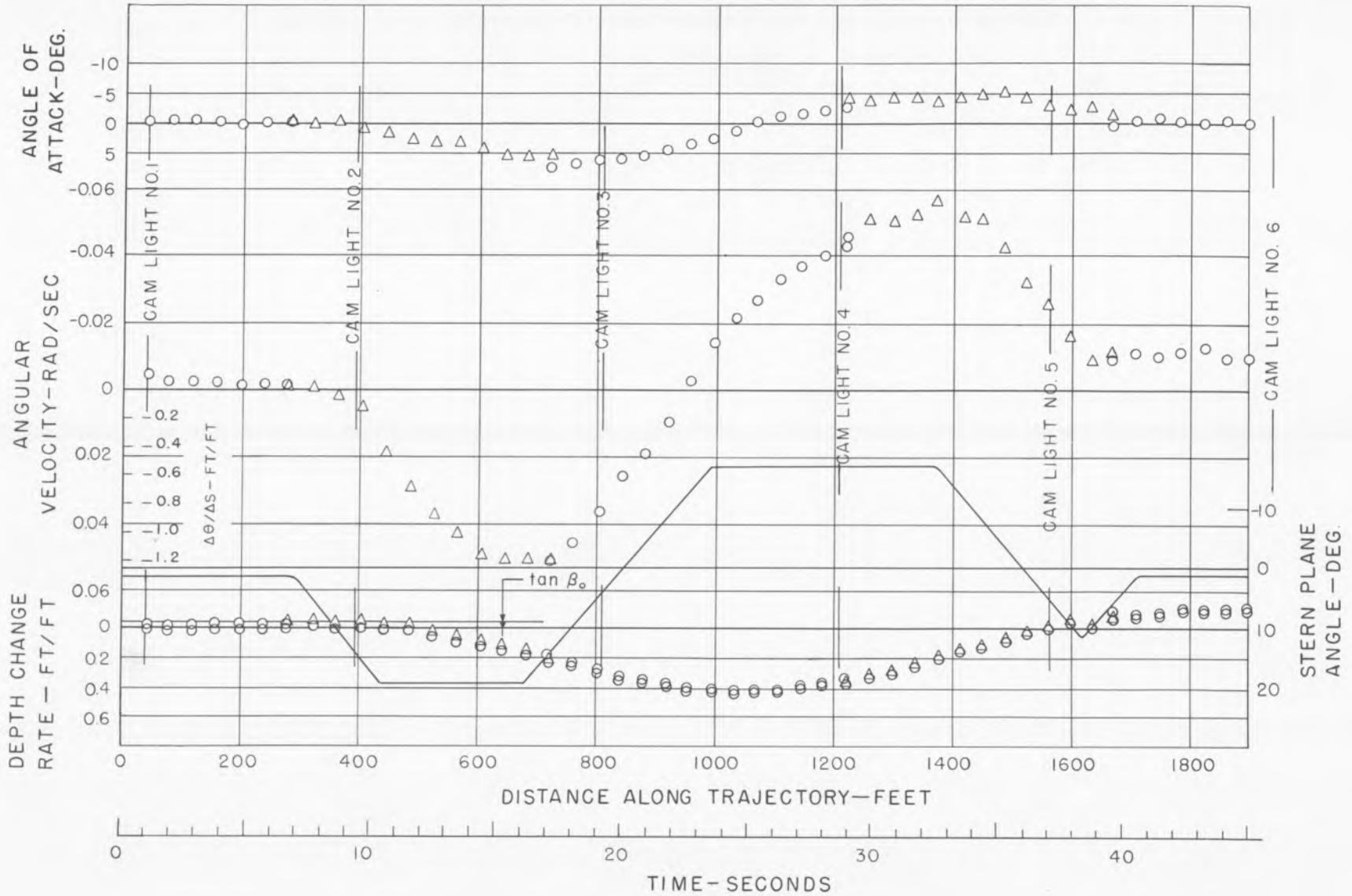
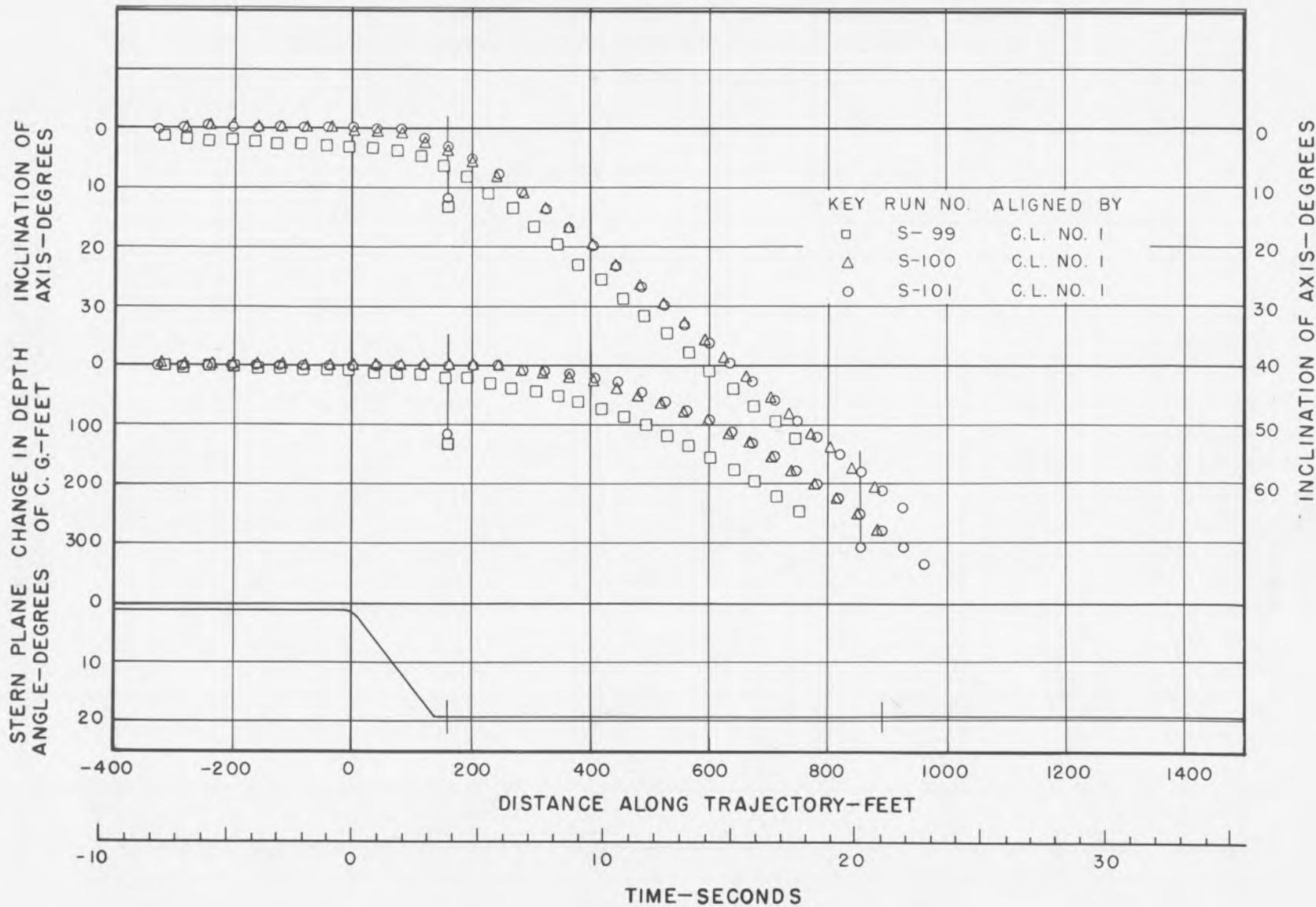


Fig. 5-1b Typical test run expanded to full scale showing rotation technique for curvature plot.

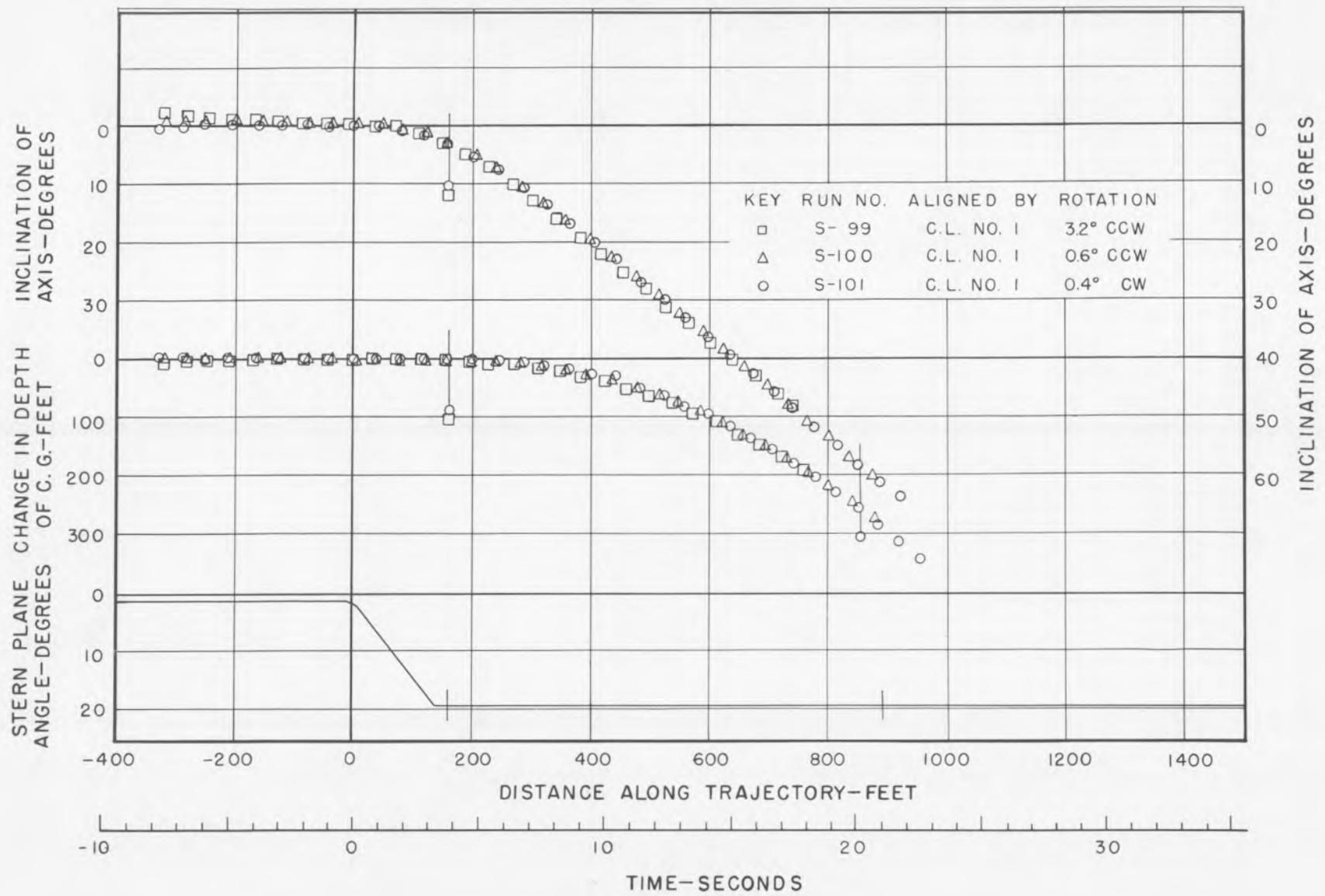
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Fig. 5-2a Effect of initial conditions upon behavior of model in dive - trajectories aligned horizontally.

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Fig. 5-2b Effect of initial conditions upon behavior of model in dive - trajectories aligned and rotated.

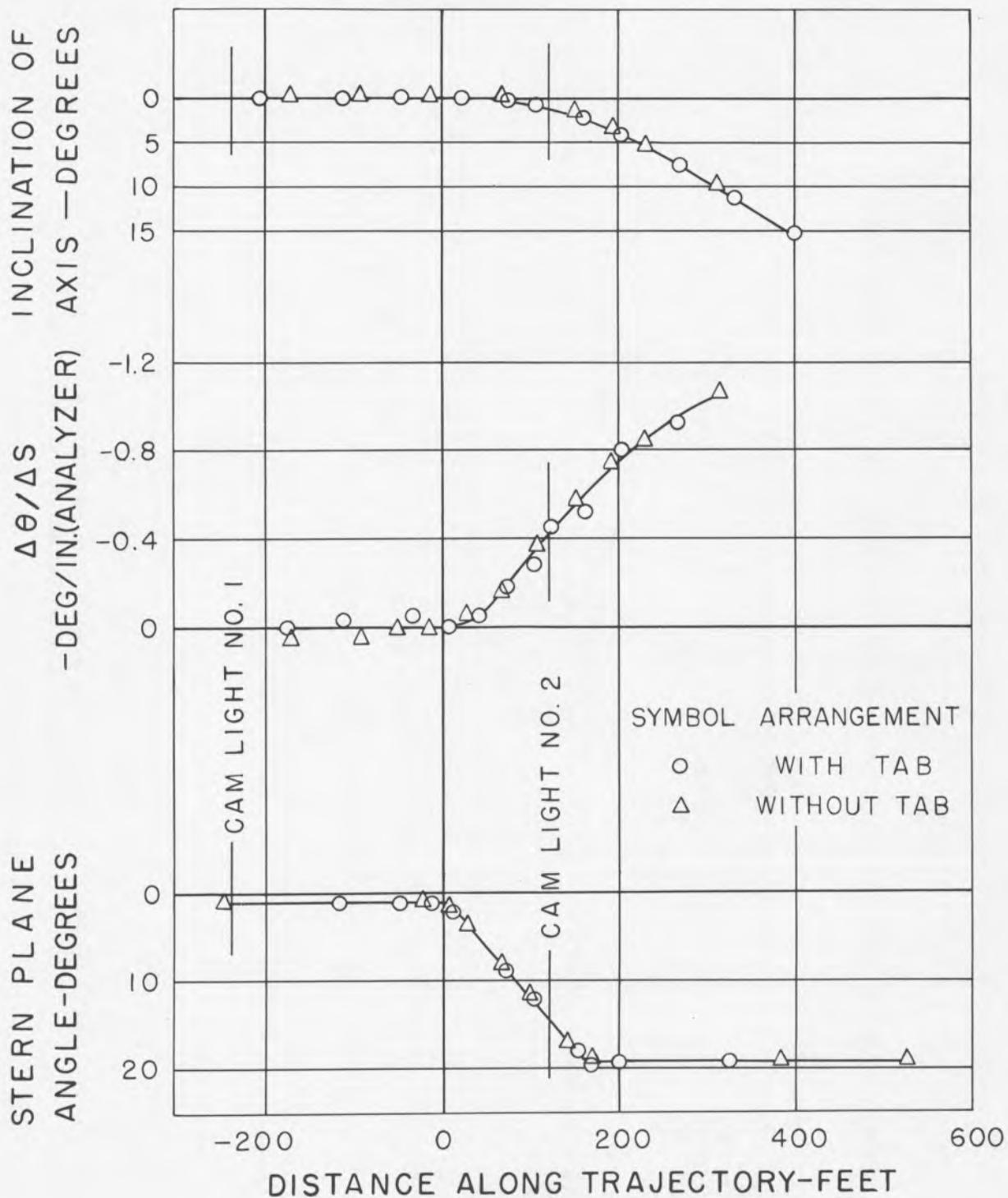


Fig. 5-2c Comparison of stern plane bench calibration and action during test run.

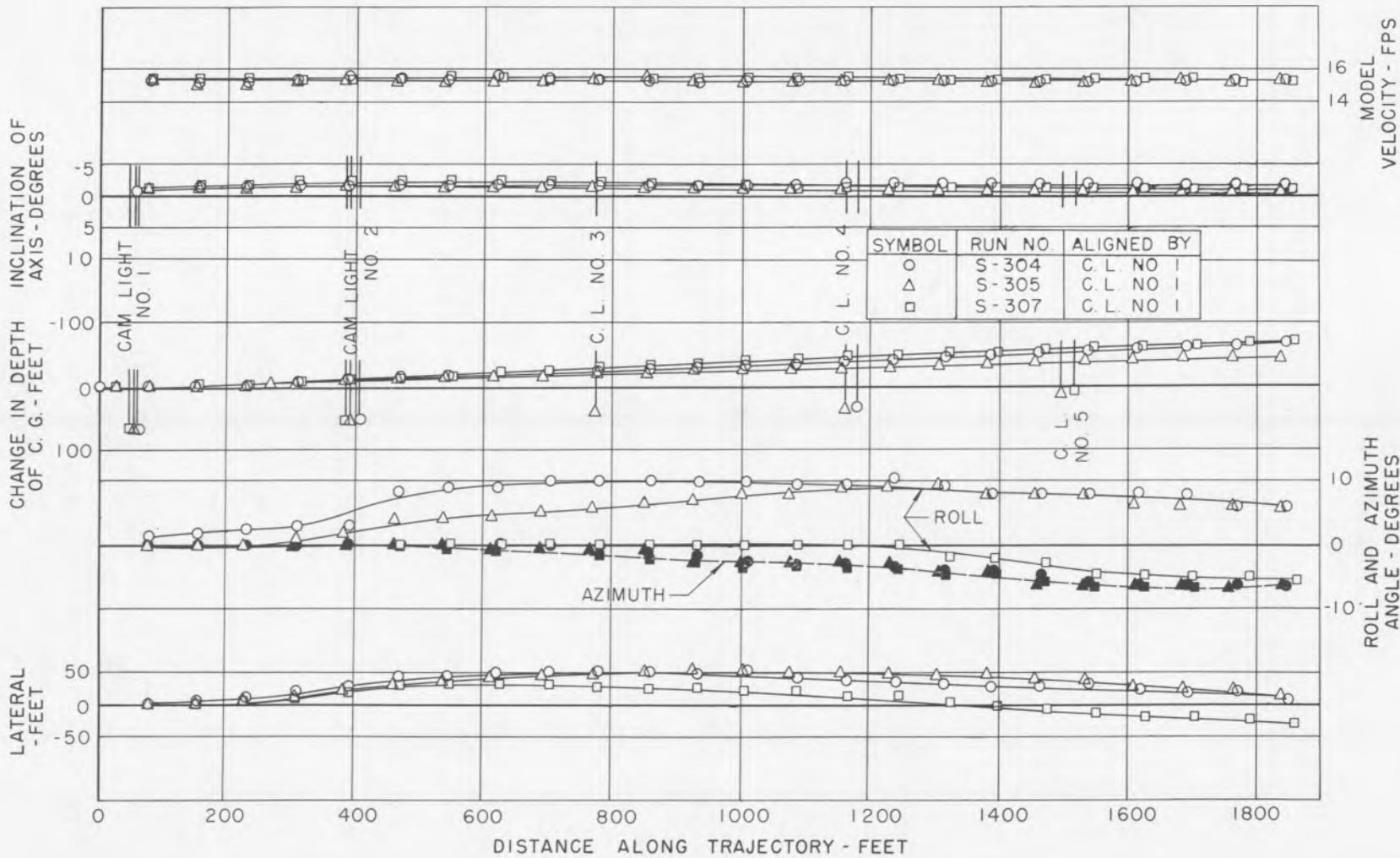
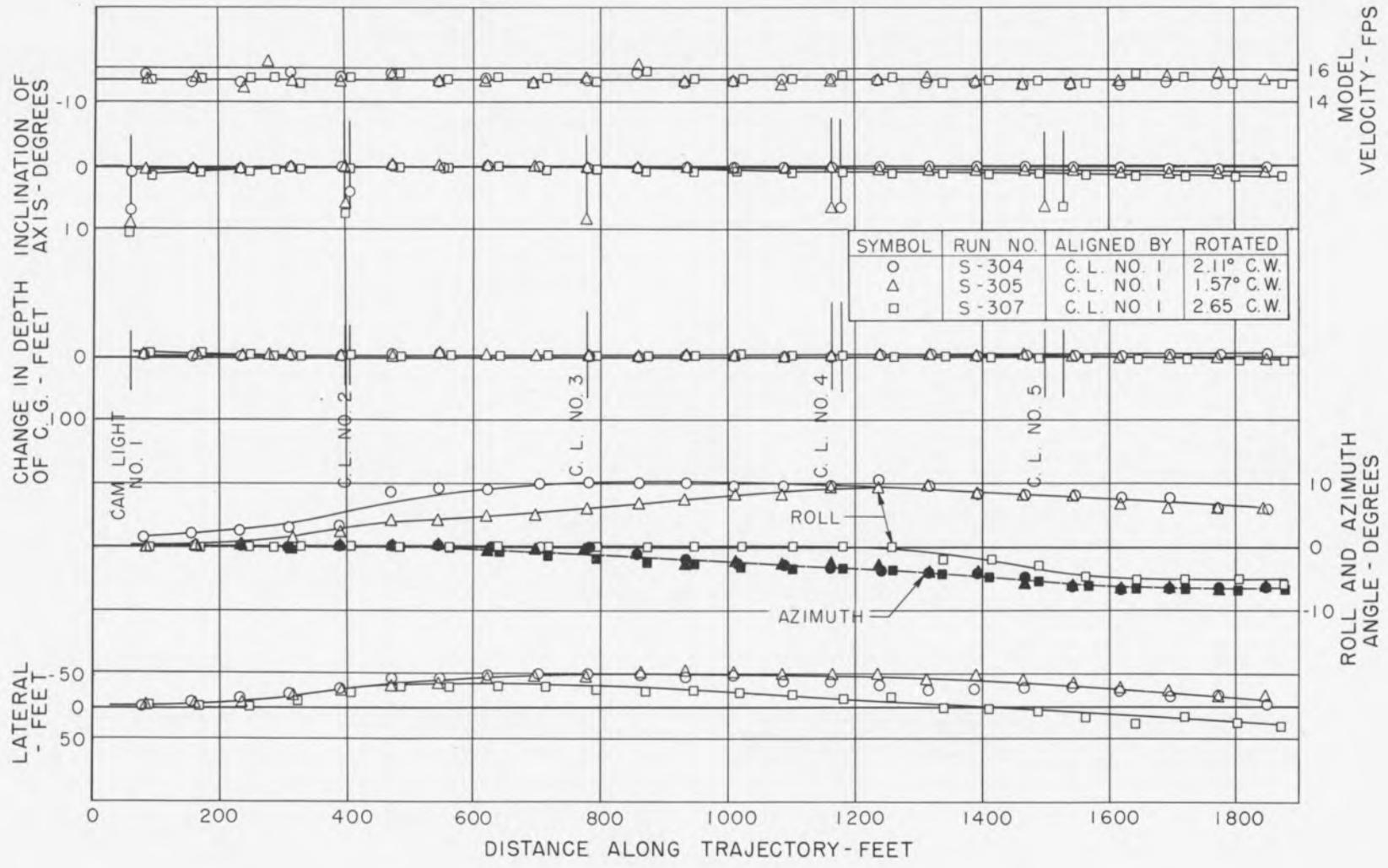


Fig. 5-3a Typical test runs with pre-set controls showing normal scatter due to launching conditions.

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Fig. 5-3b Typical test runs with pre-set controls with initial launching conditions, corrected.

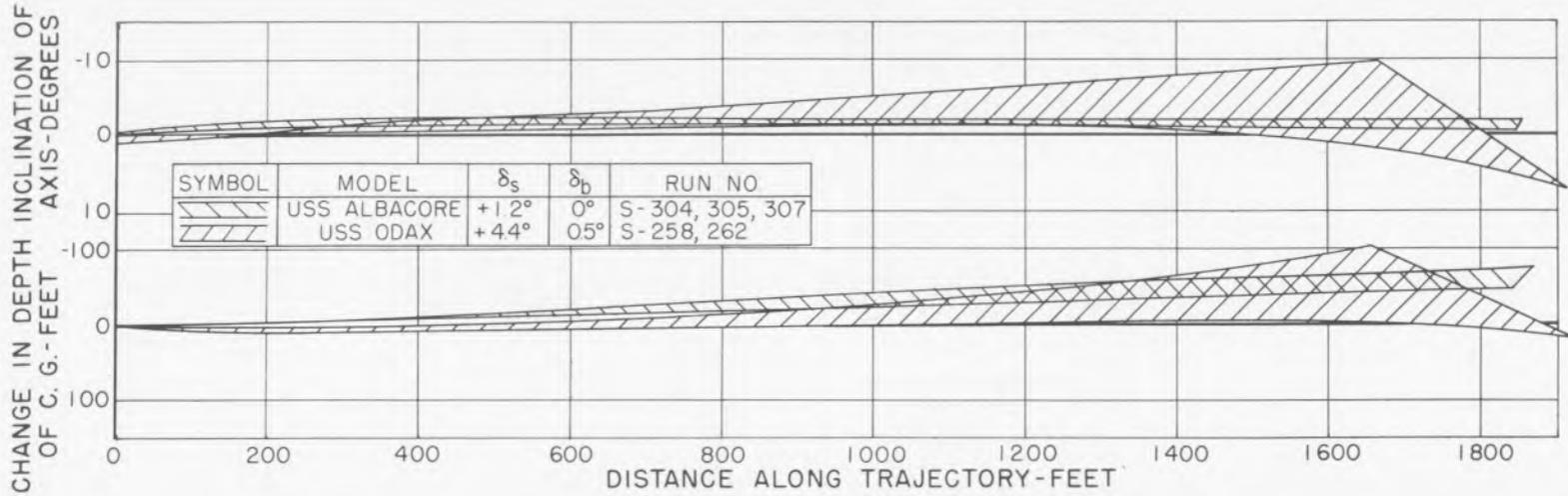


Fig. 5-4a Comparison of neutral runs for the USS Odax model and the USS albacore model - initial conditions uncorrected.

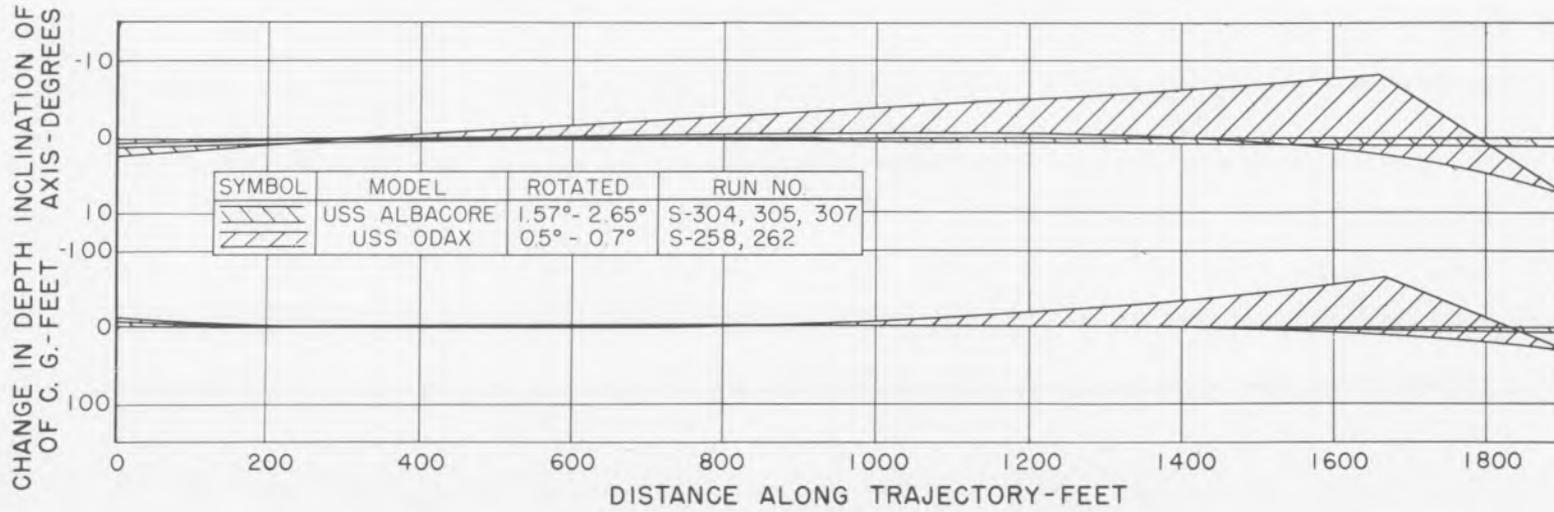


Fig. 5-4b Comparison of typical neutral test runs for the USS Odax model and USS Albacore model - initial conditions corrected.

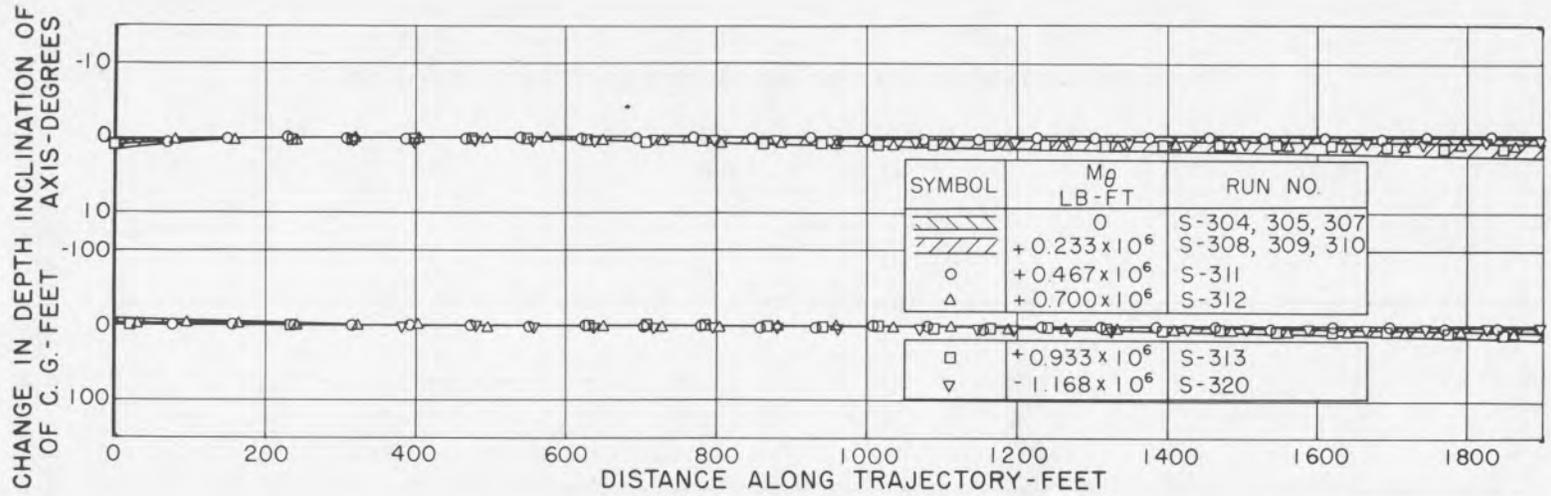


Fig. 5-5a Effect of static trim or metacentric moment upon trajectory of model.

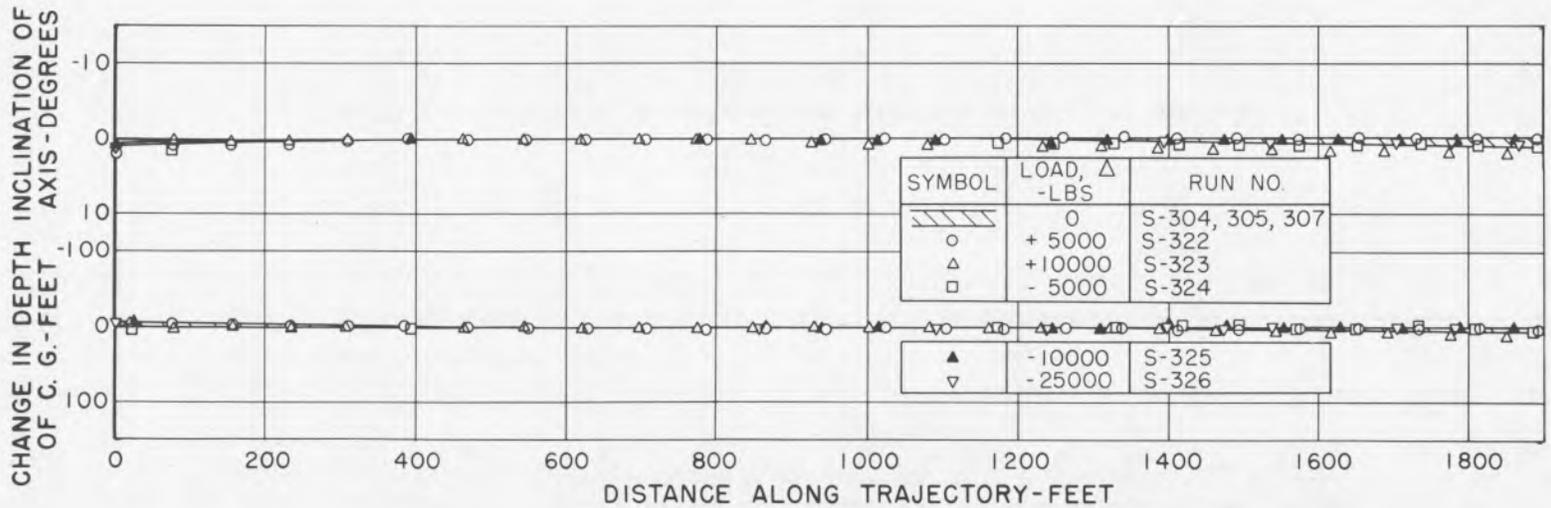


Fig. 5-5b Effects of change of buoyancy upon trajectory of model.

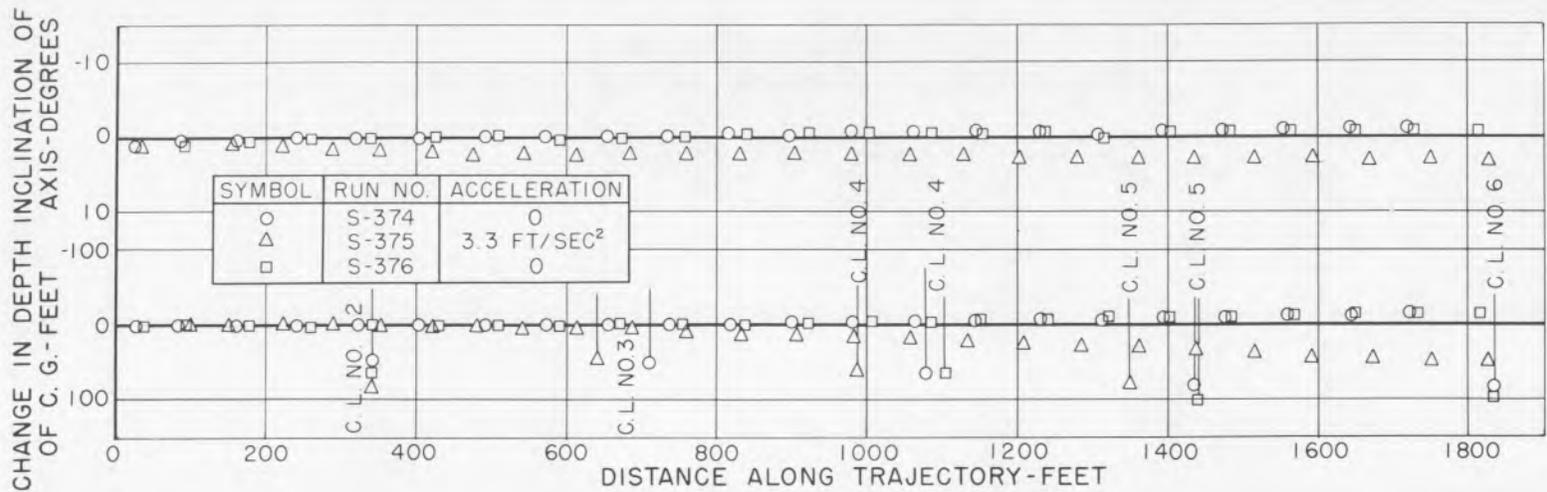


Fig. 5-6a Effect of acceleration upon trajectory of model.

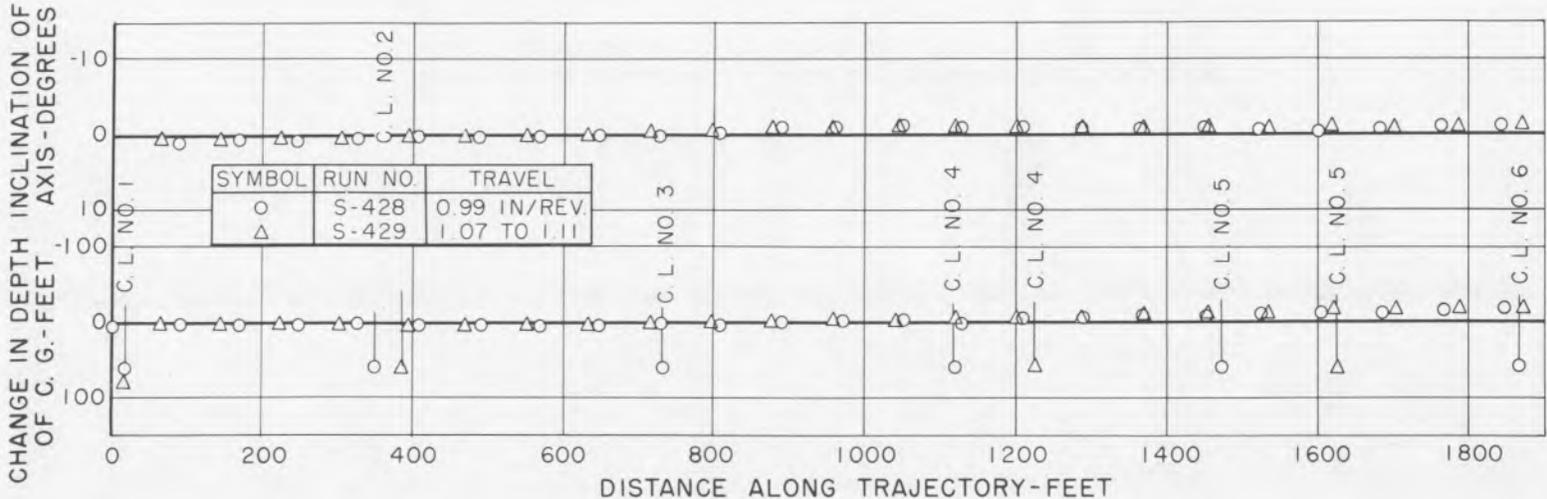


Fig. 5-6b Effect of propeller slip on trajectory of model.

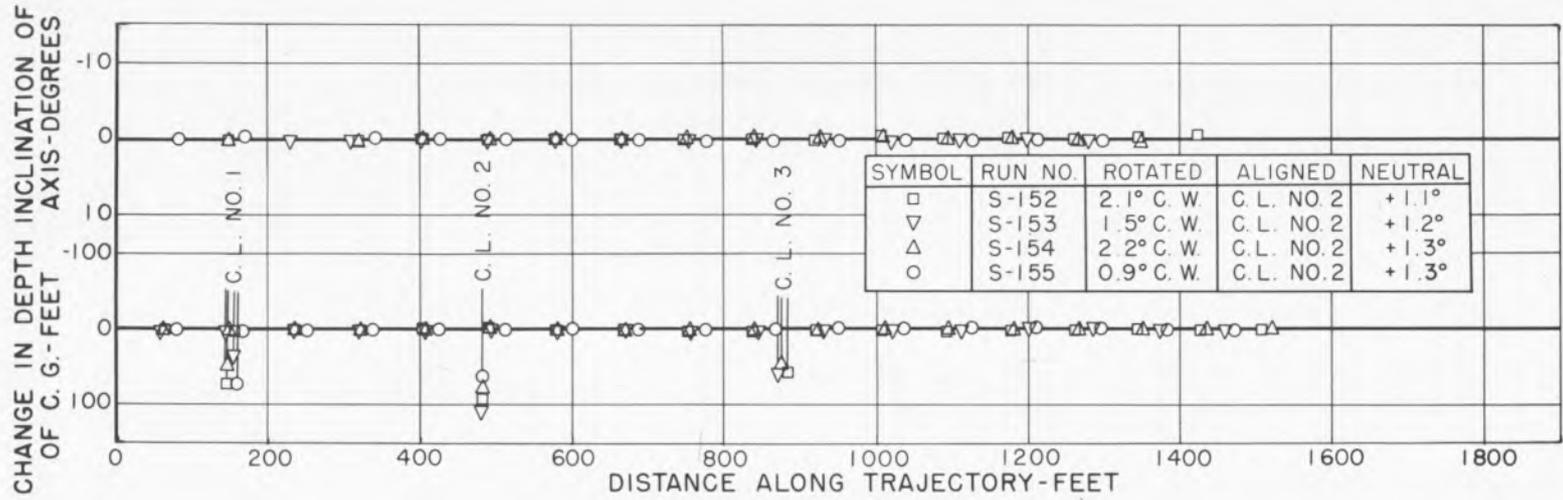


Fig. 5-7 Accuracy of setting neutral angles.

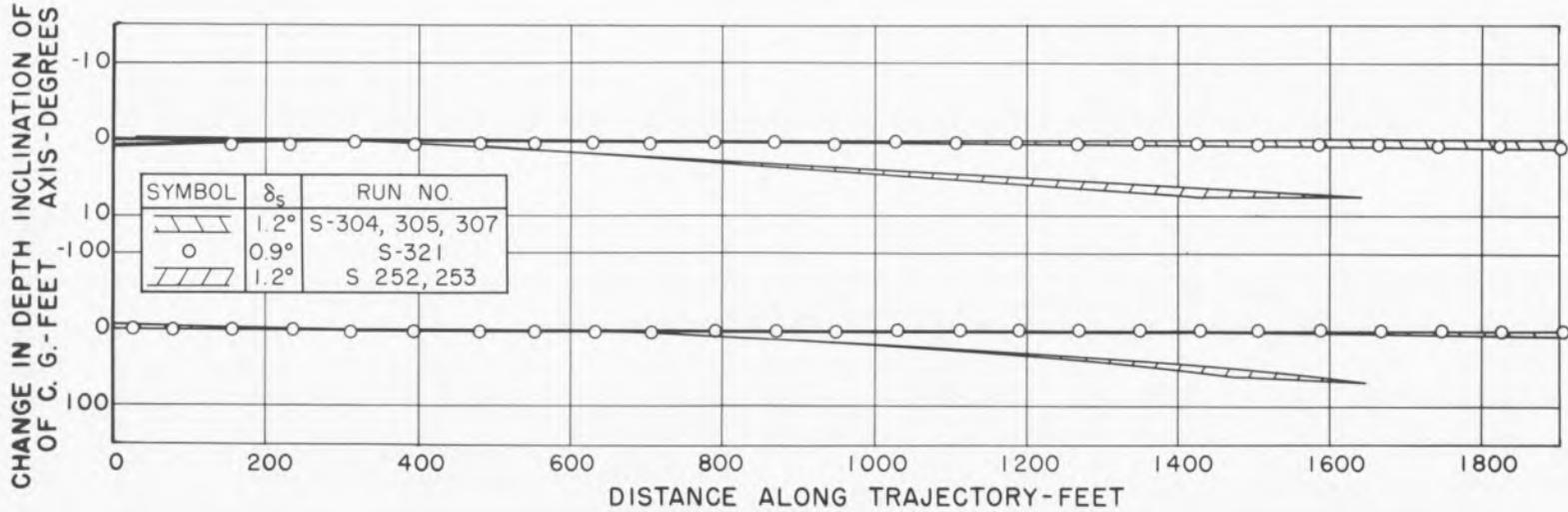


Fig. 5-8 Effect of hull alignment on trajectory and stern plane neutral angle.

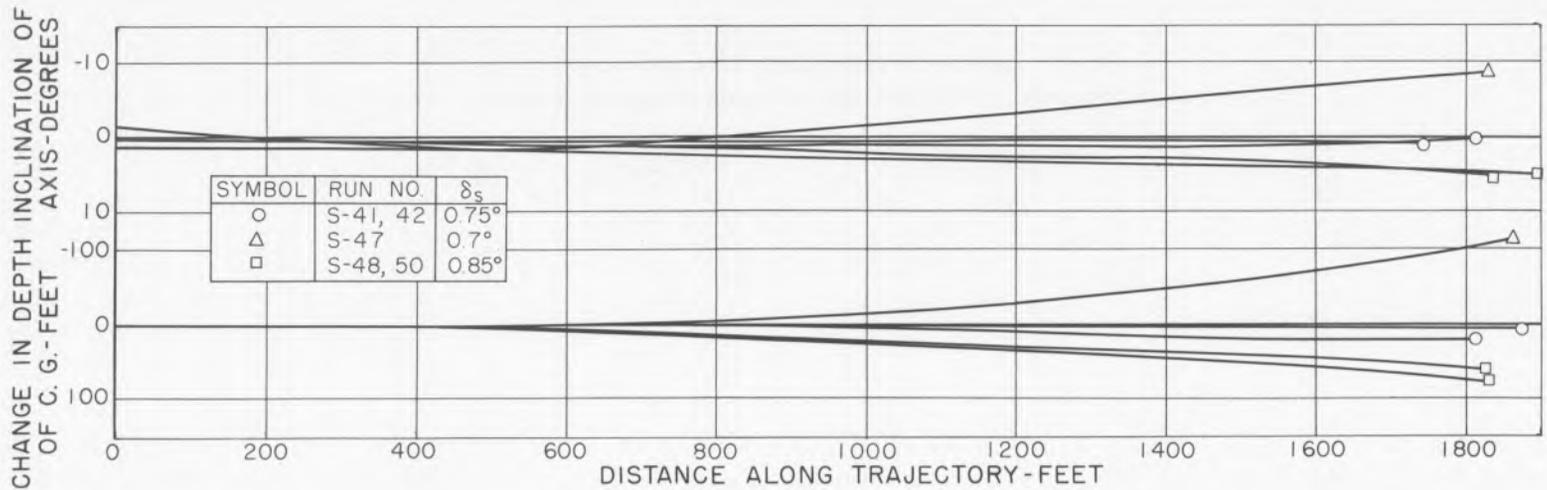


Fig. 5-9 Neutral trajectories for original configuration with plated fins.

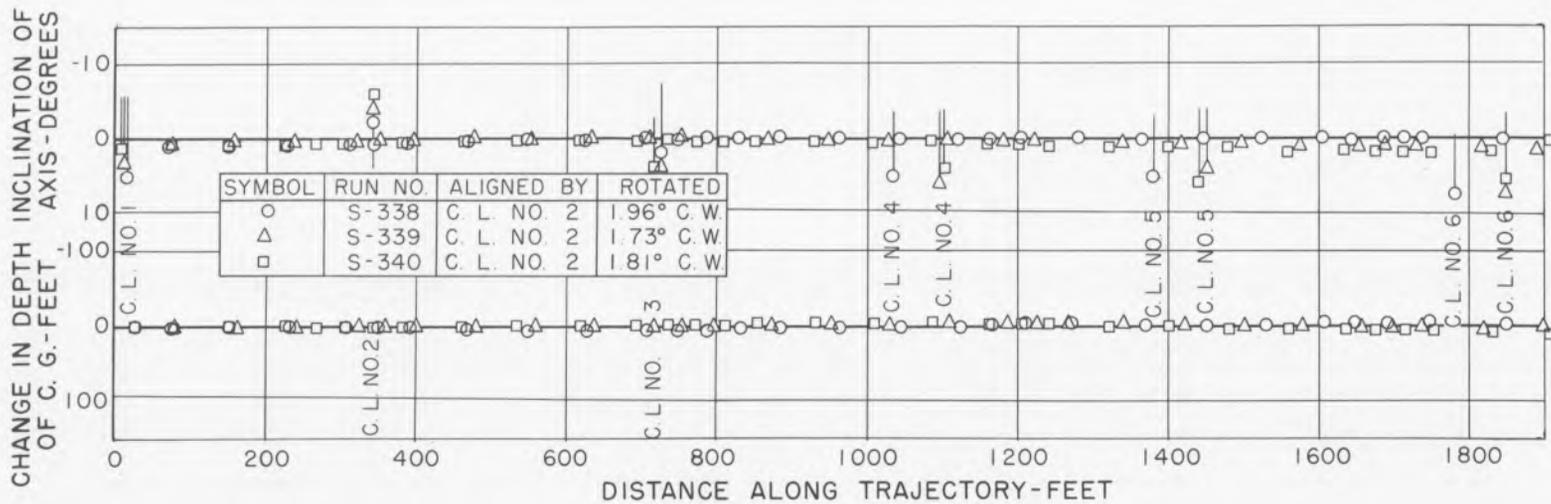
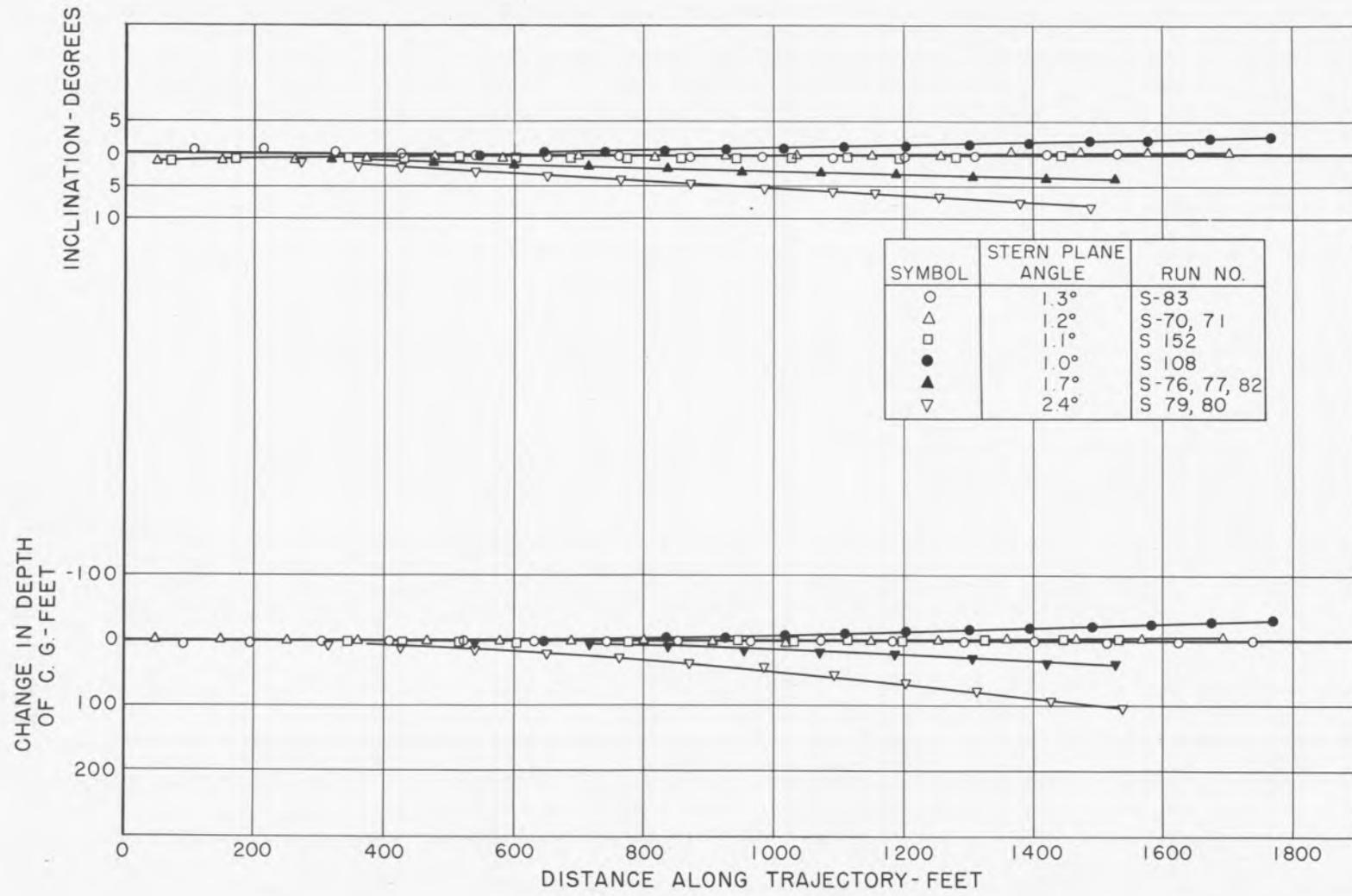


Fig. 5-10 Effect of yaw and roll.

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Fig. 5-11a Effect of variation of the neutral stern plane angle on the trajectory for original configuration.

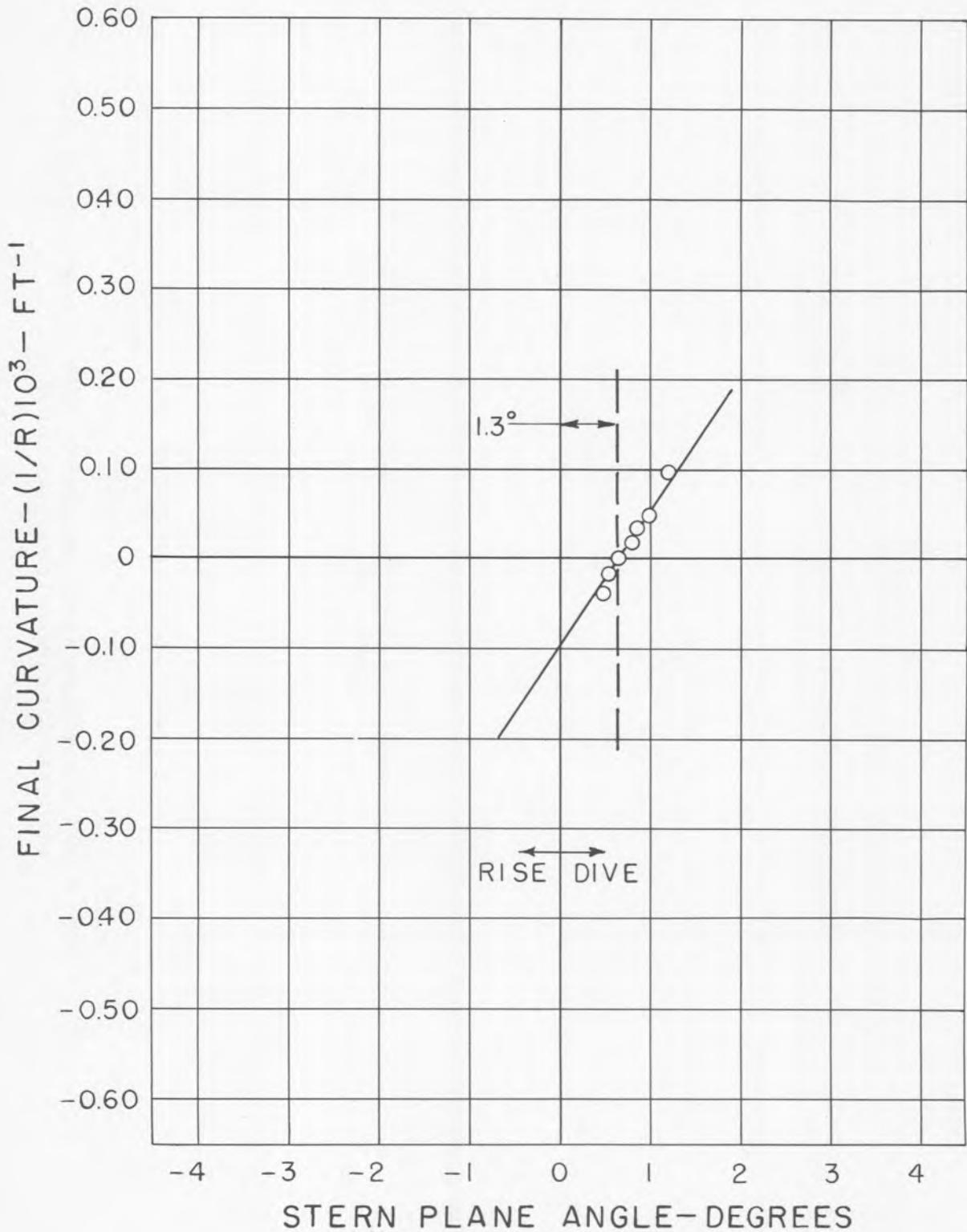


Fig. 5-11b Final curvature for original configuration for small stern plane angles.

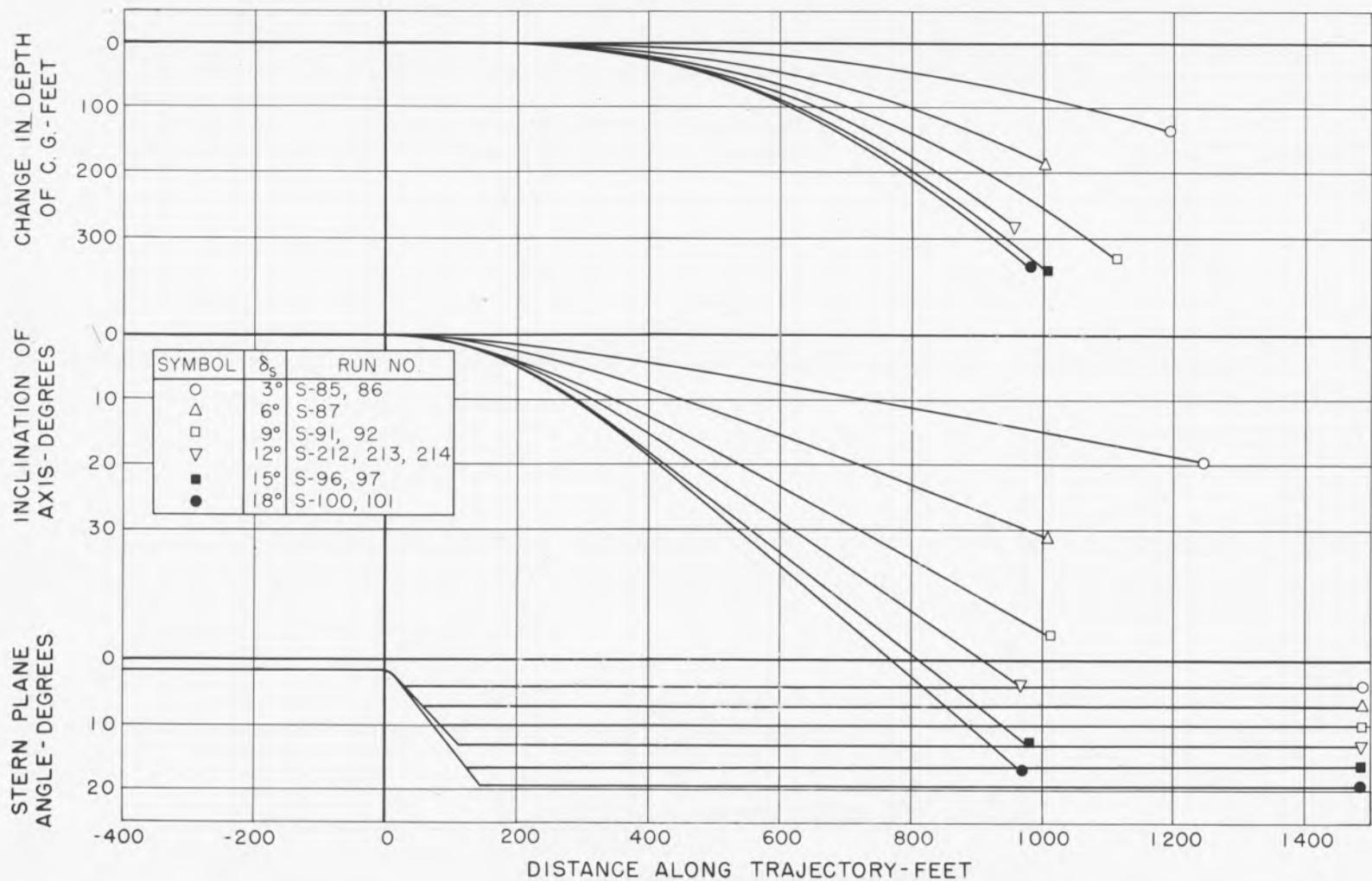


Fig. 5-12a Trajectory response on entering a dive for original configuration.

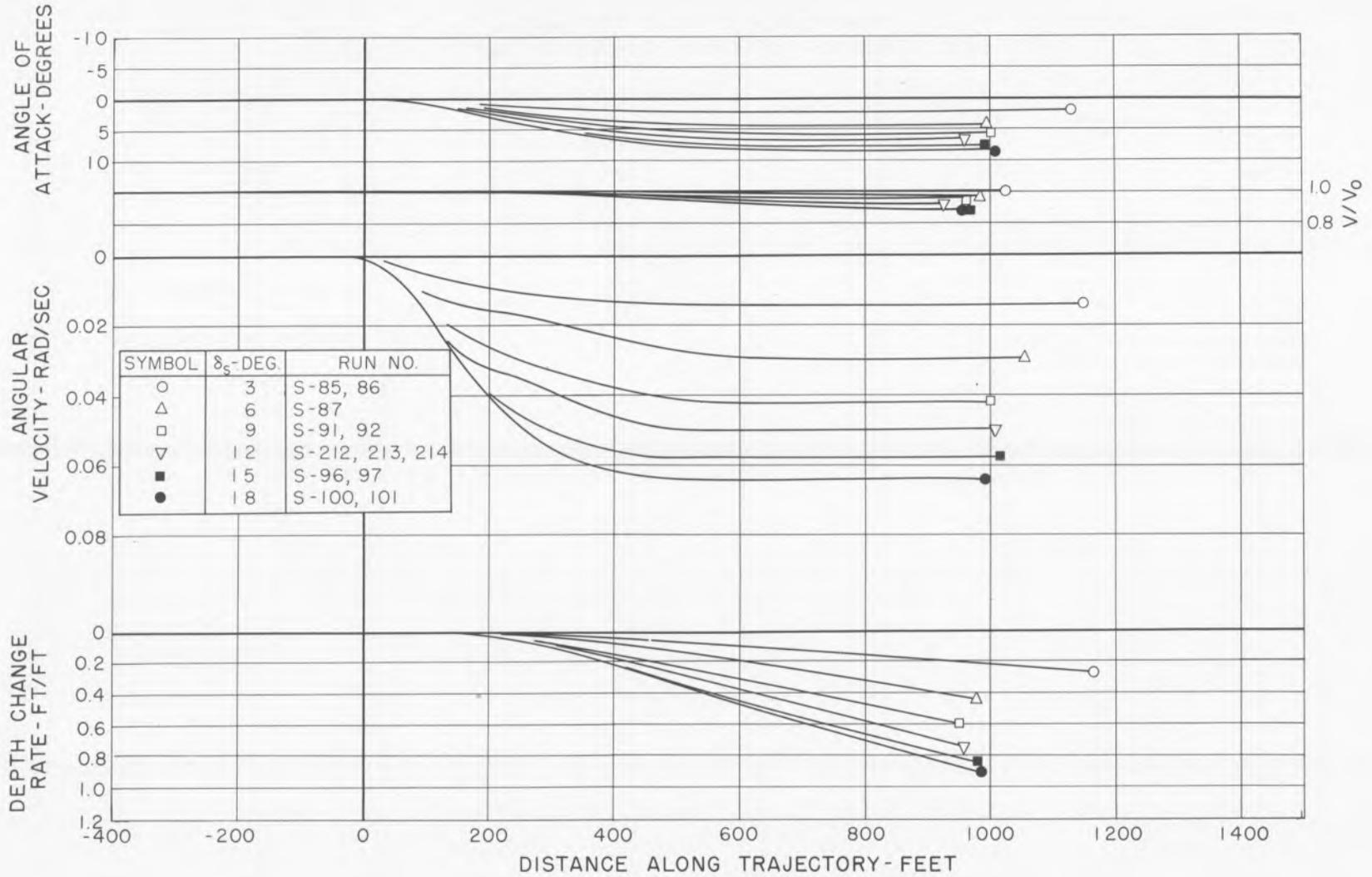


Fig. 5-12b Curvature response on entering a dive for original configuration.

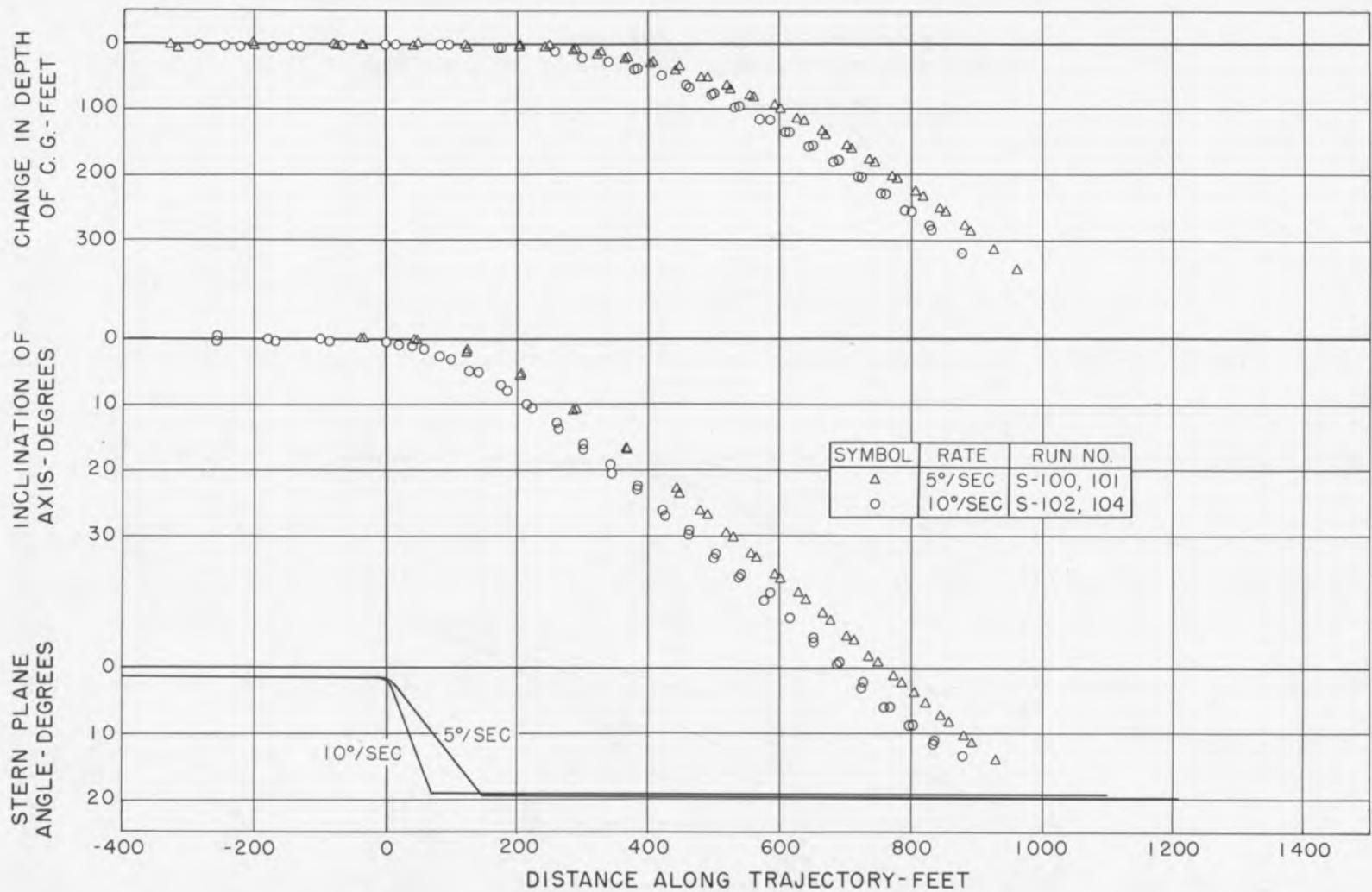


Fig. 5-12c Effect of plane rate upon transient response in dive for original configuration.

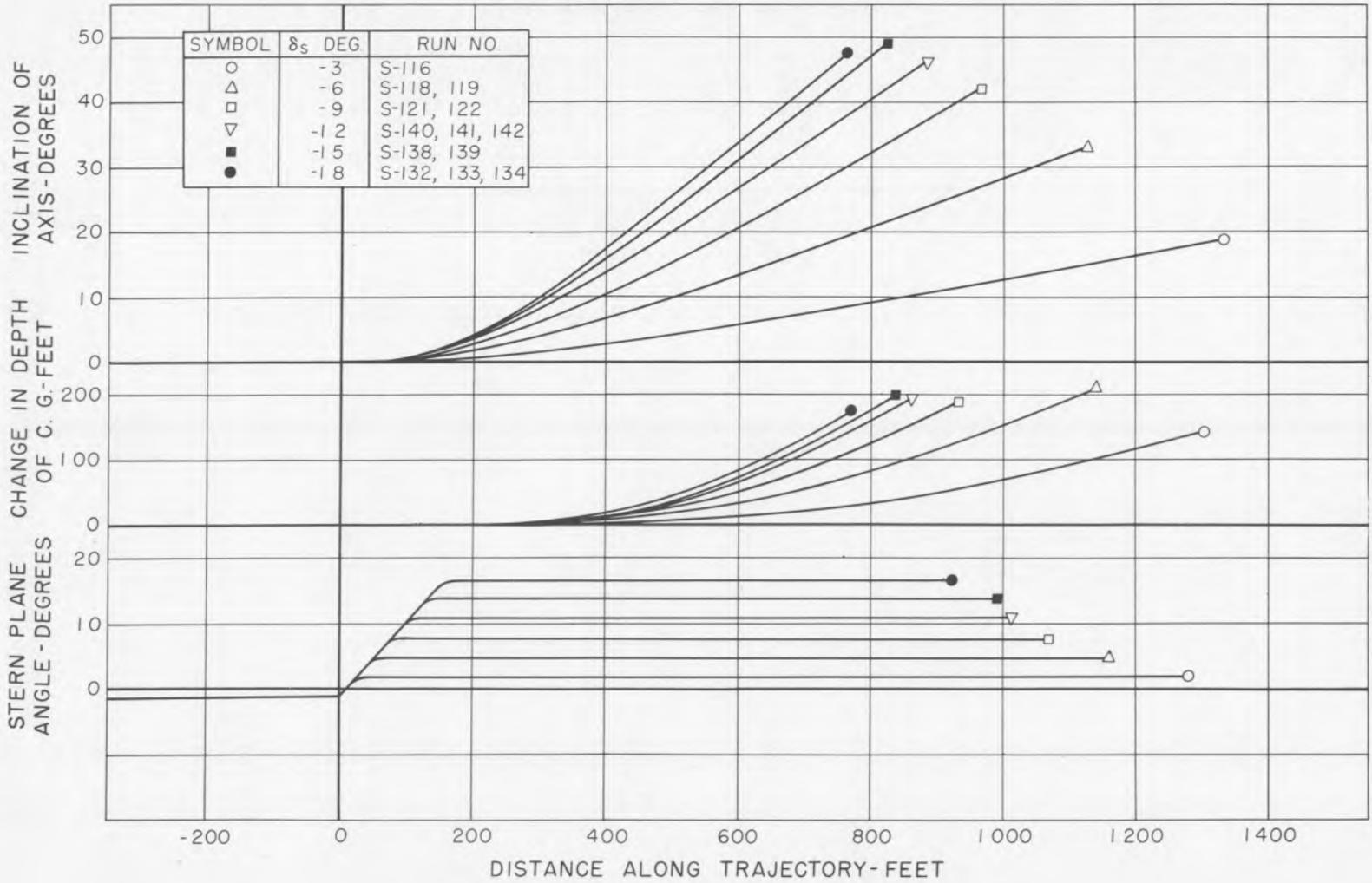


Fig. 5-13a Trajectory response on entering a climb for original configuration.

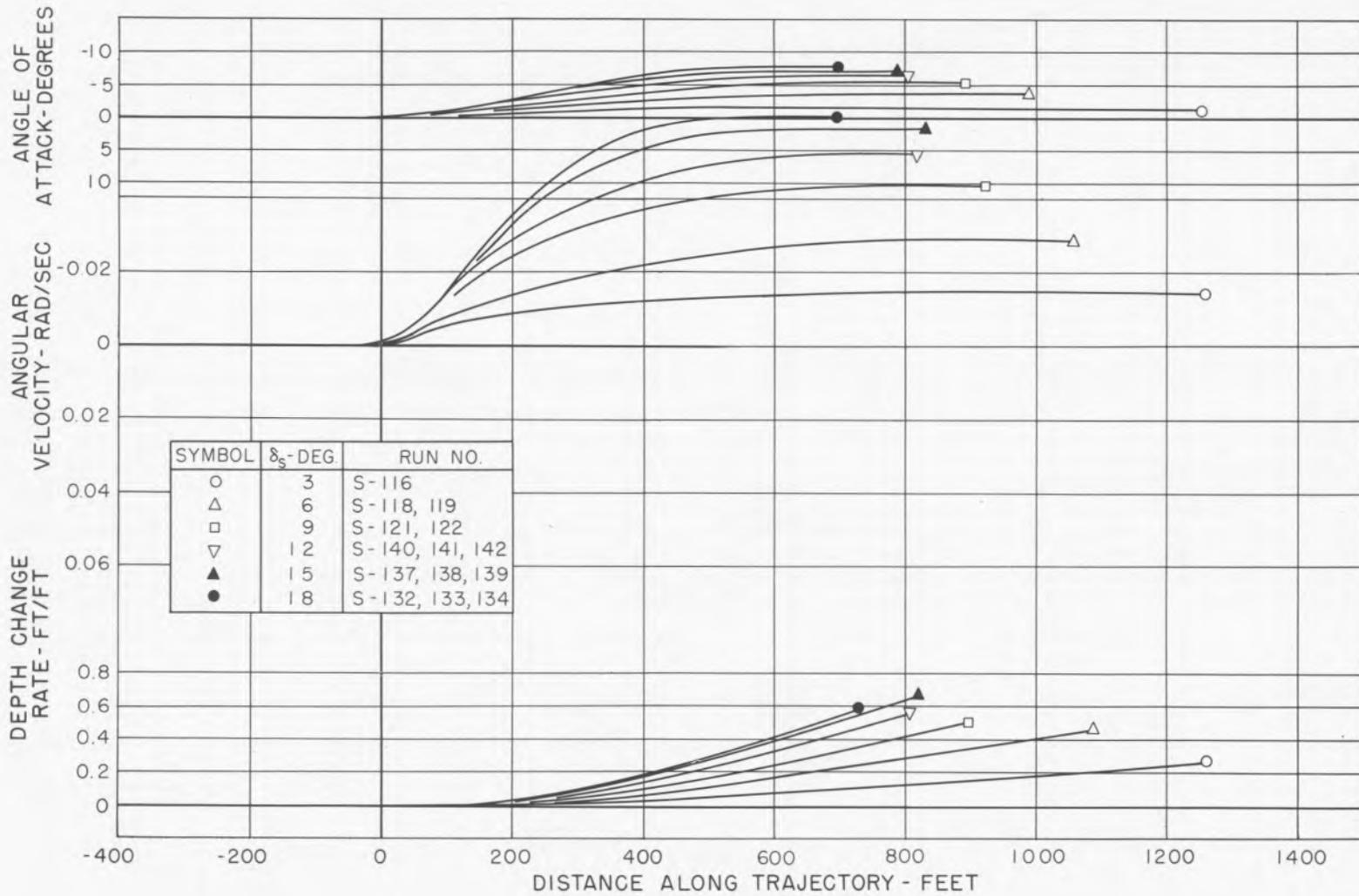


Fig. 5-13b Curvature response on entering a climb for original configuration.

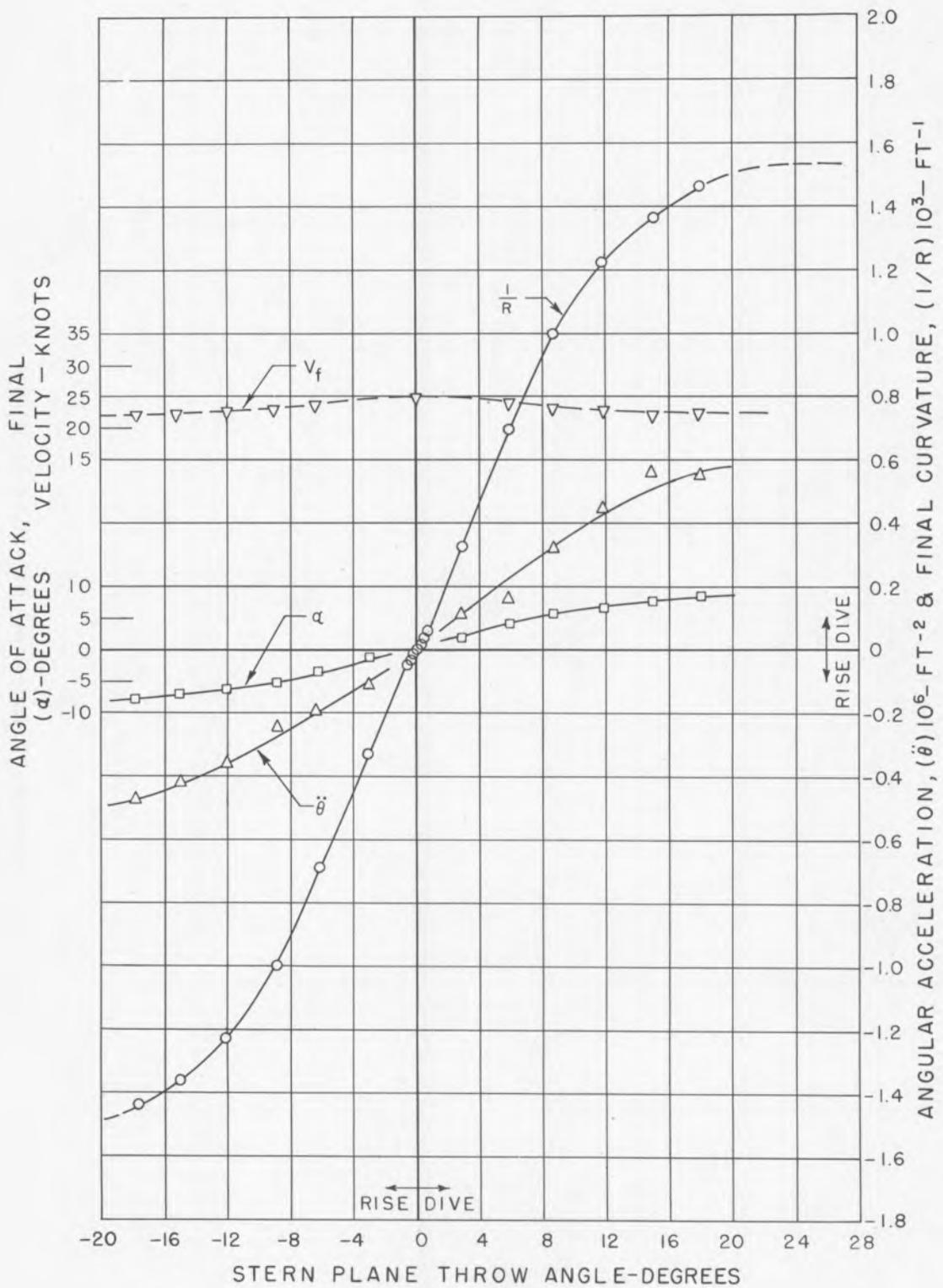


Fig. 5-14 Transient and equilibrium conditions in dive and climb for original configurations.

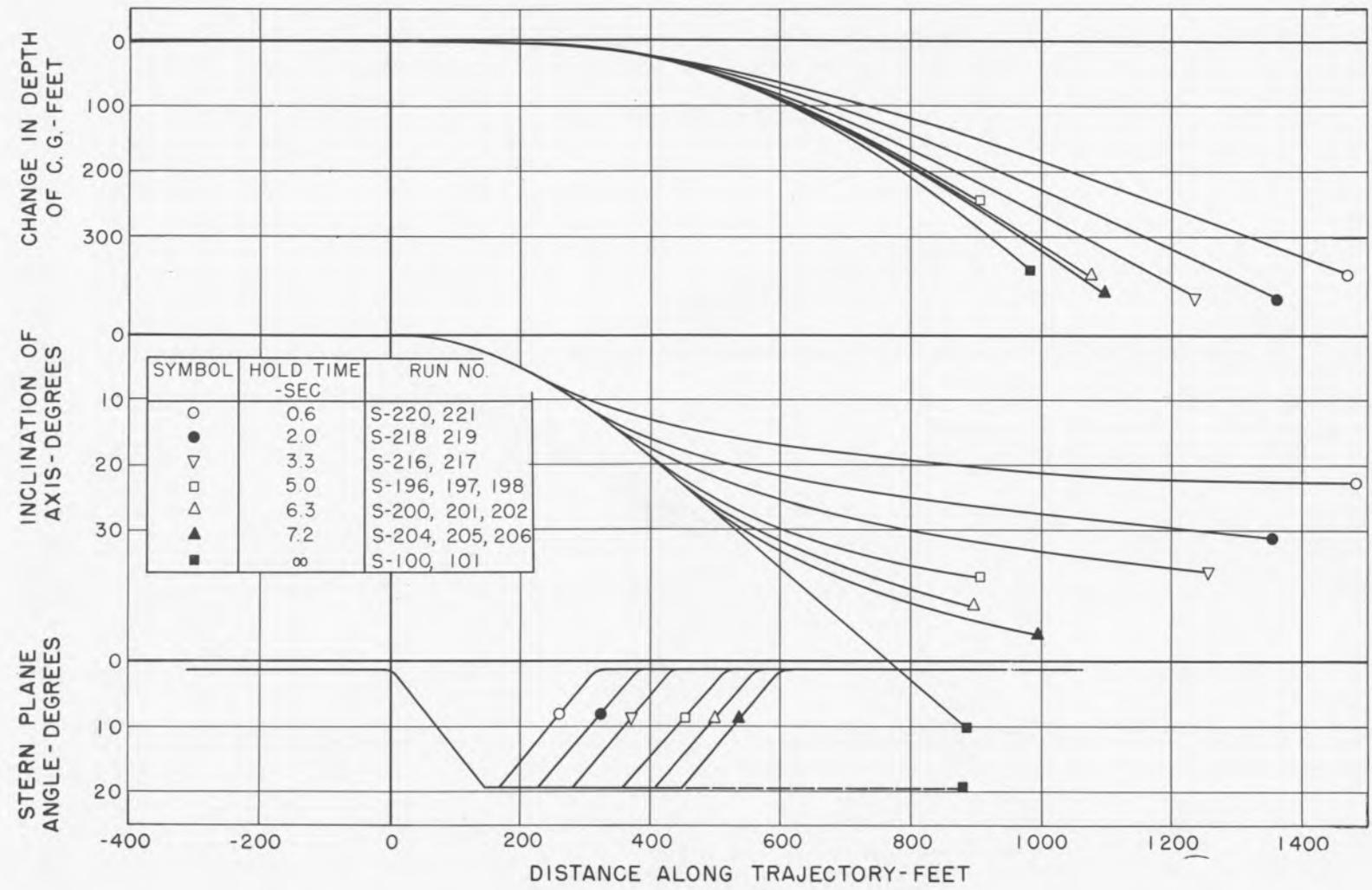


Fig. 5-15a Trajectory response in dive incline maneuvers for original configuration.

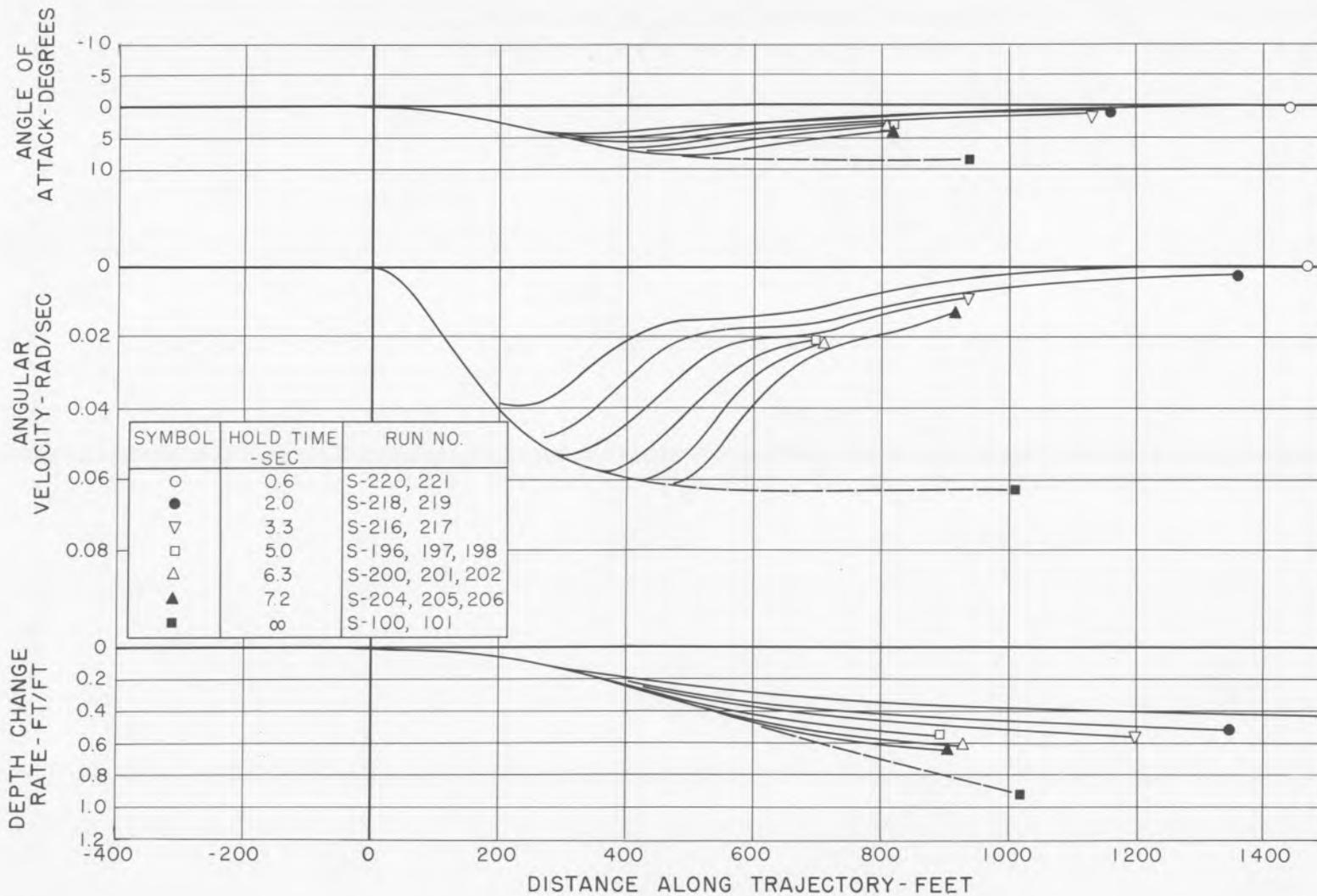


Fig. 5-15b Curvature response in dive incline maneuvers for original configuration.

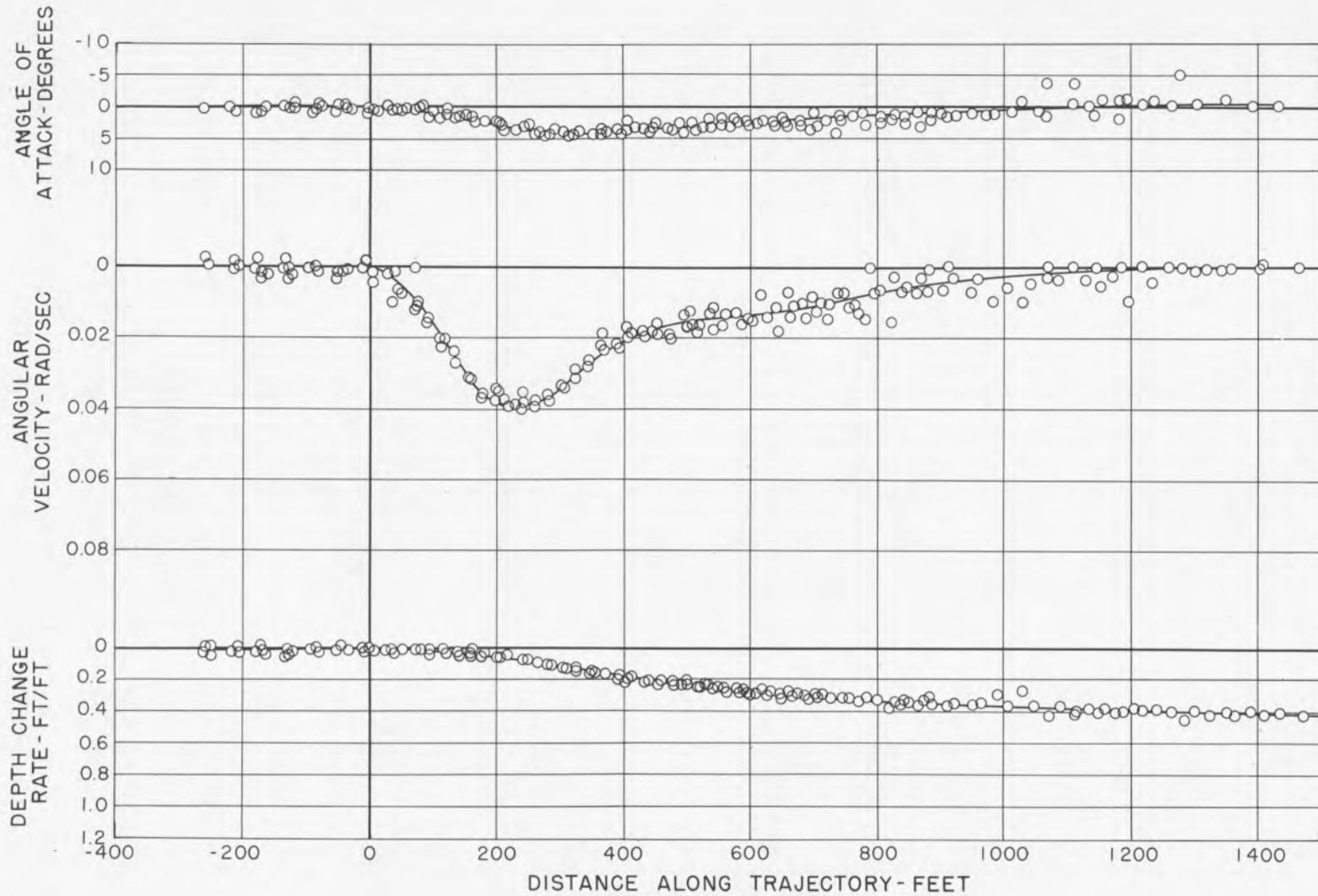


Fig. 5-15c Curvature response for five test runs in a dive incline maneuver showing consistency of data for original configuration.

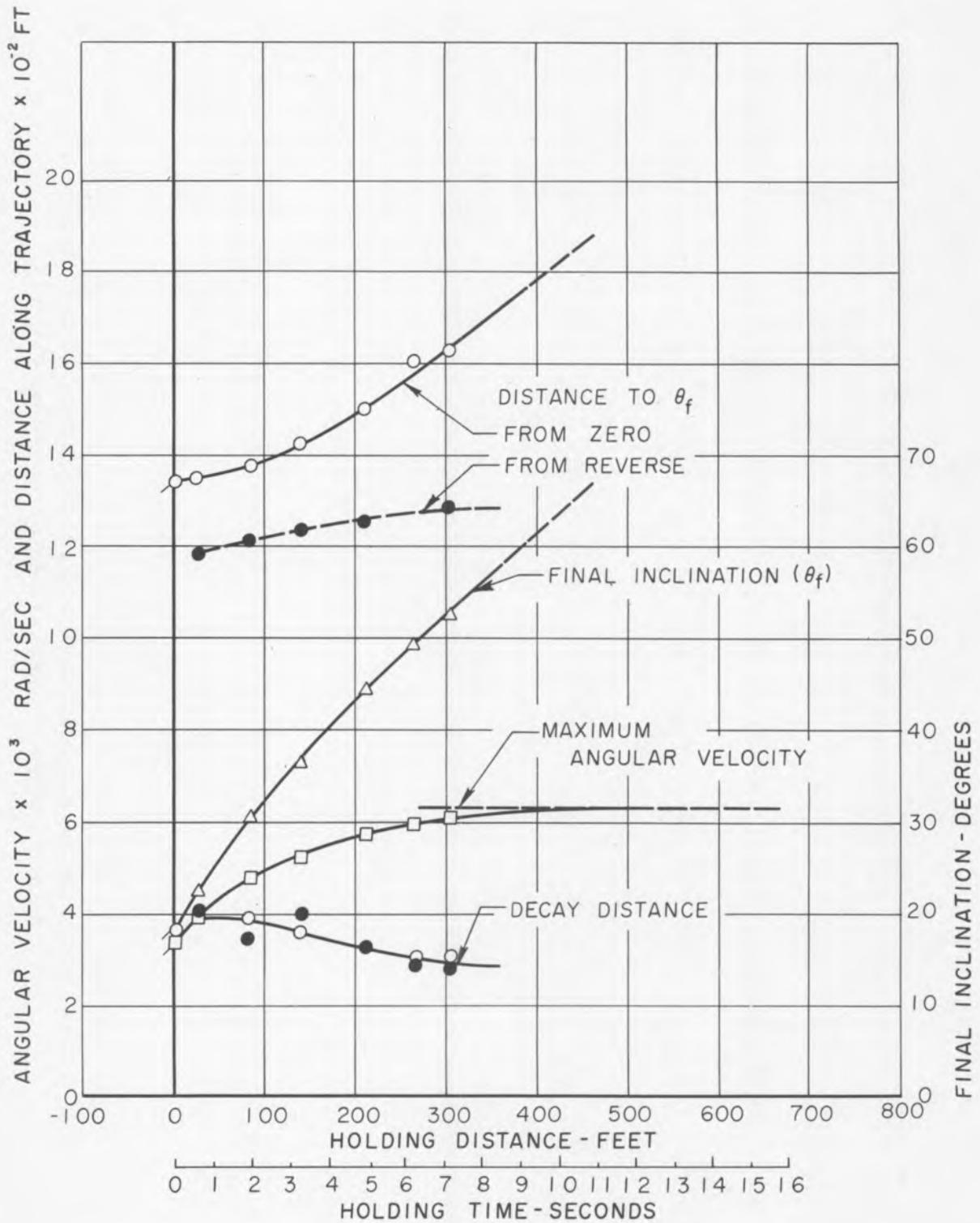
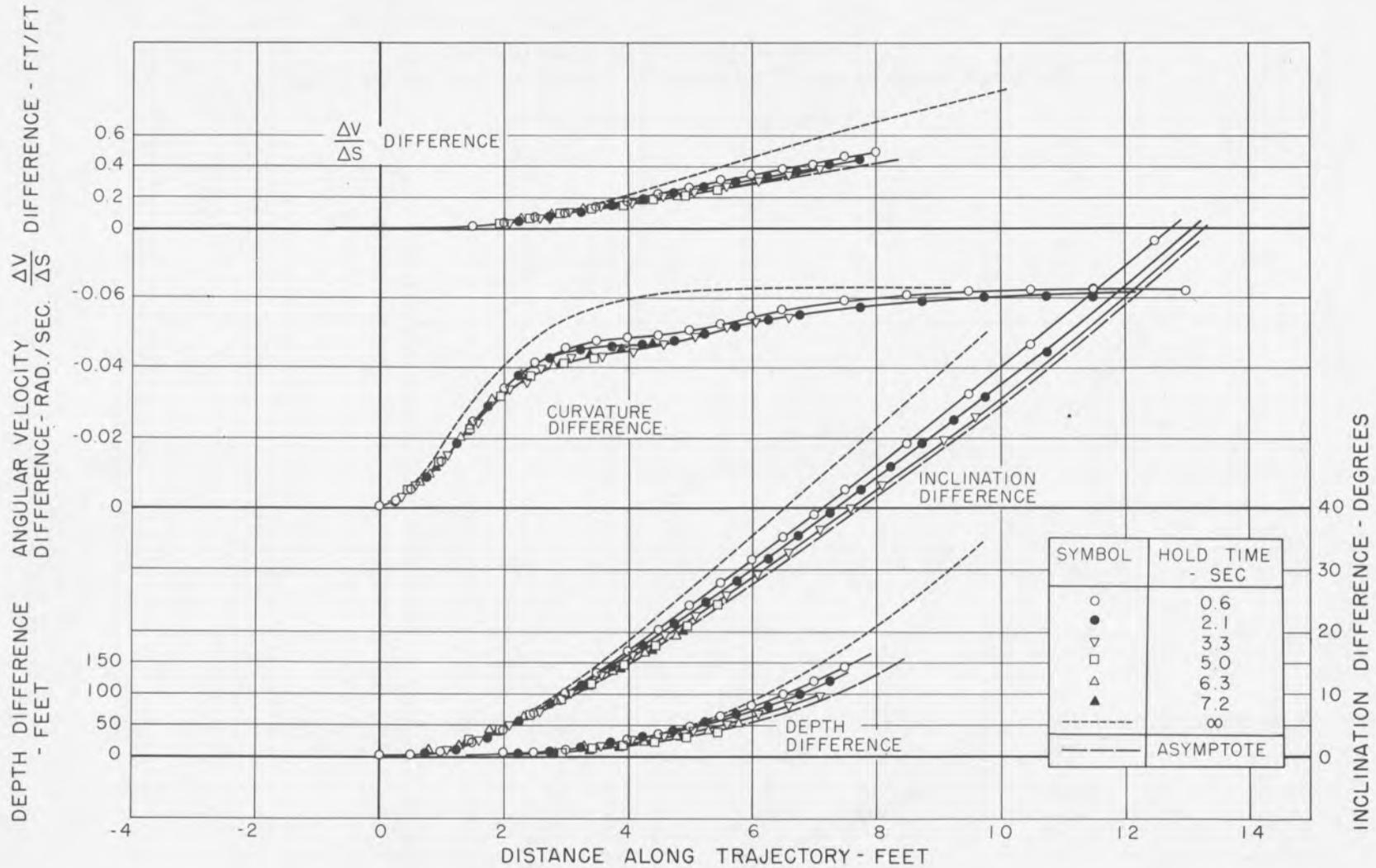


Fig. 5-15d Transient and equilibrium conditions for dive incline maneuvers for original configuration.

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Fig. 5-15e Trajectory and curvature response difference curves in dive incline maneuvers for original configuration.

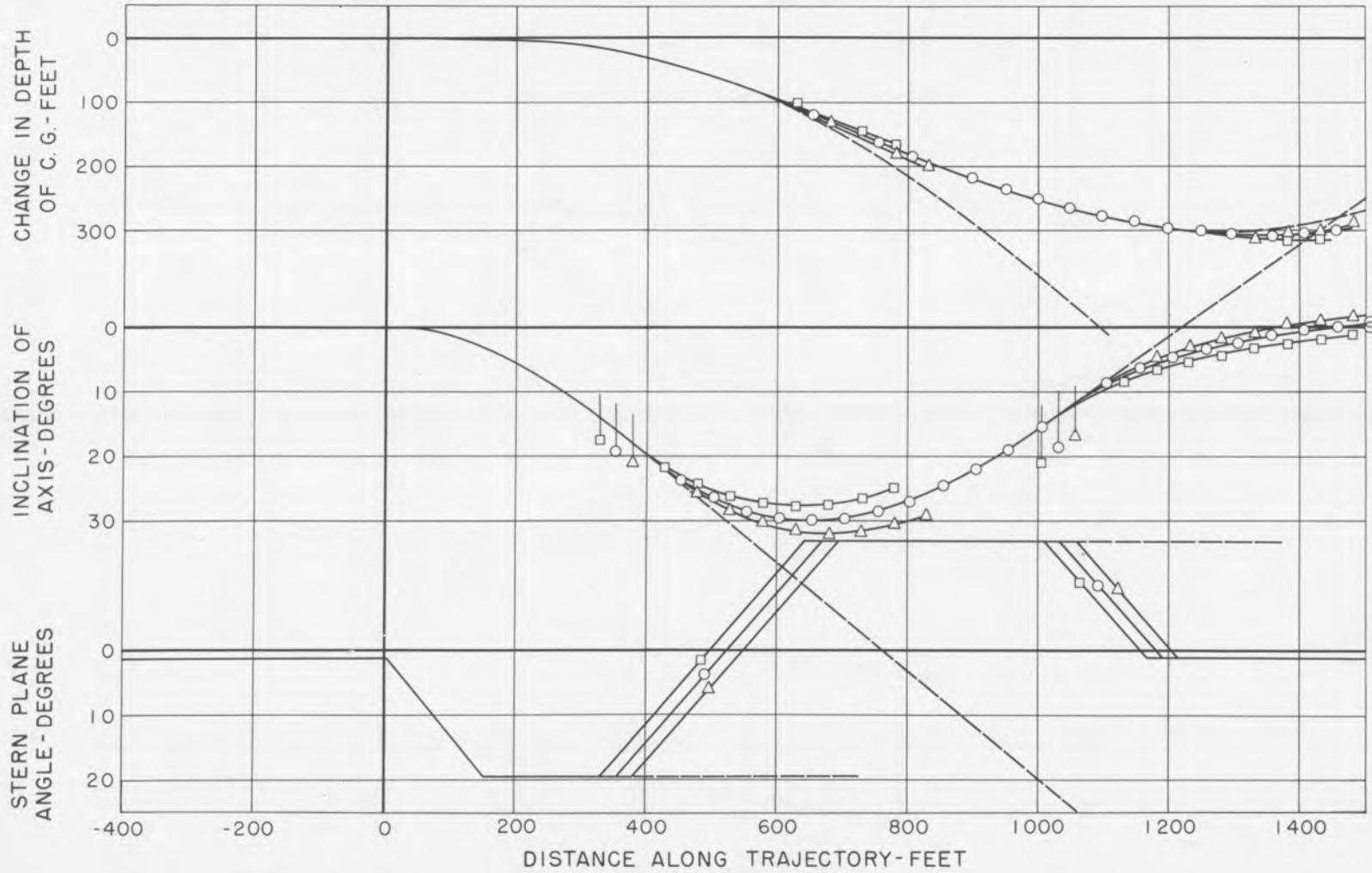


Fig. 5-16 Technique of synthesizing 300-ft depth changing trajectory and control program.

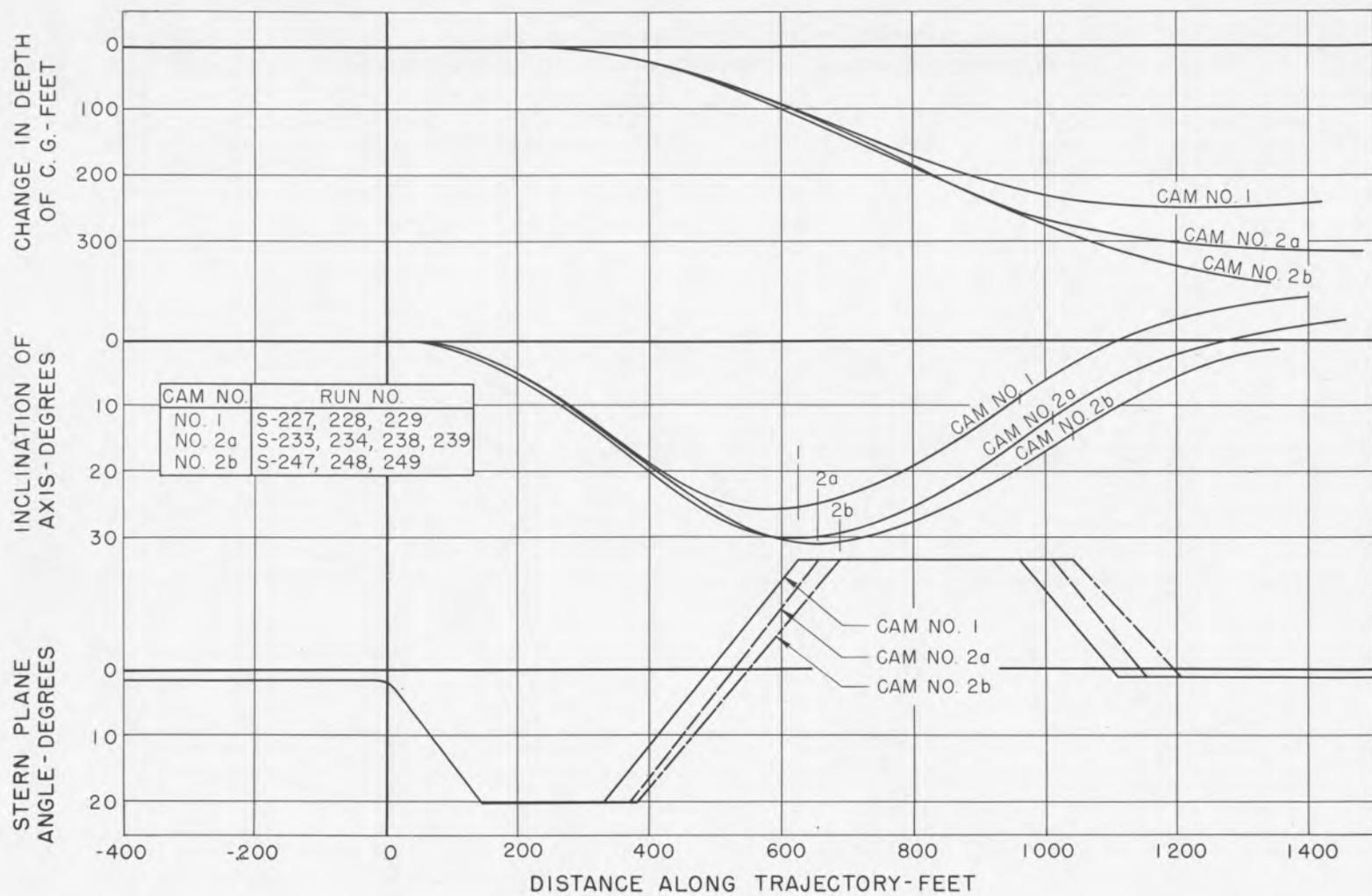


Fig. 5-17a Trajectory response in depth changing maneuvers for original configuration.

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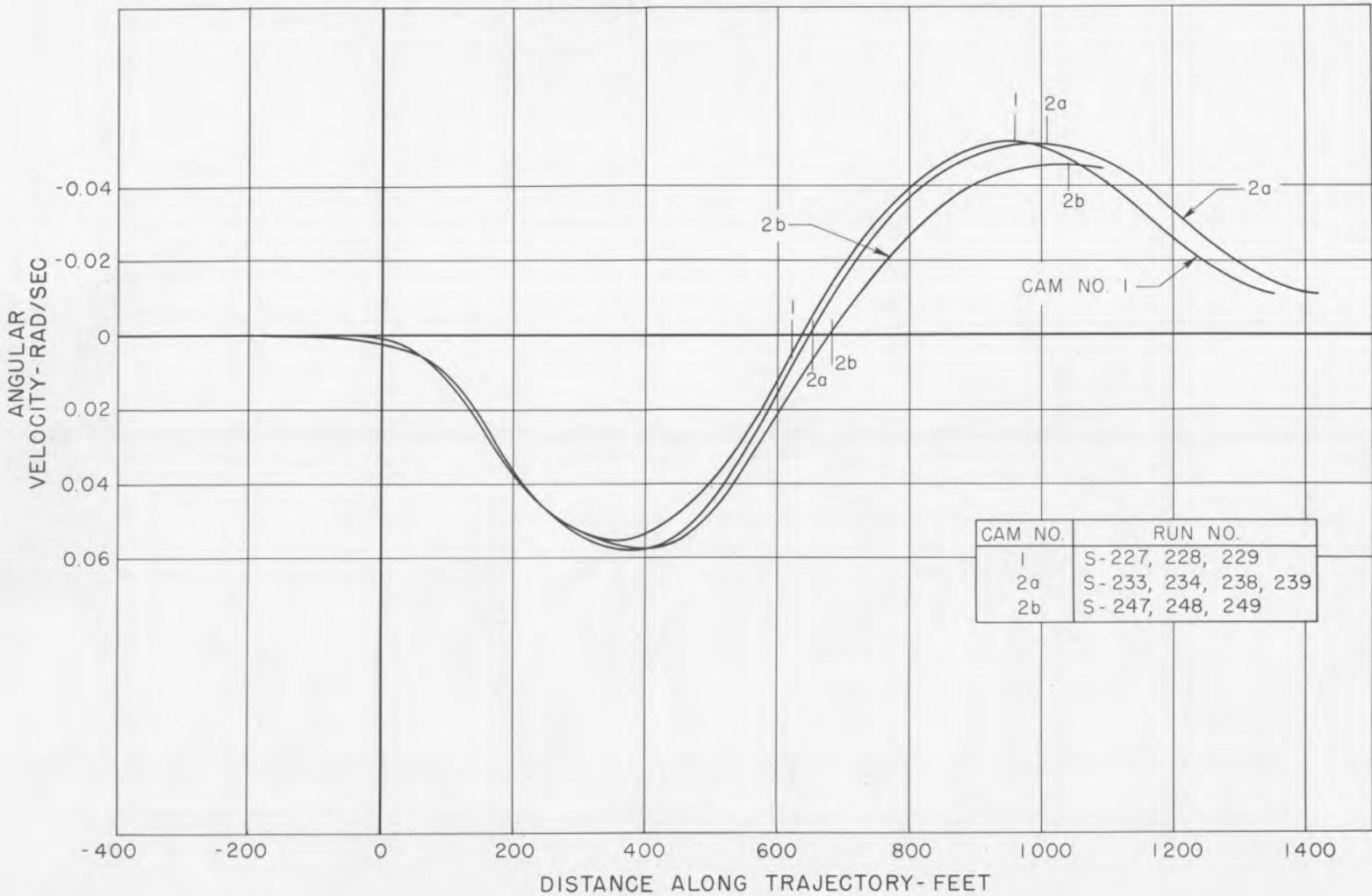


Fig. 5-17b Curvature response in depth changing maneuvers for original configuration.

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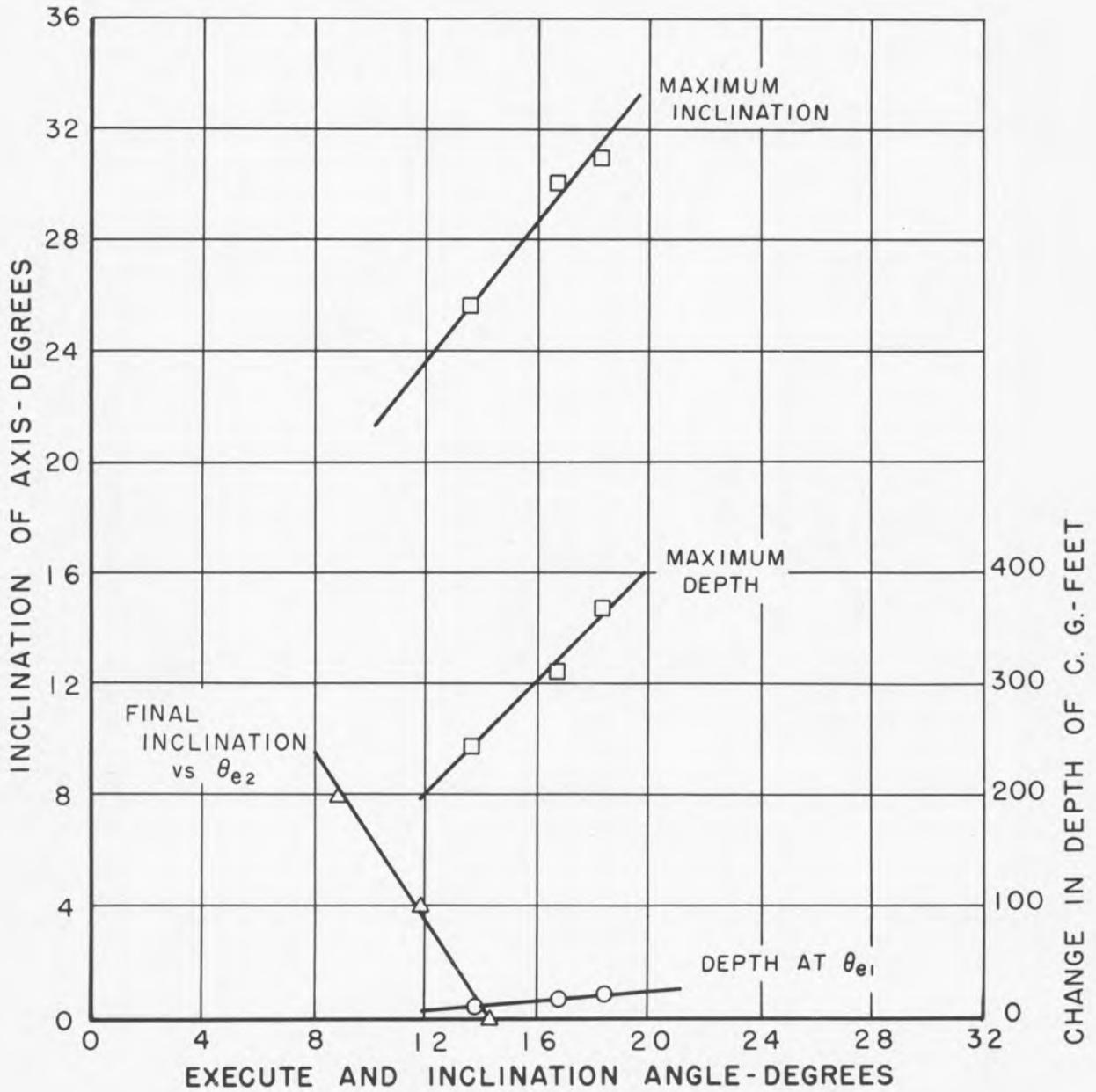


Fig. 5-17c Anticipation requirements in depth changing maneuvers with 18° plane angles for original configuration.

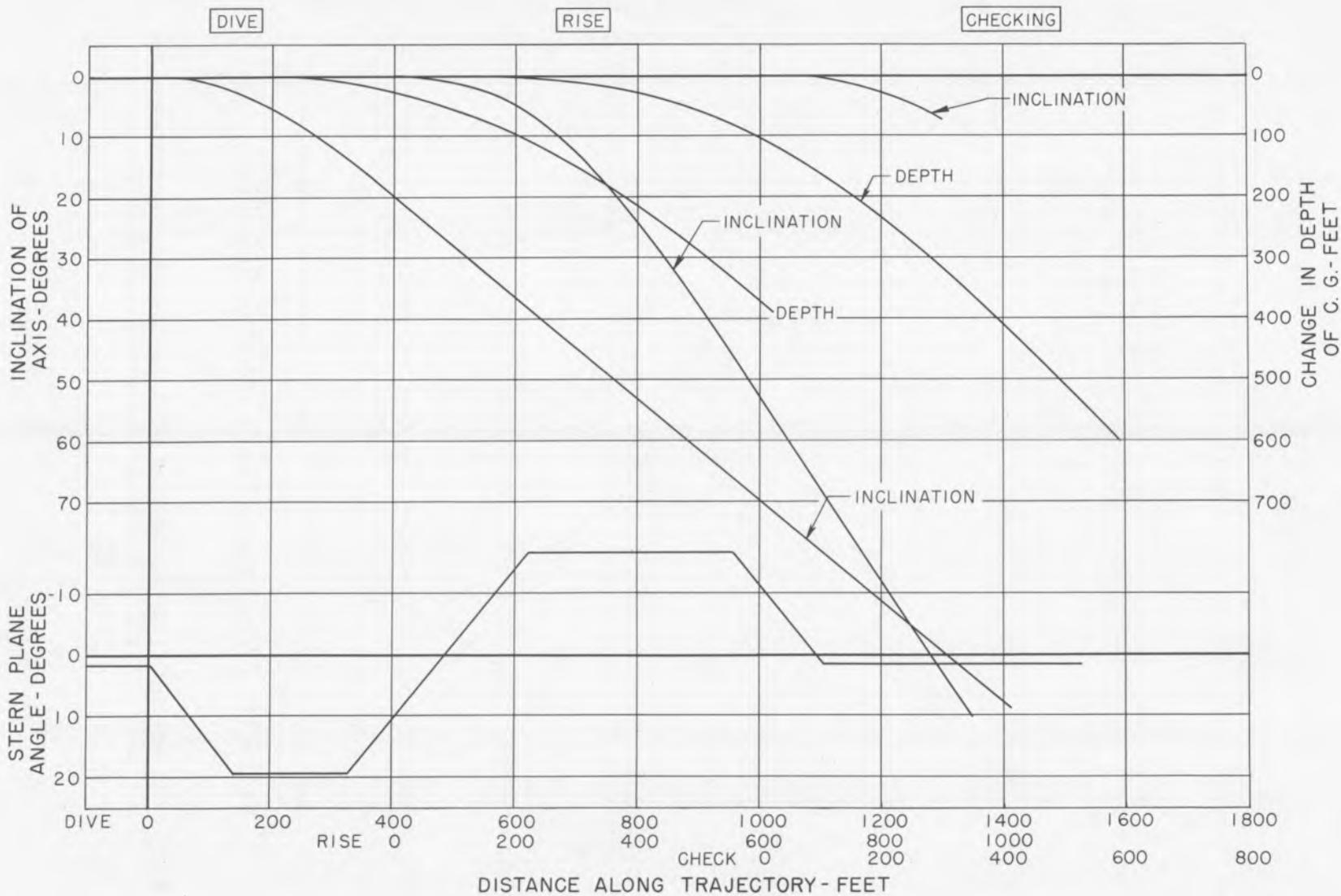


Fig. 5-18 Trajectory elements in depth changing maneuvers for 18° plane angles with original configuration.

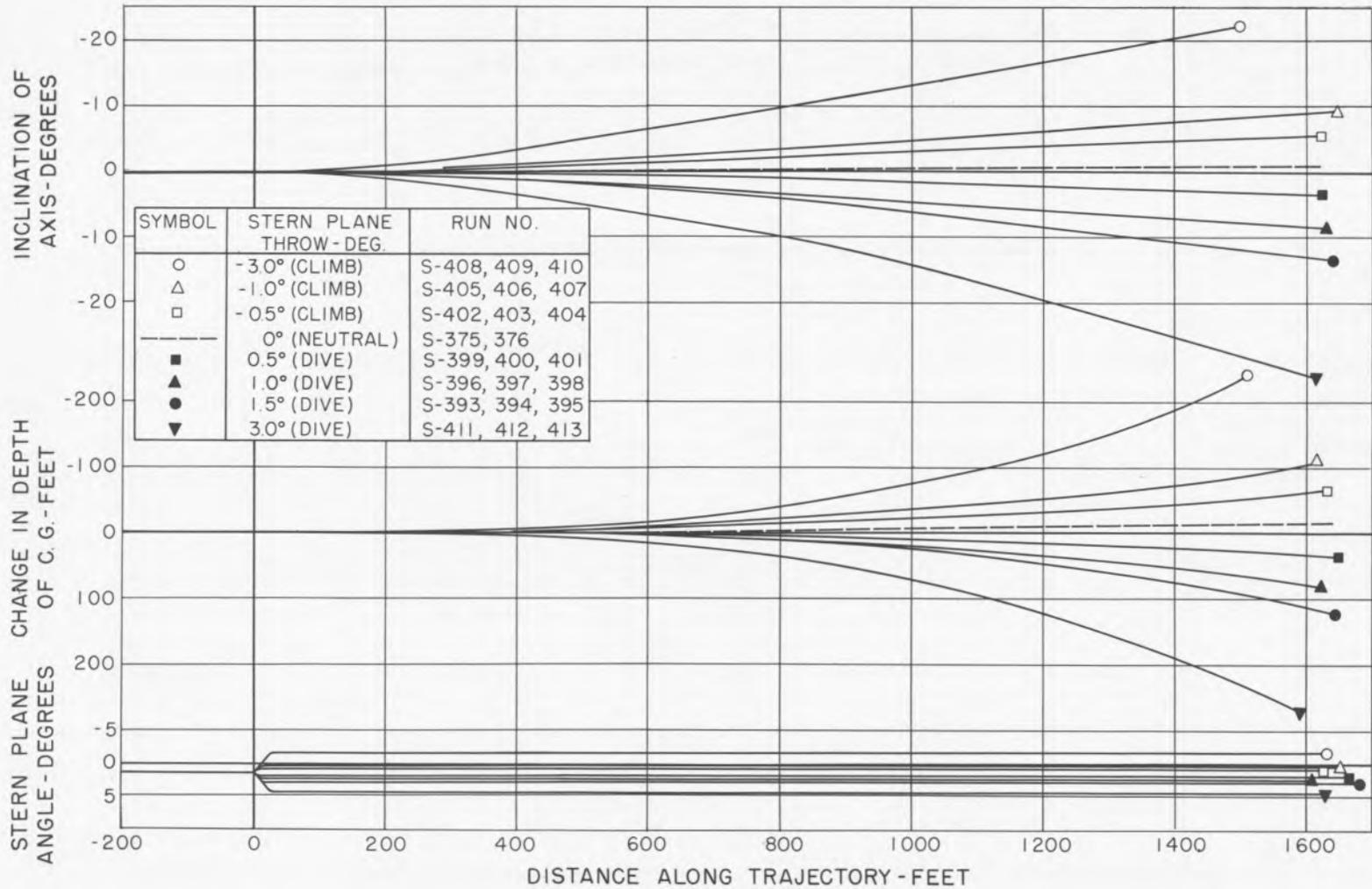


Fig. 5-19a Trajectory response in dive and climb for small stern plane throw angles for revised configuration.

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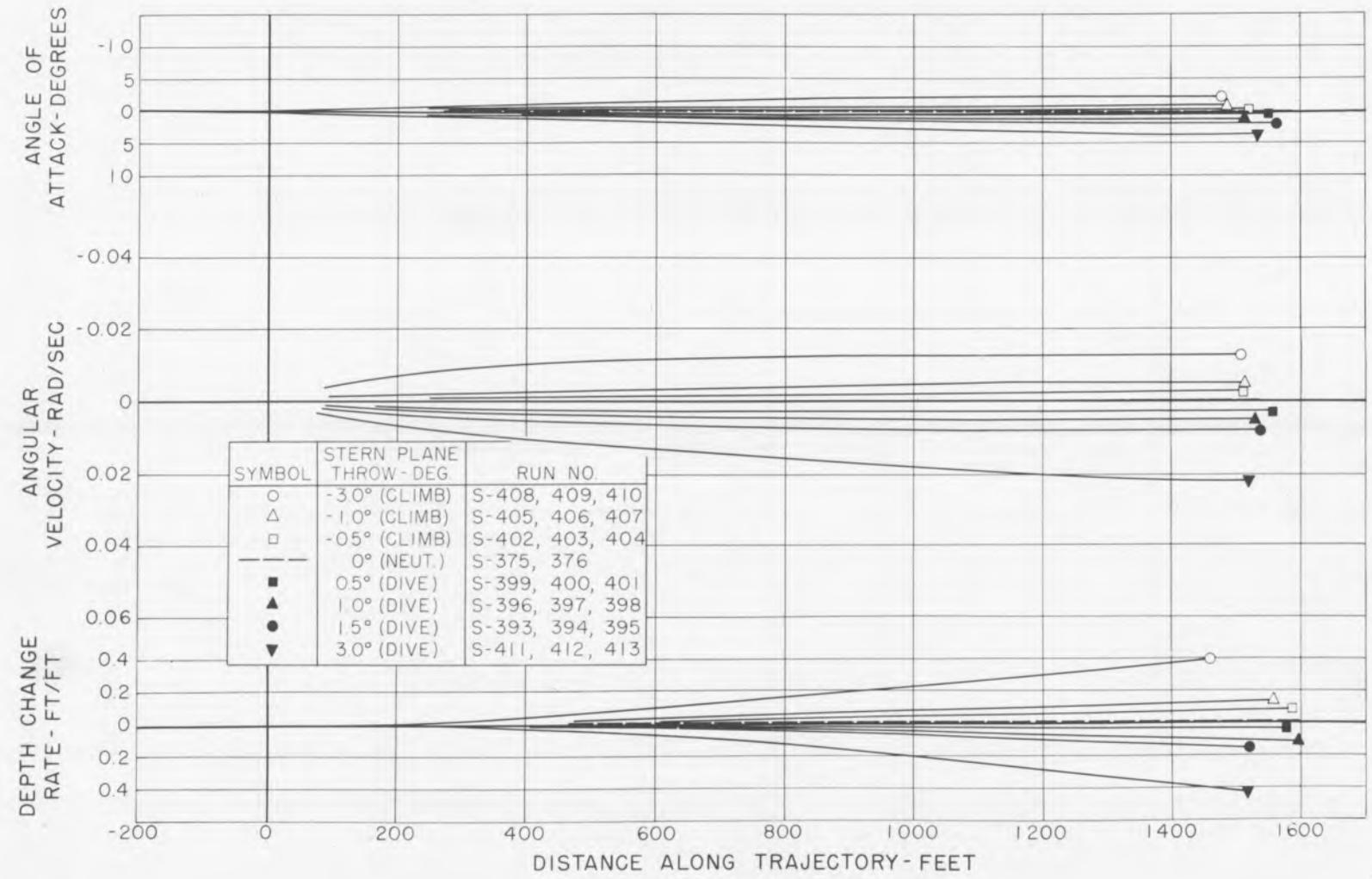


Fig. 5-19b Curvature response in dive and climb for small stern plane throw angles for revised configuration.

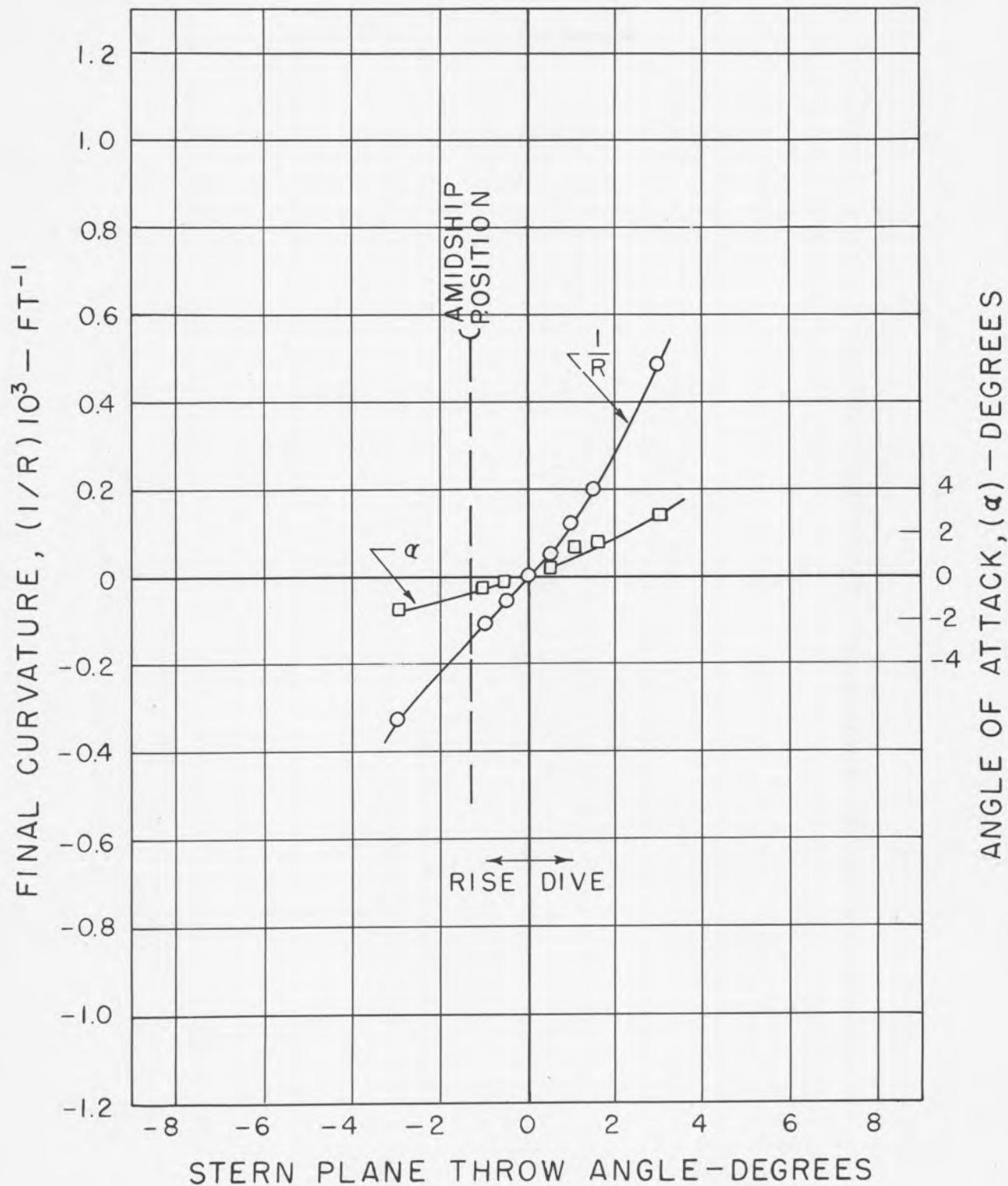


Fig. 5-19c Equilibrium turning conditions for small angles in dive and climb for revised configuration.

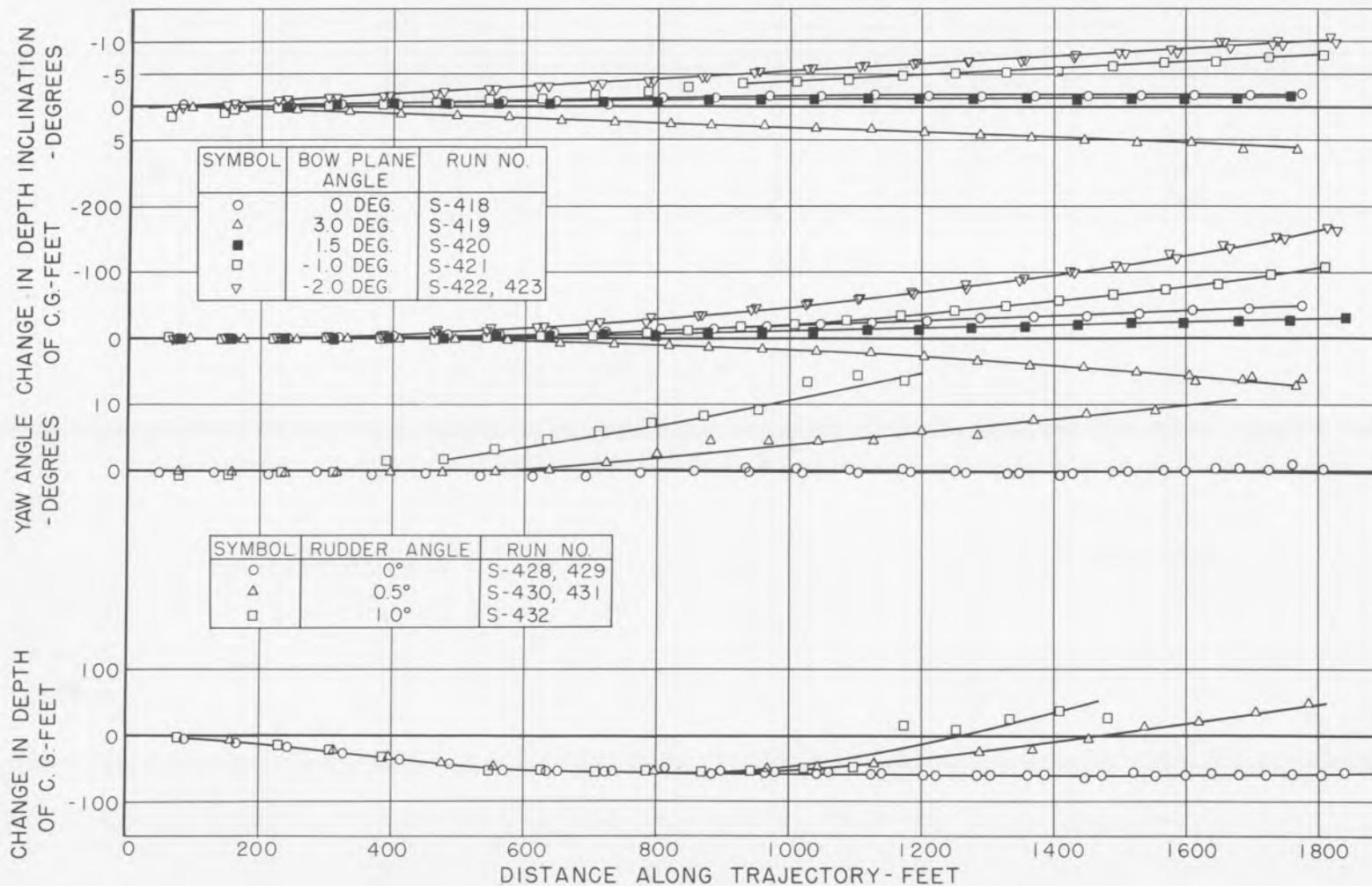


Fig. 5-20a Trajectory response for small bow plane and rudder angles for revised configuration.

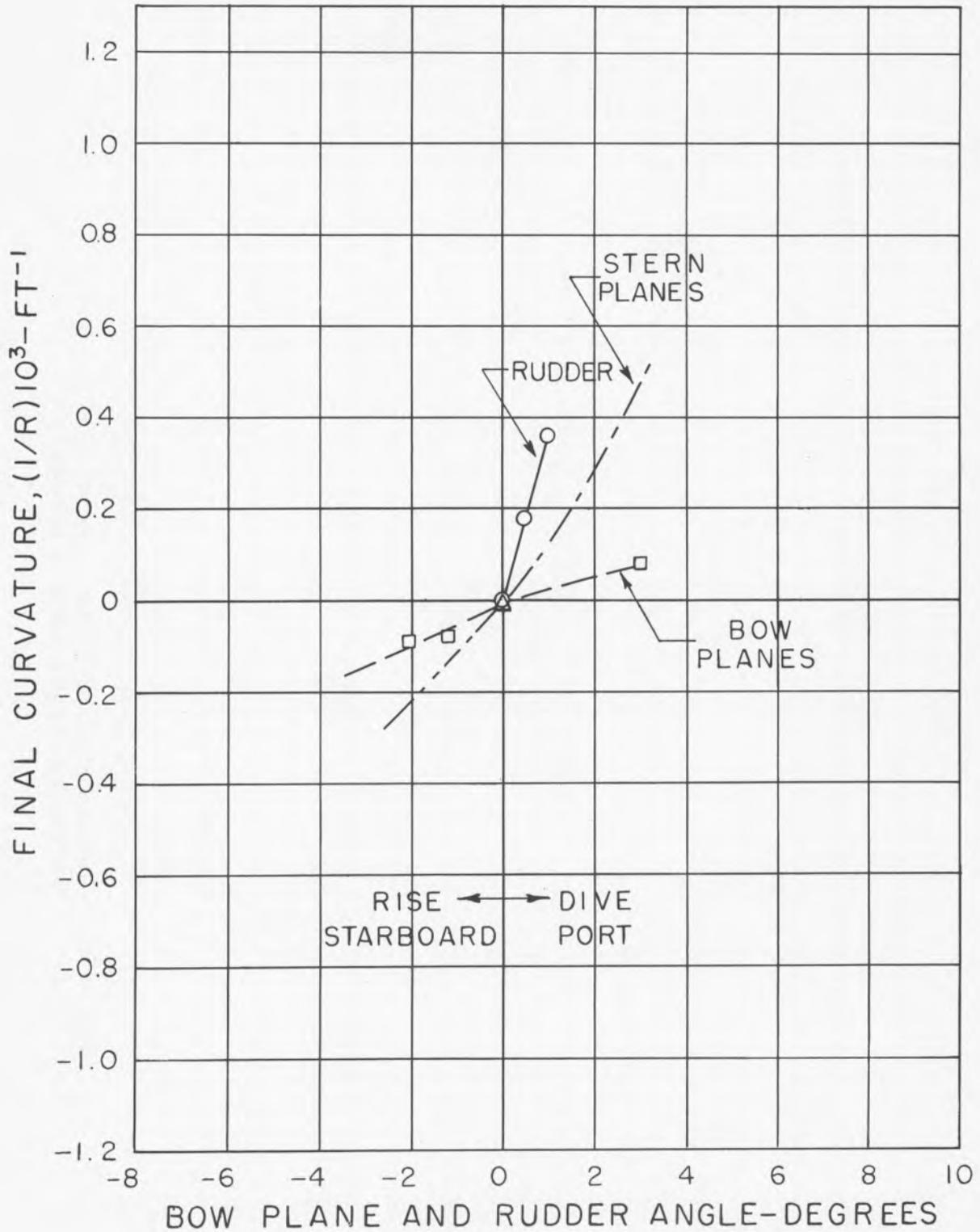


Fig. 5-20b Equilibrium turning rates for small rudder and bow plane angles for revised configuration.

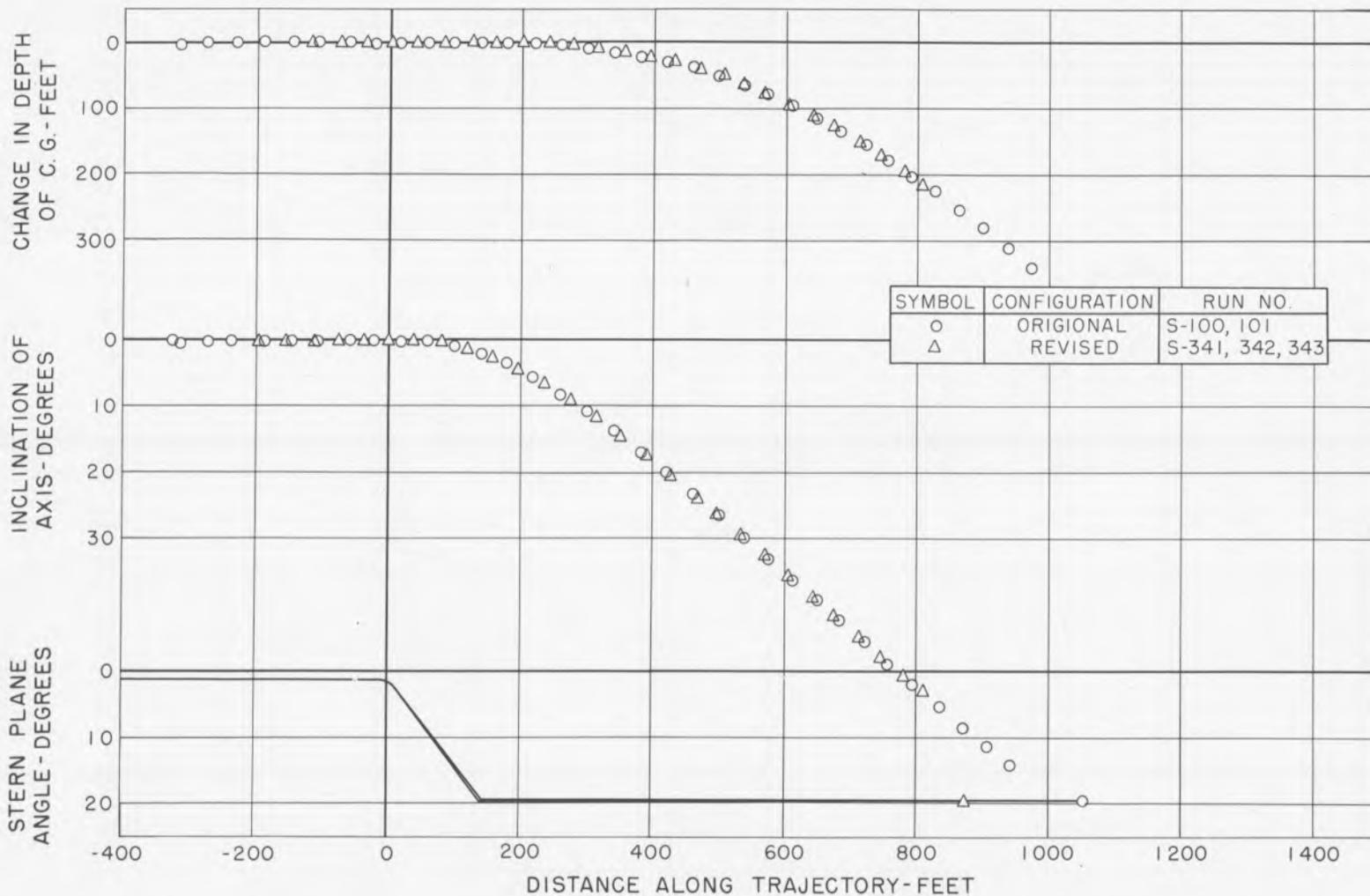


Fig. 5-21a Comparison of trajectory response of original and revised configurations in dive.

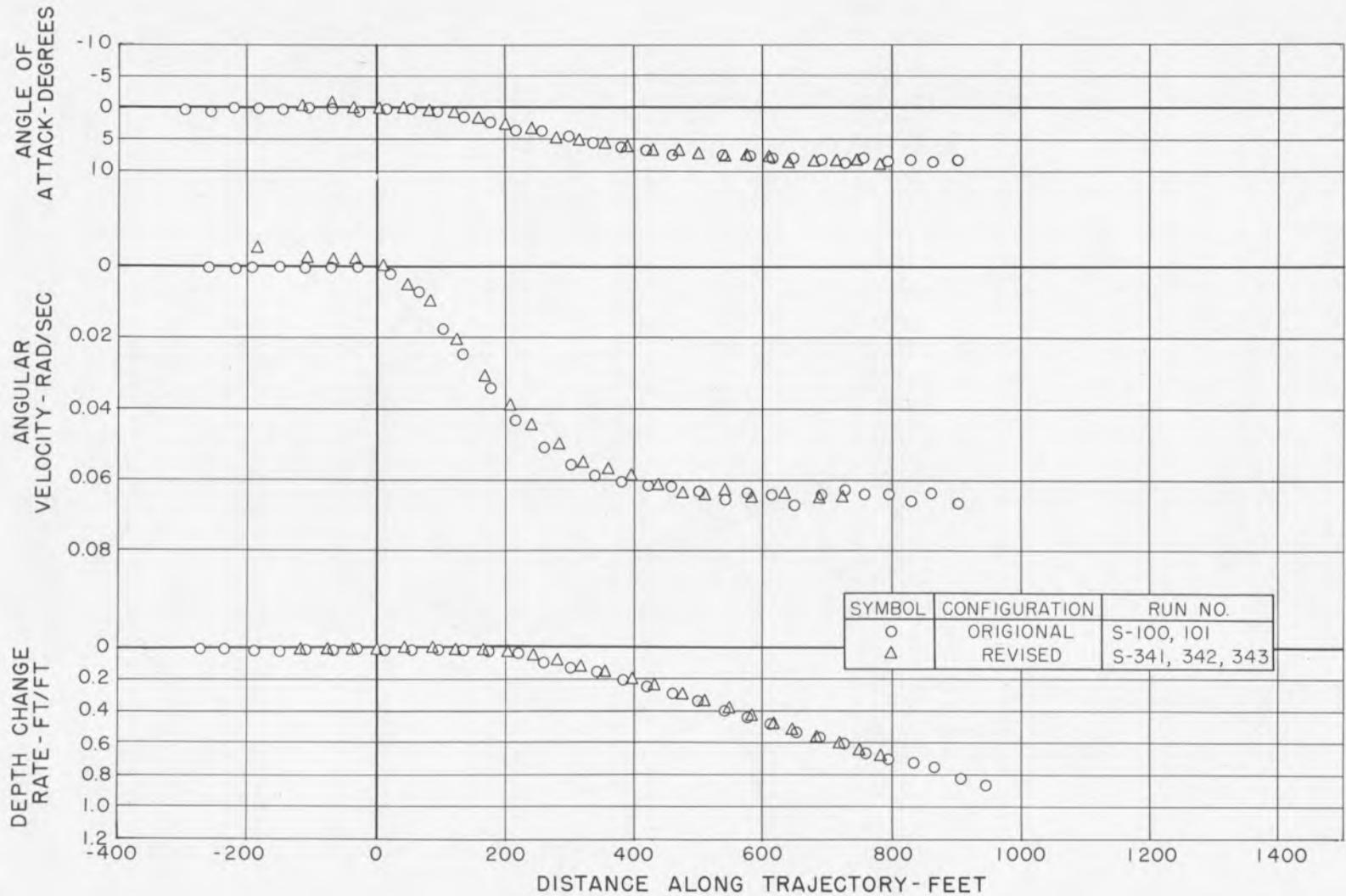


Fig. 5-21b Comparison of curvature response for original and revised configuration in dive.

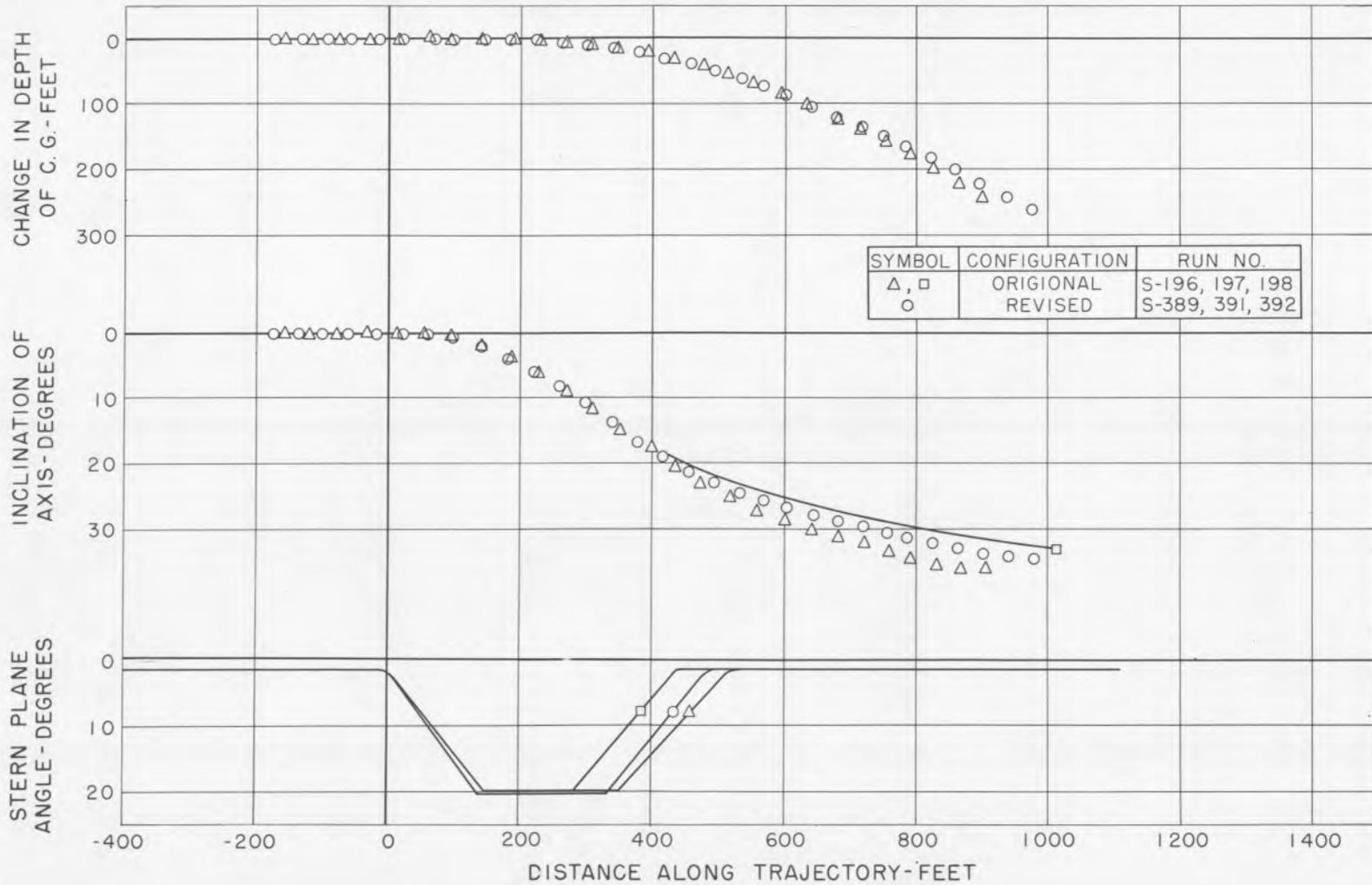


Fig. 5-22a Comparison of trajectory response of original and revised configuration in a dive incline maneuver.

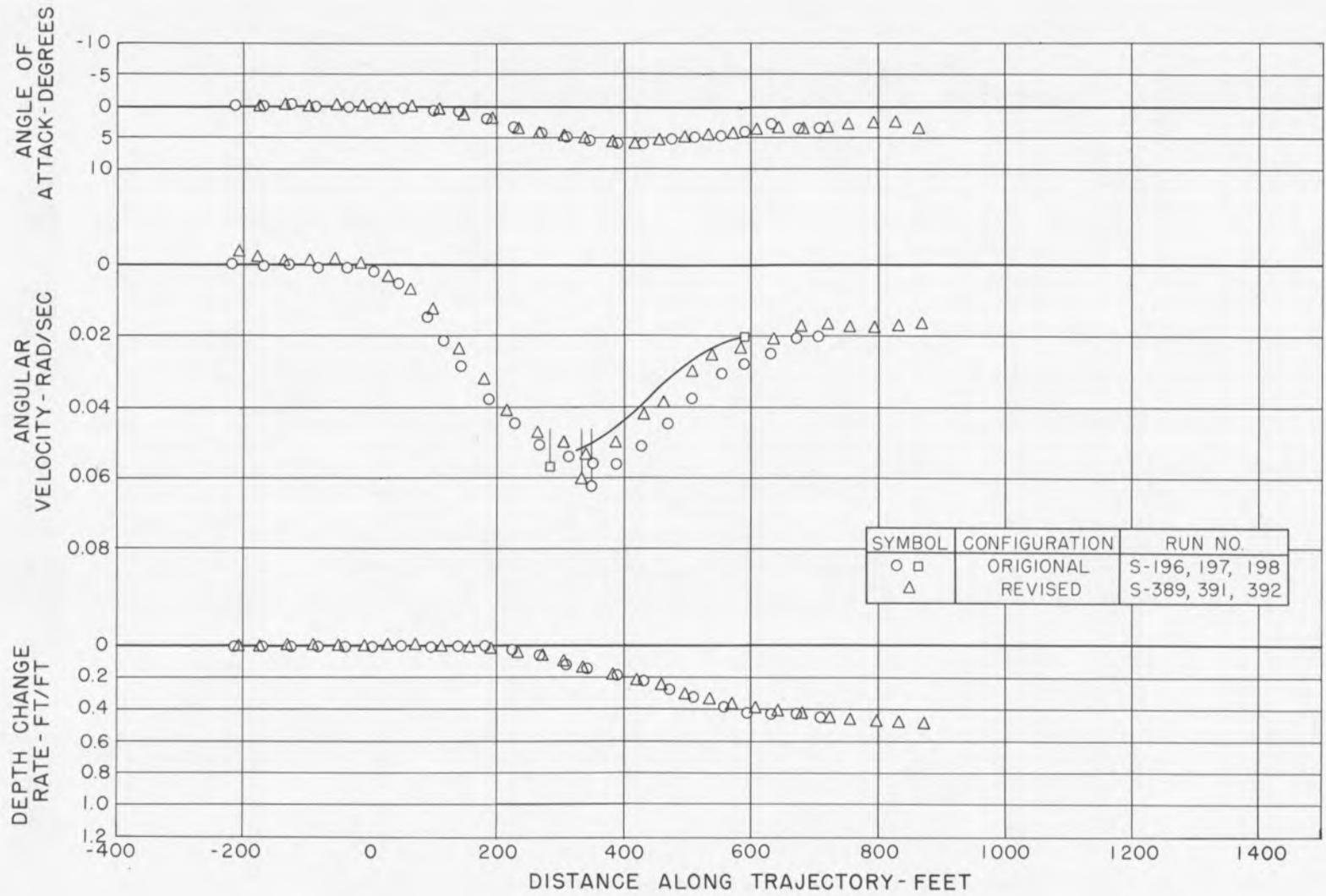


Fig. 5-22b Comparison of curvature response of original and revised configuration in a dive incline maneuver.

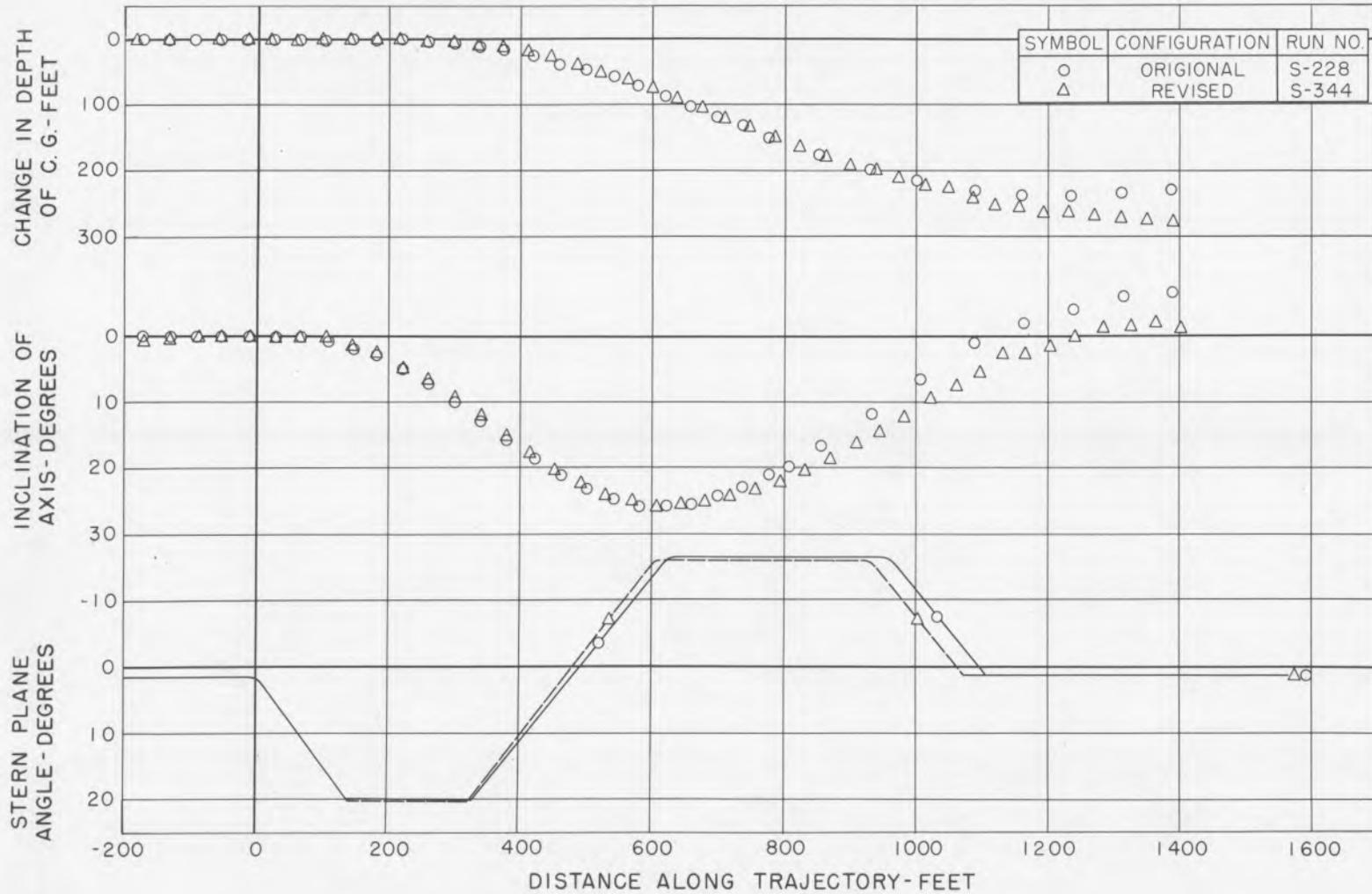


Fig. 5-23a Comparison of trajectory response of original and revised configurations in depth changing.

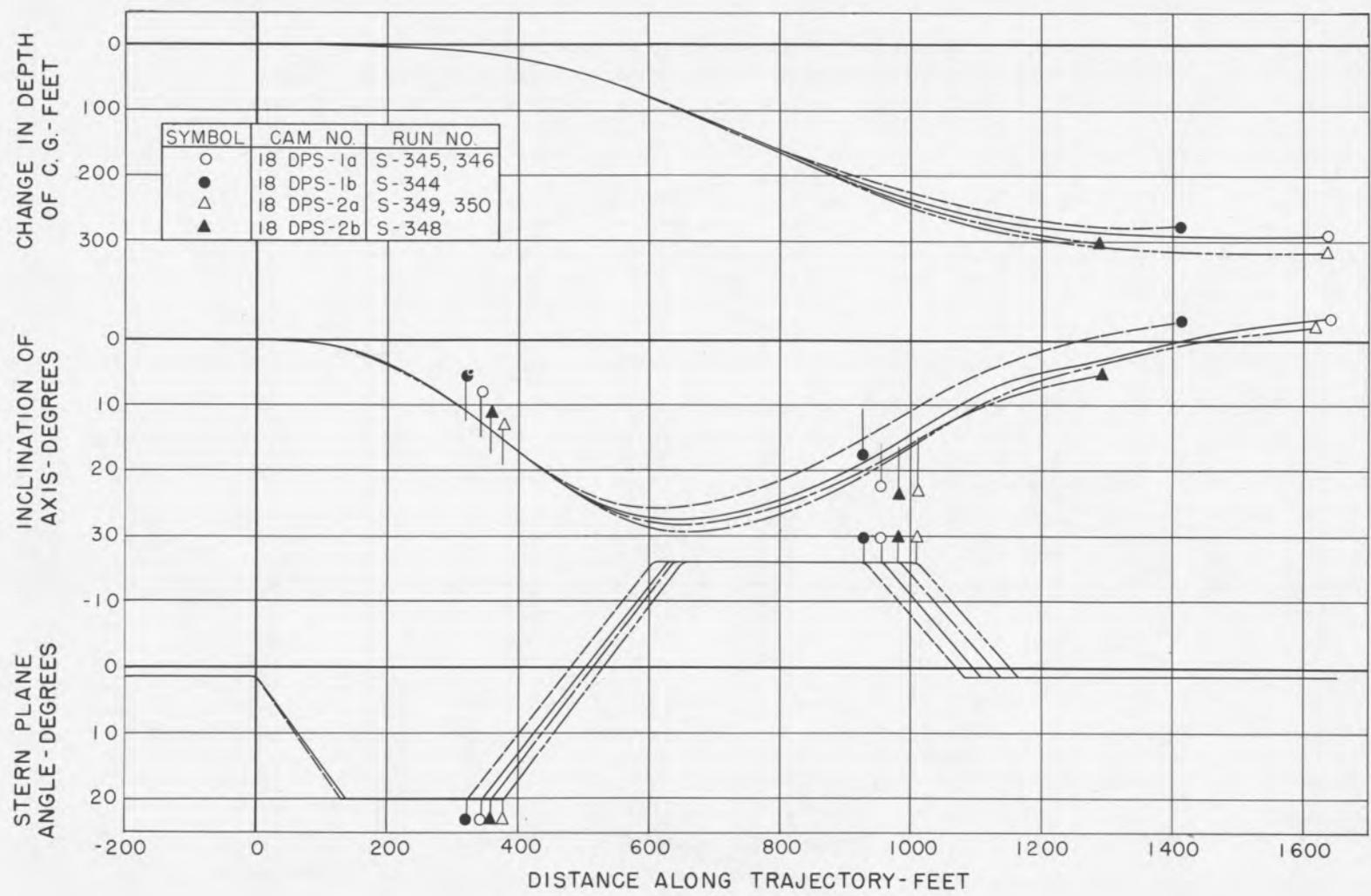


Fig. 5-23b Trajectory response in depth changing maneuvers for revised configuration - 18° plane angles.

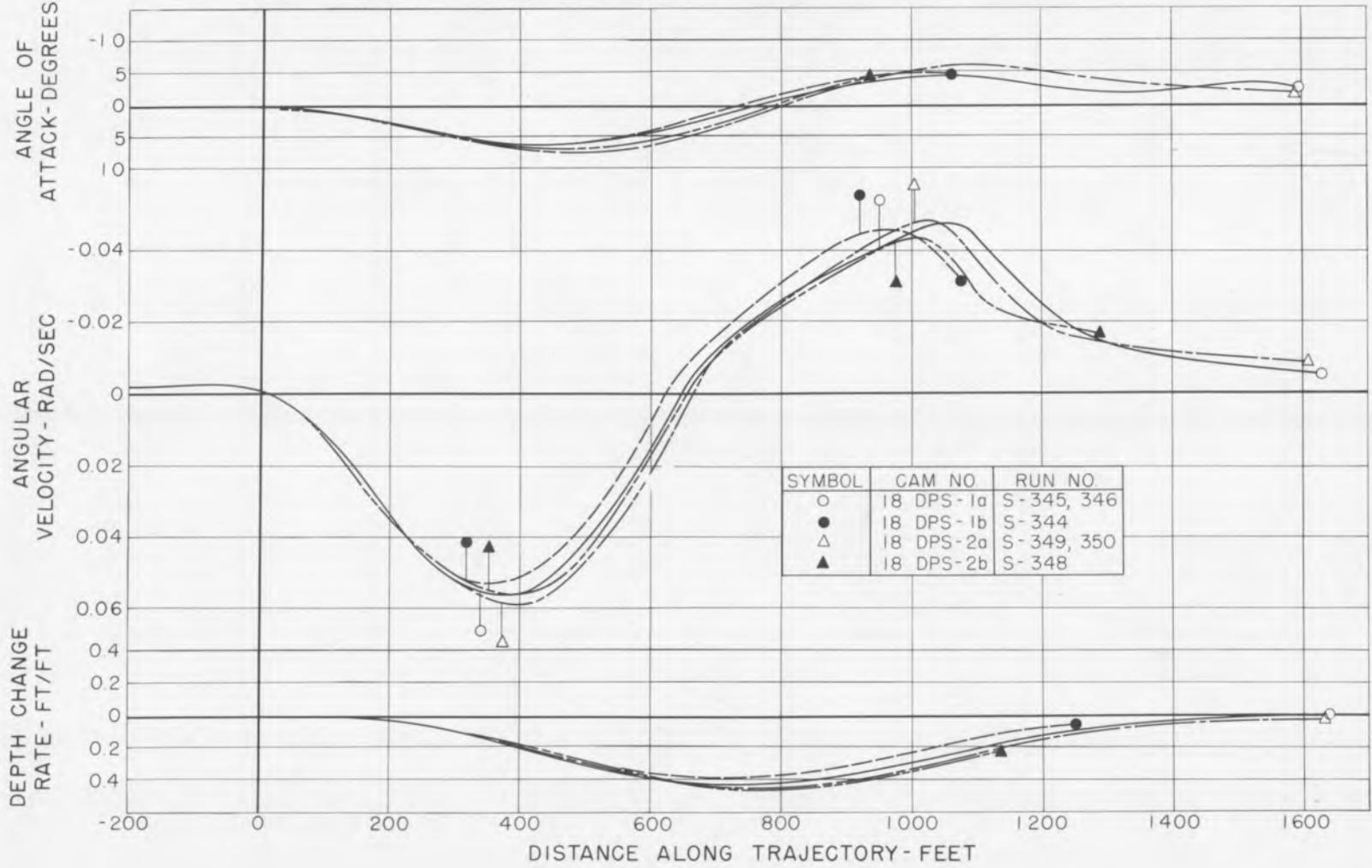


Fig. 5-23c Curvature response in depth changing maneuver for revised configuration - 18° plane angles.

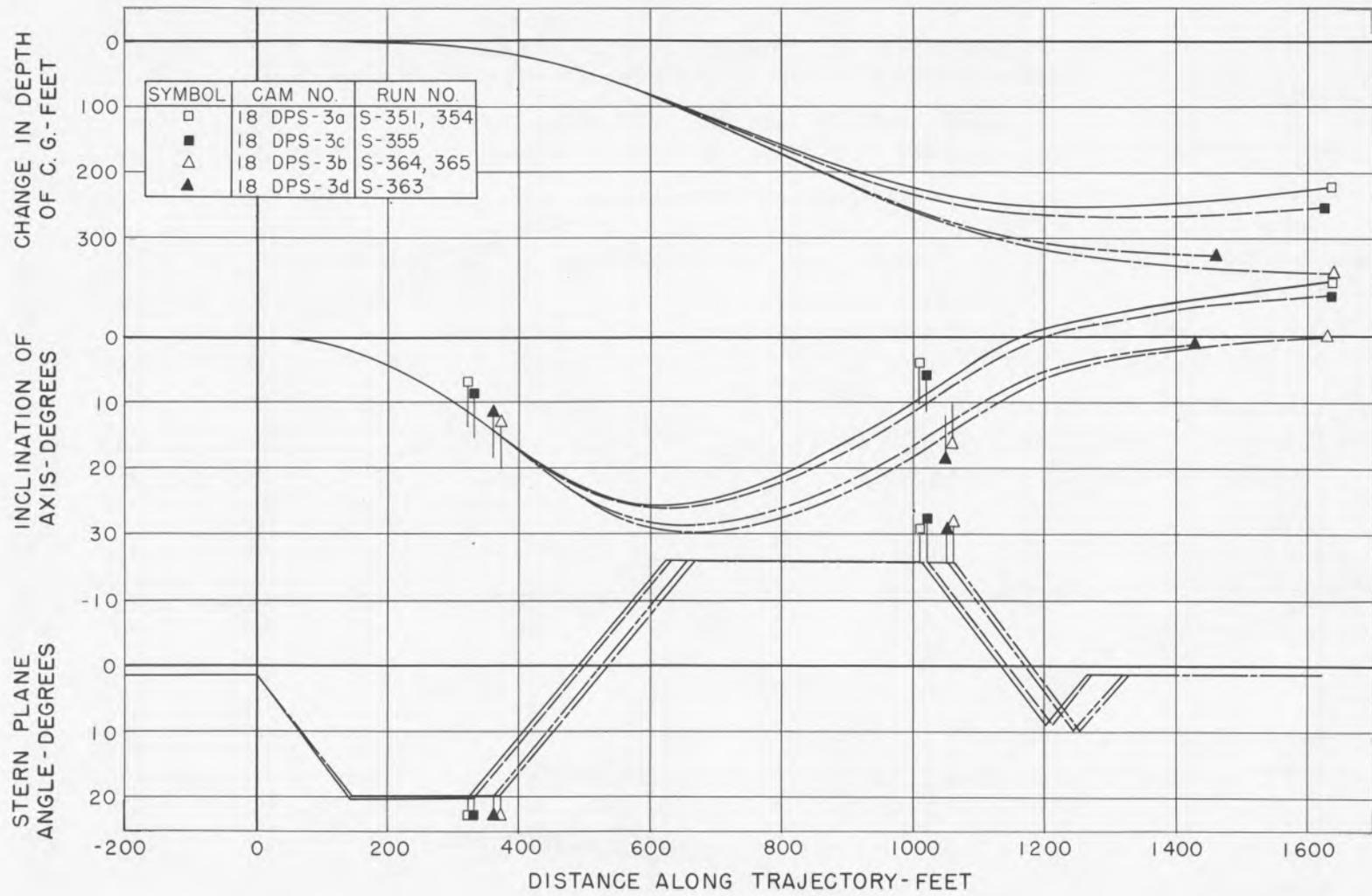


Fig. 5-24a Trajectory response in depth changing maneuvers for revised configuration - 18° plane angles and 7° checking angle.

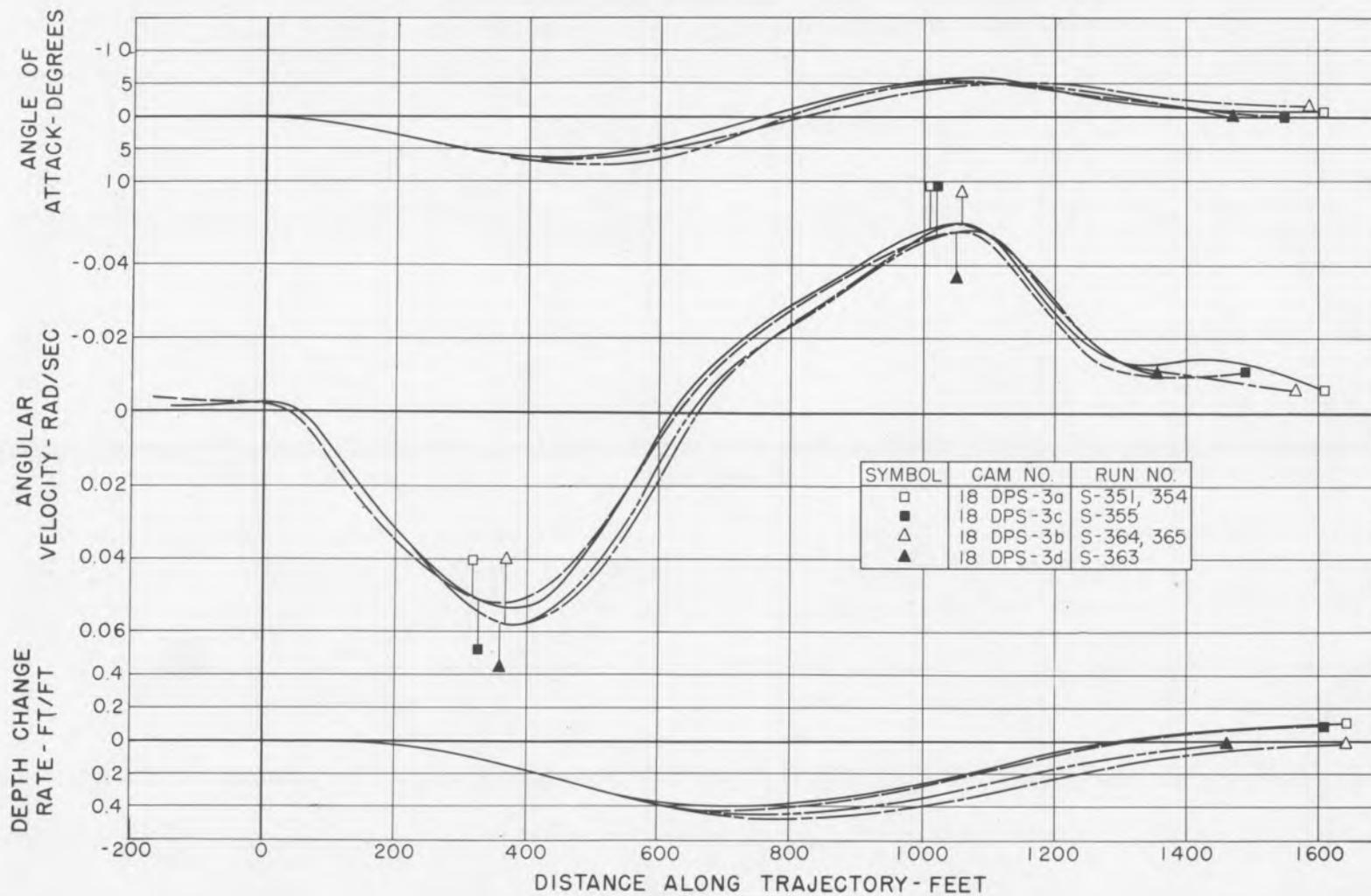


Fig. 5-24b Curvature response in depth changing maneuvers for revised configuration - 18° plane angles and 7° checking angle.

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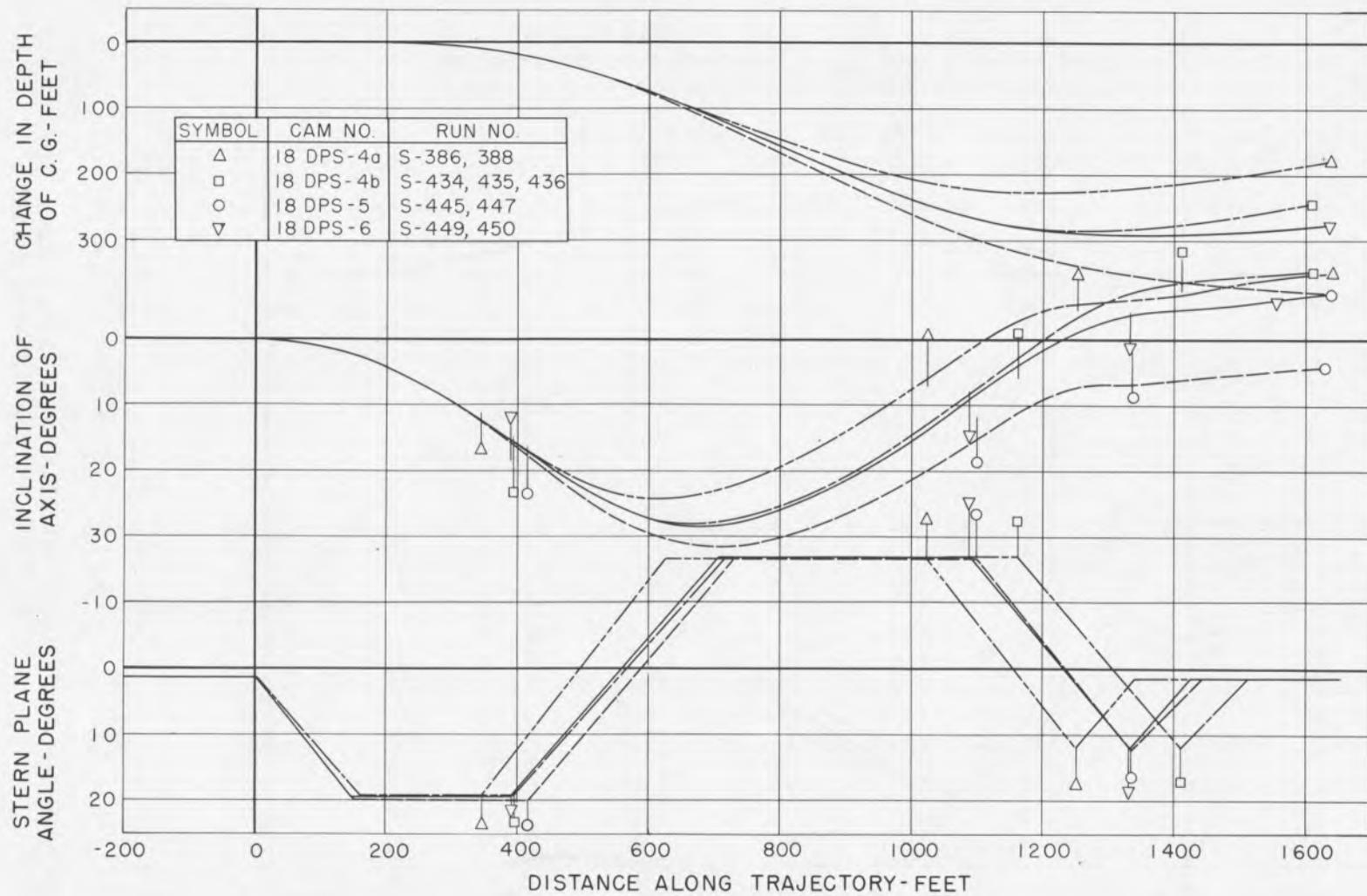


Fig. 5-25a Trajectory response in depth changing maneuvers for revised configuration - 18° plane angles and 10° checking angle.

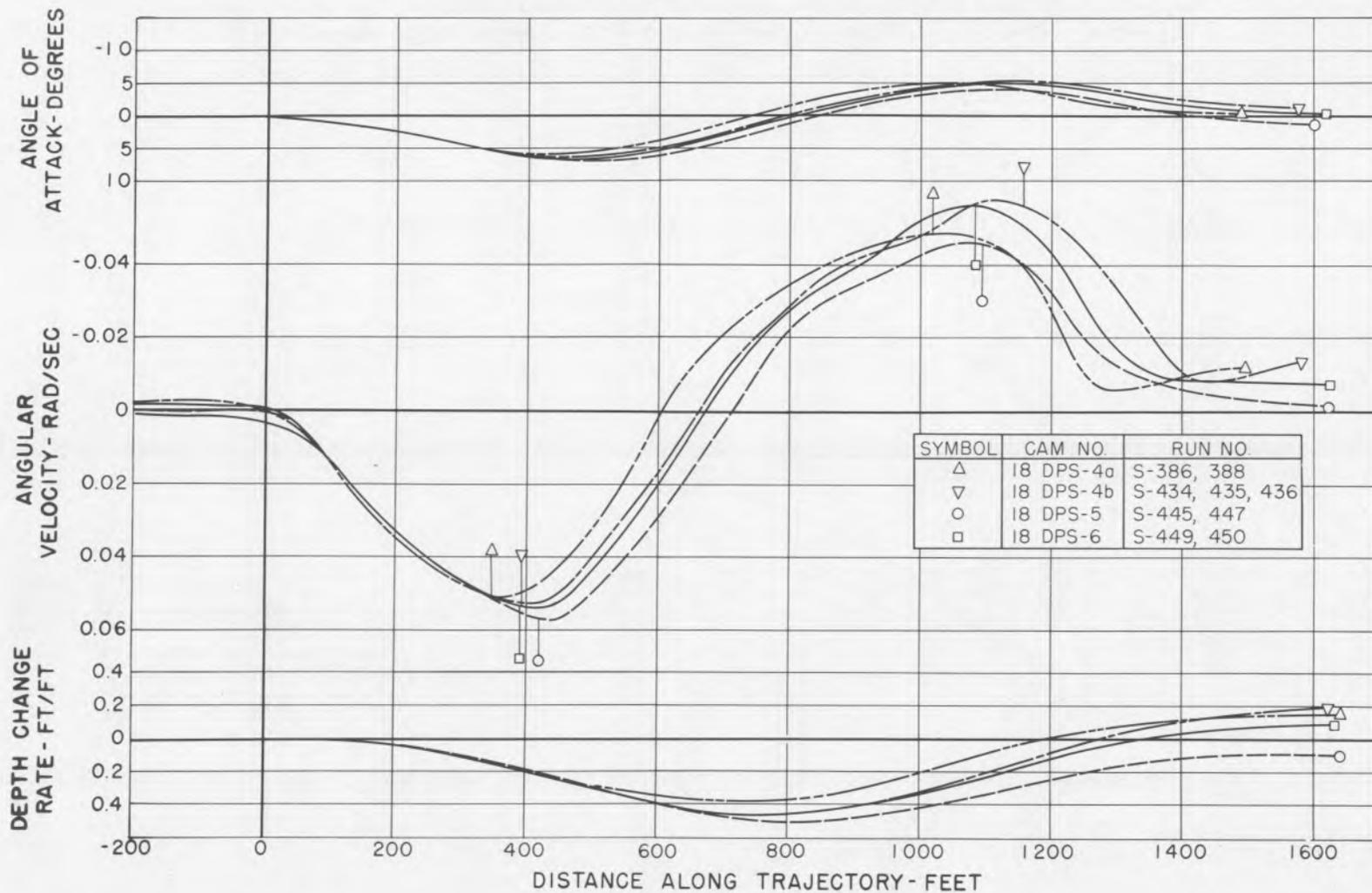


Fig. 5-25b Curvature response in depth changing maneuvers for revised configuration - 18° plane angles and 10° checking angle.

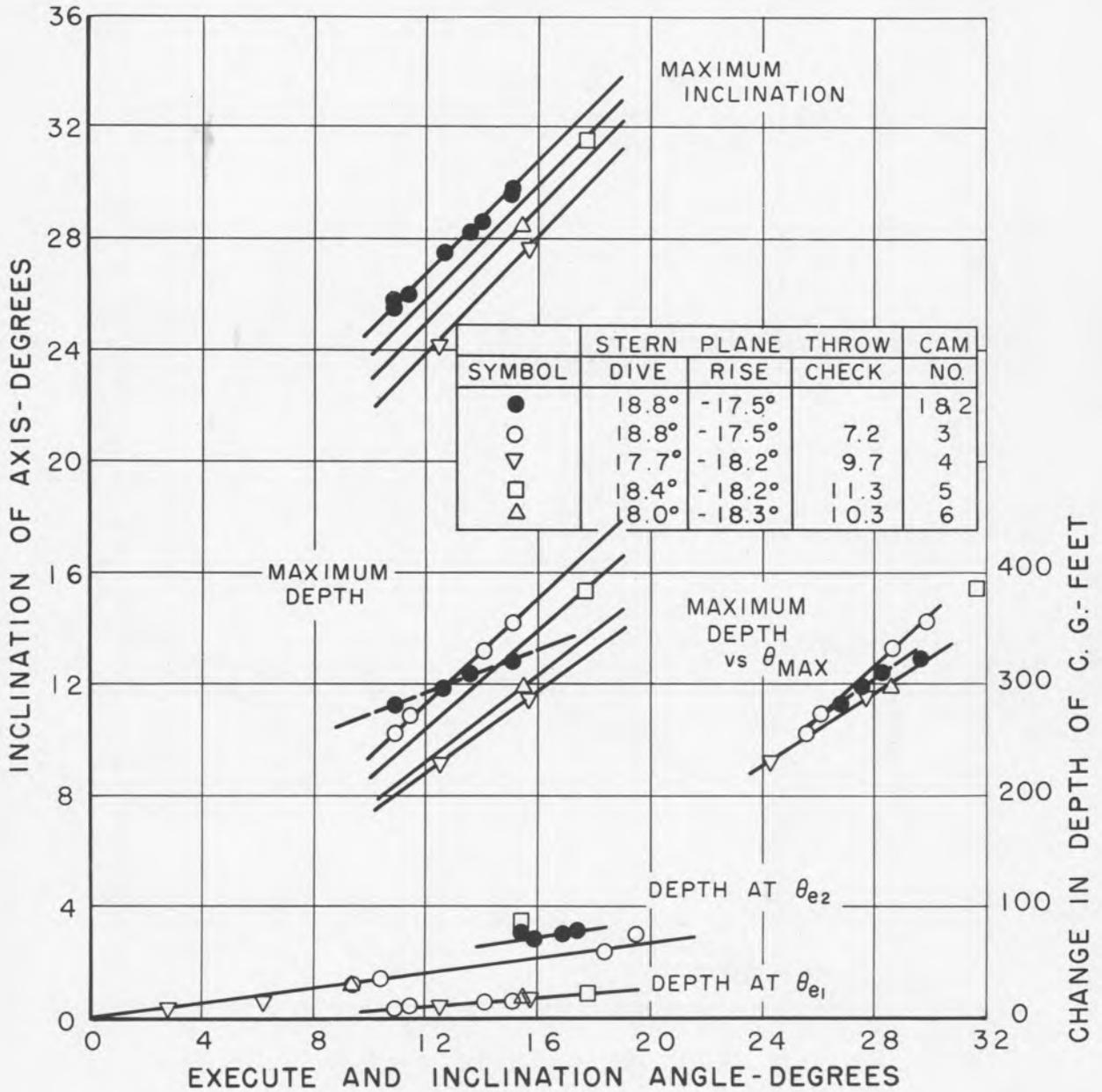


Fig. 5-26a Anticipation requirements in depth changing maneuvers for revised configuration with 18° plane angles.

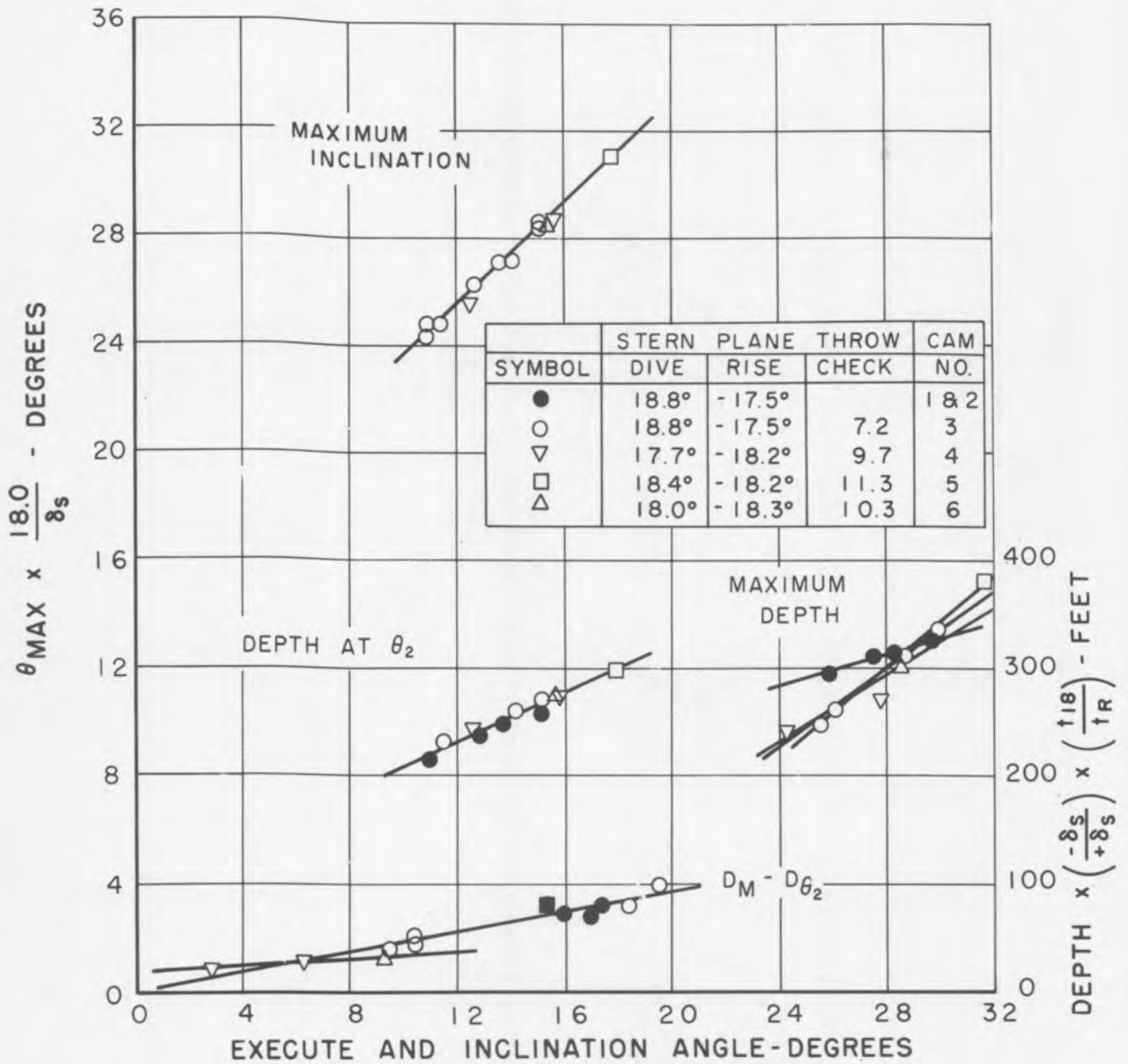
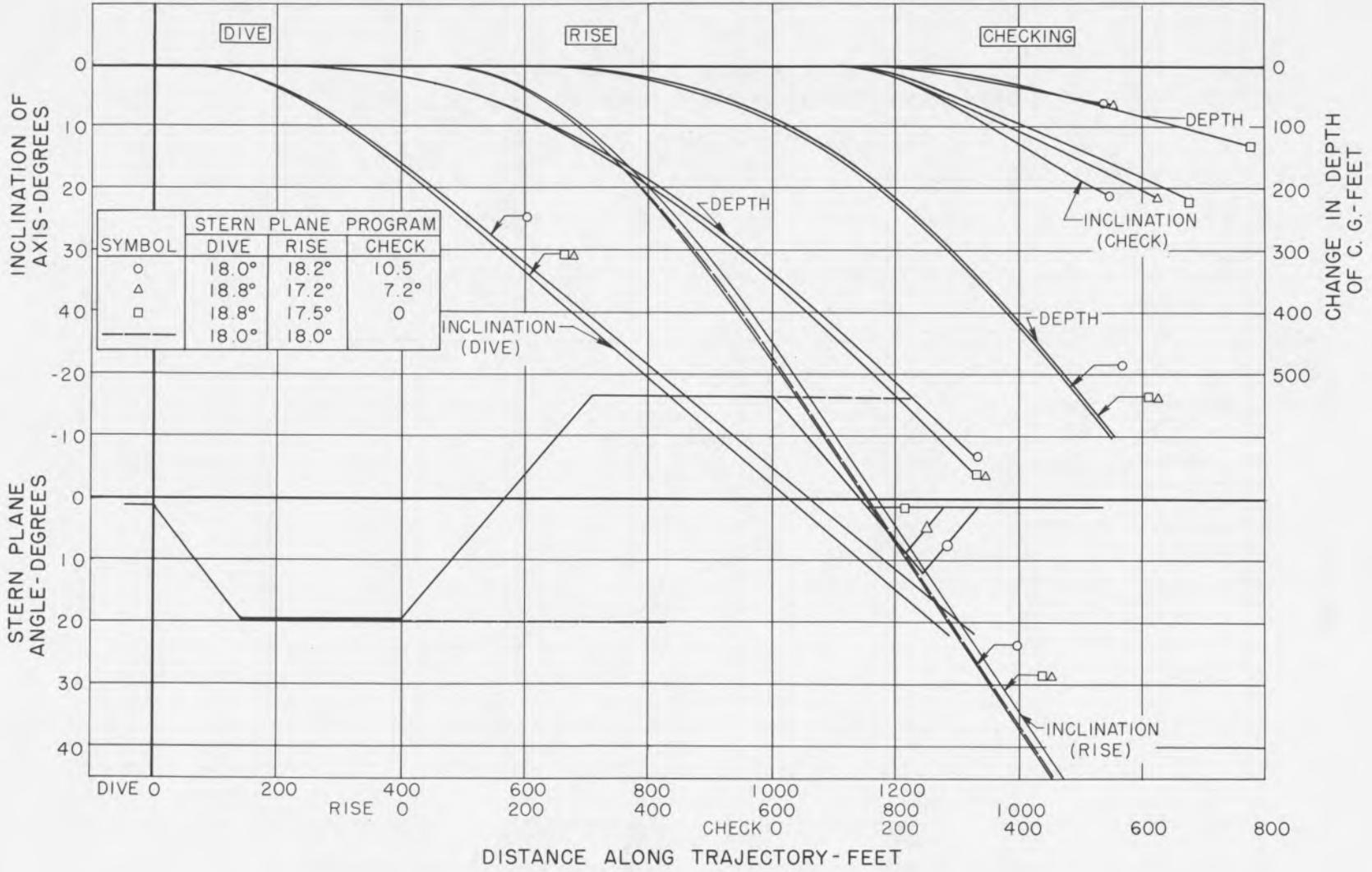


Fig. 5-26b Correlation of anticipation requirements for revised configuration in depth changing maneuvers.

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Fig. 5-27a Trajectory elements for revised configuration in depth changing maneuver with 18° plane angles.

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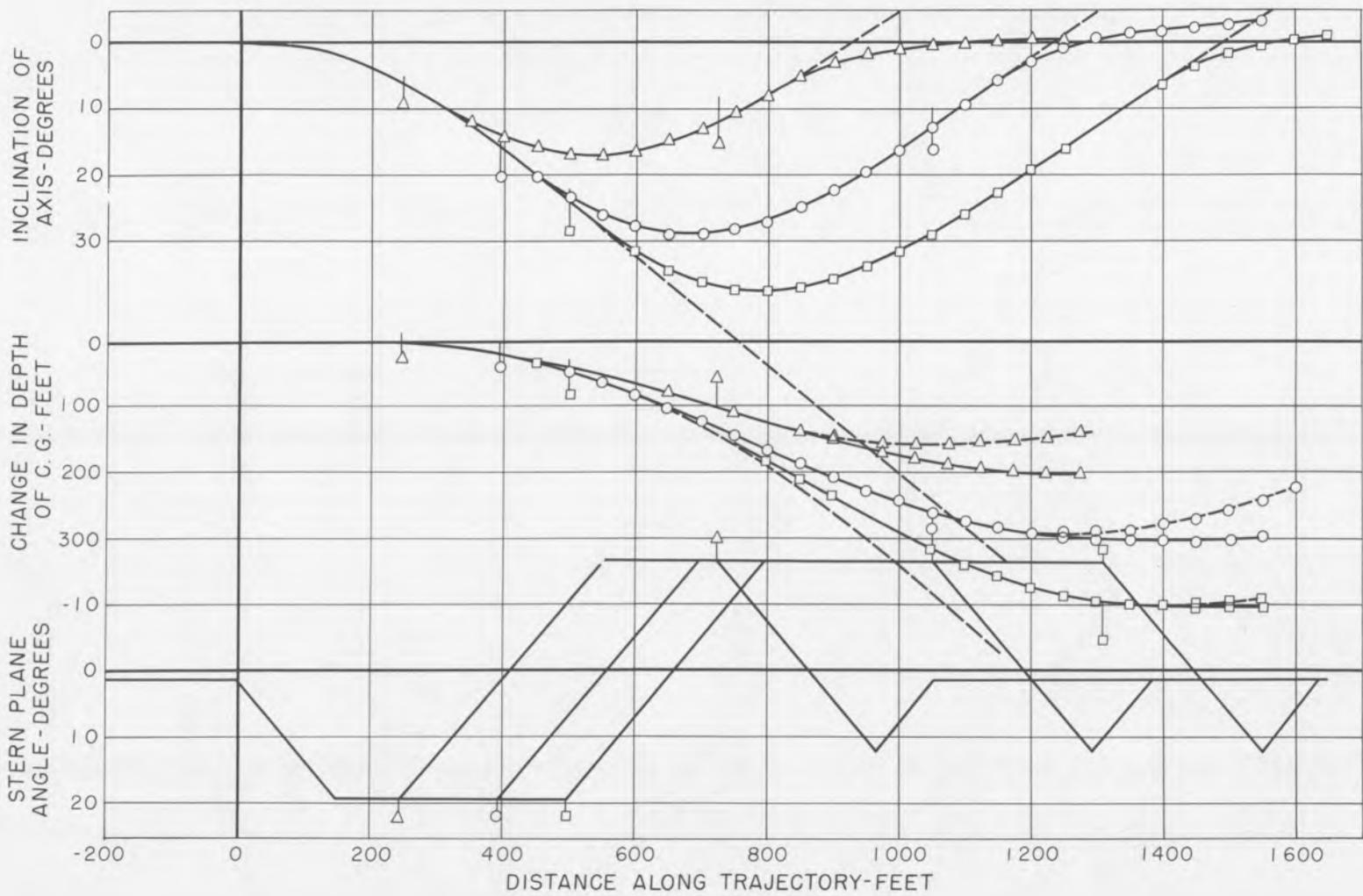
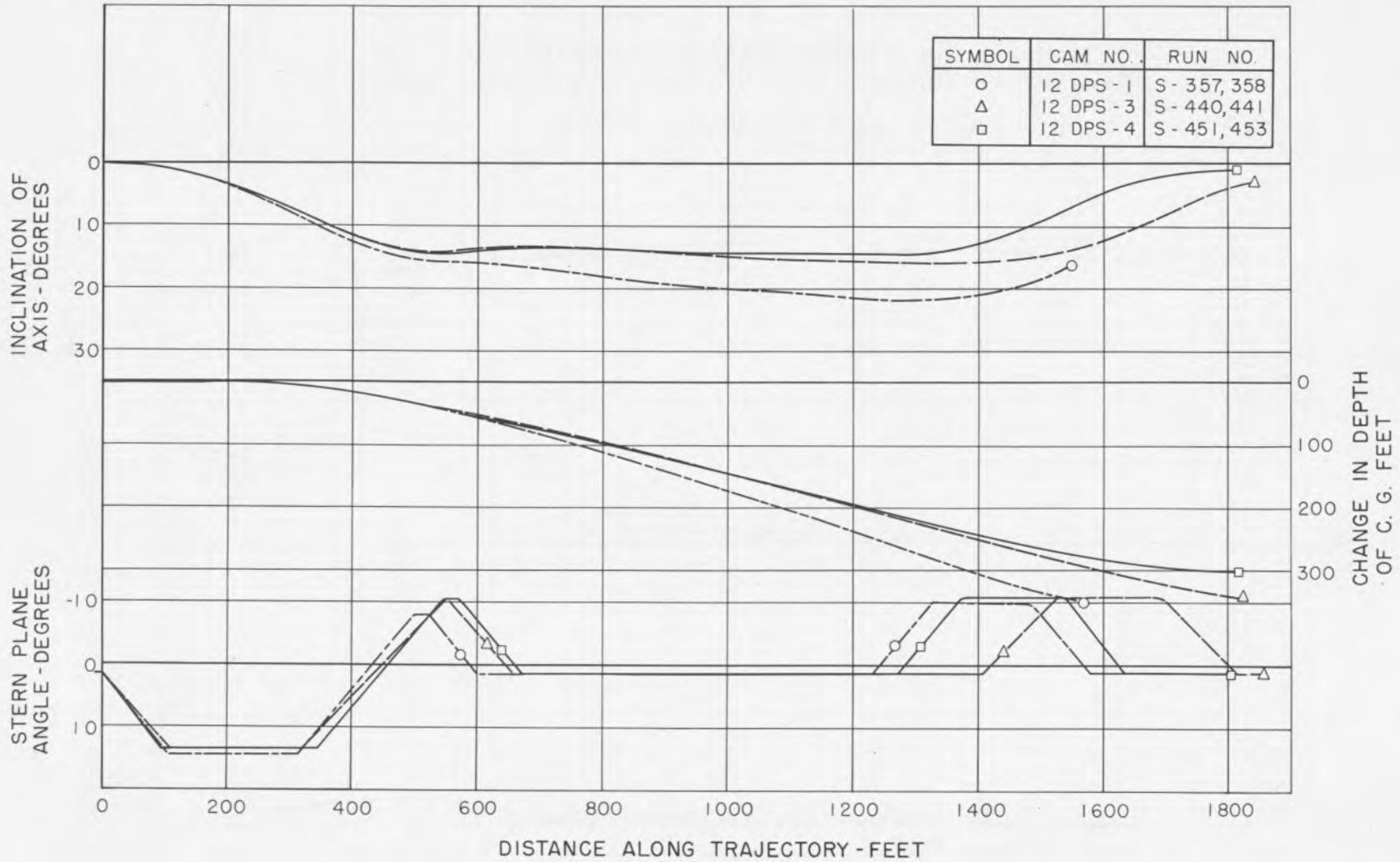


Fig. 5-27b - Predicted depth-changing maneuvers for revised configuration.

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Fig. 5-28a Trajectory response in depth changing maneuvers for revised configuration with 12° plane angles.

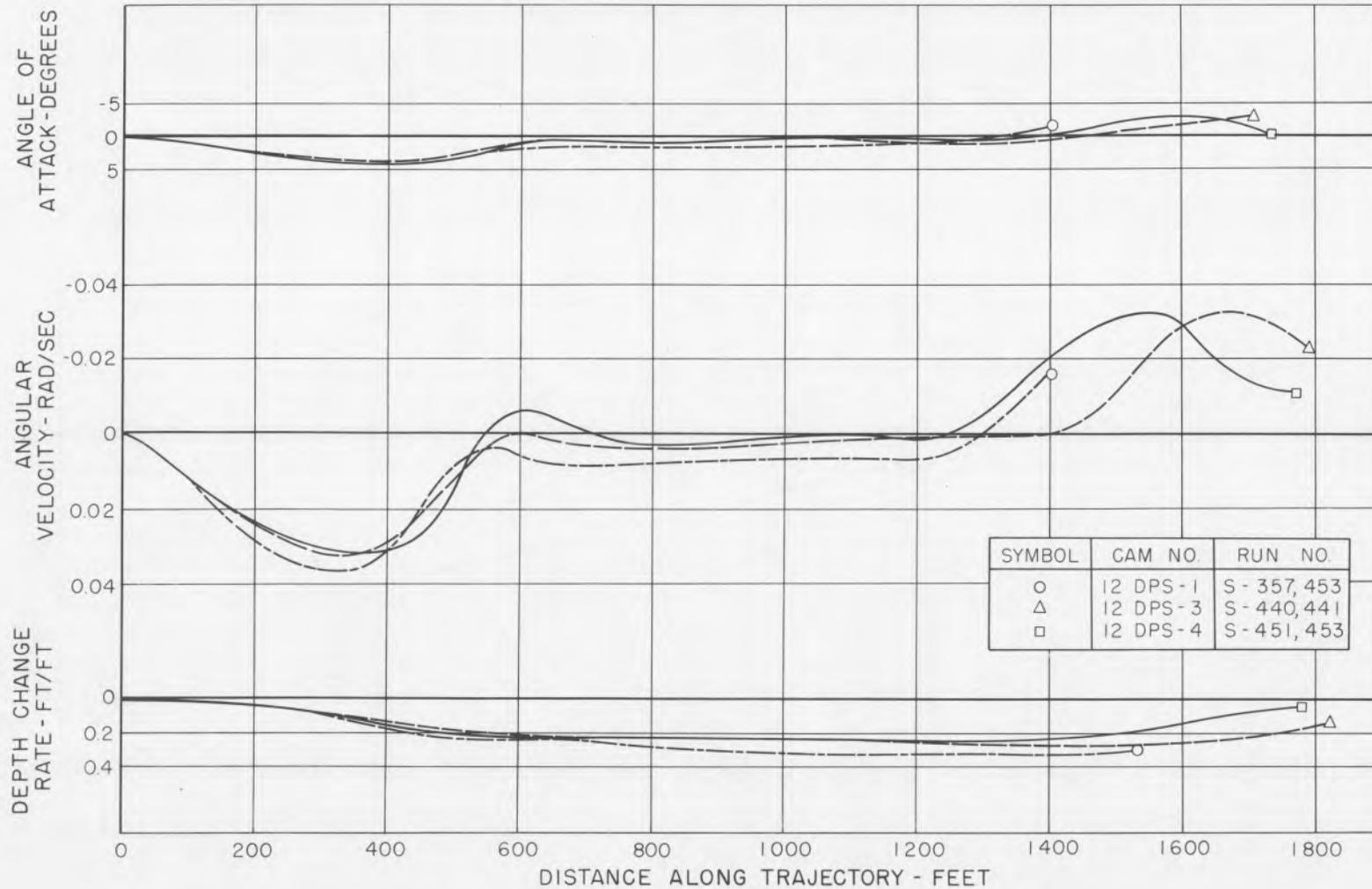


Fig. 5-28b Curvature response in depth changing maneuvers for revised configuration with 12° plane angles.

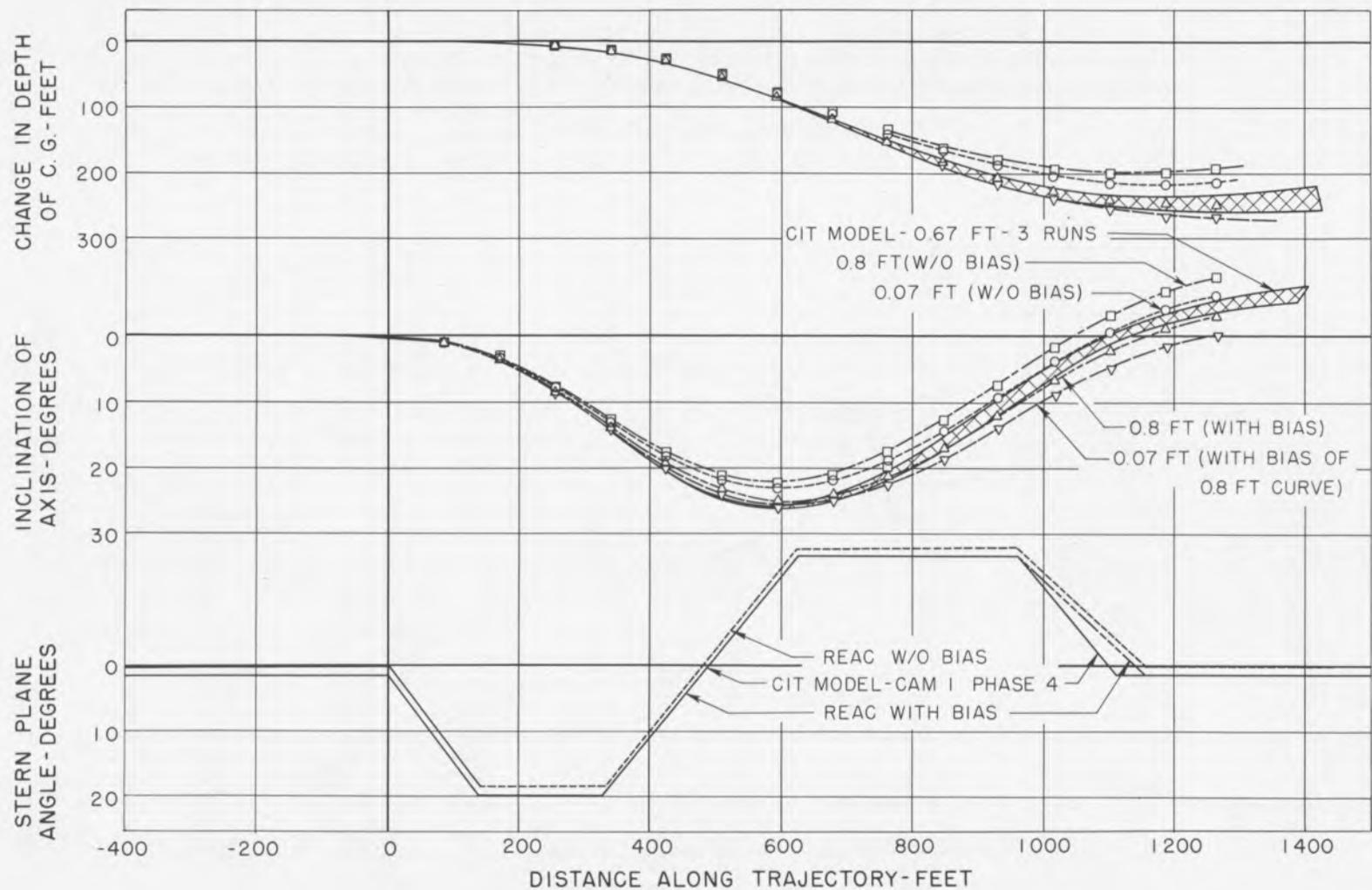


Fig. 5-29a Comparison of experimental and computed trajectories in depth changing maneuvers for original configuration for 15 fps model speed and 25 knot prototype speed.

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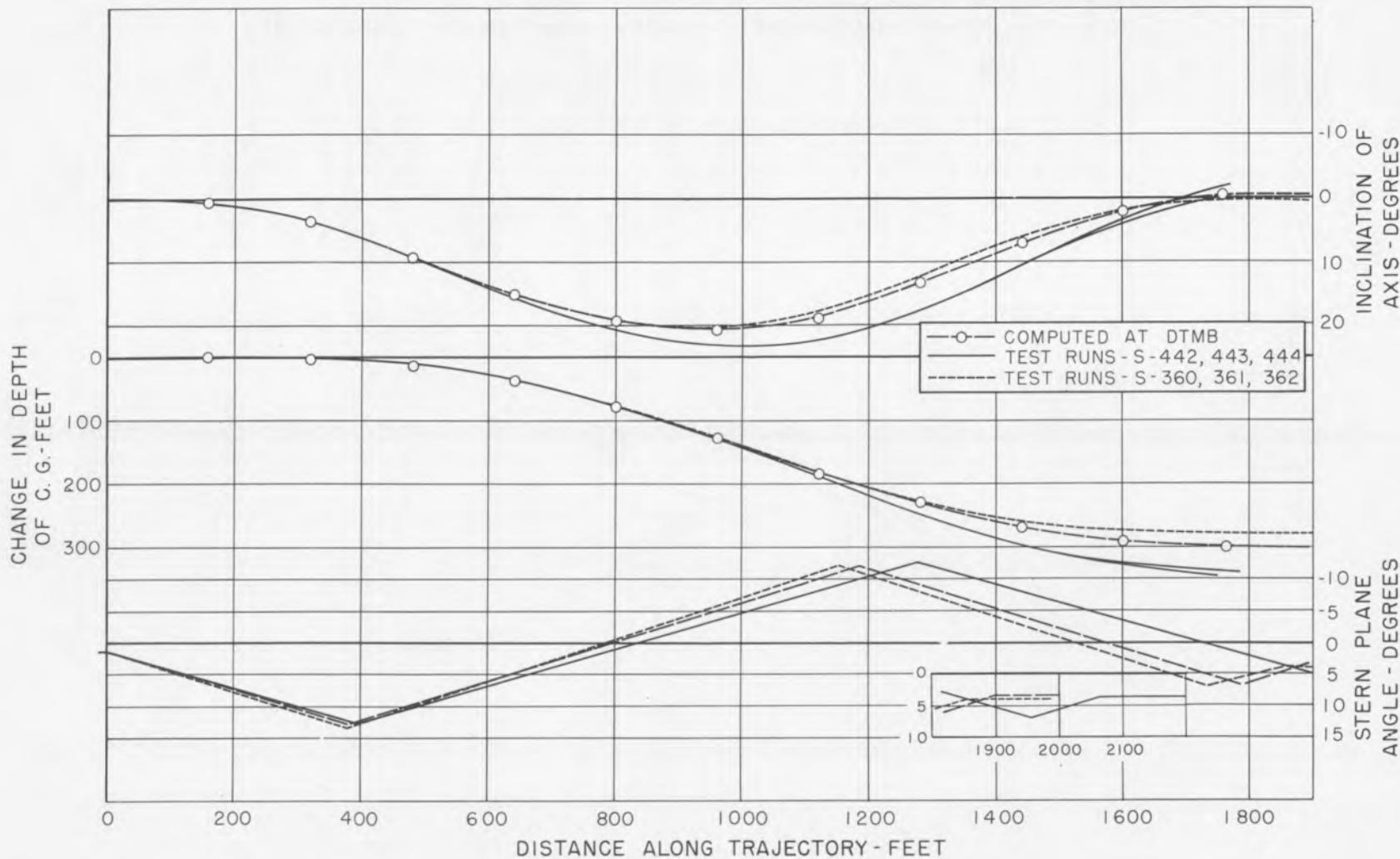
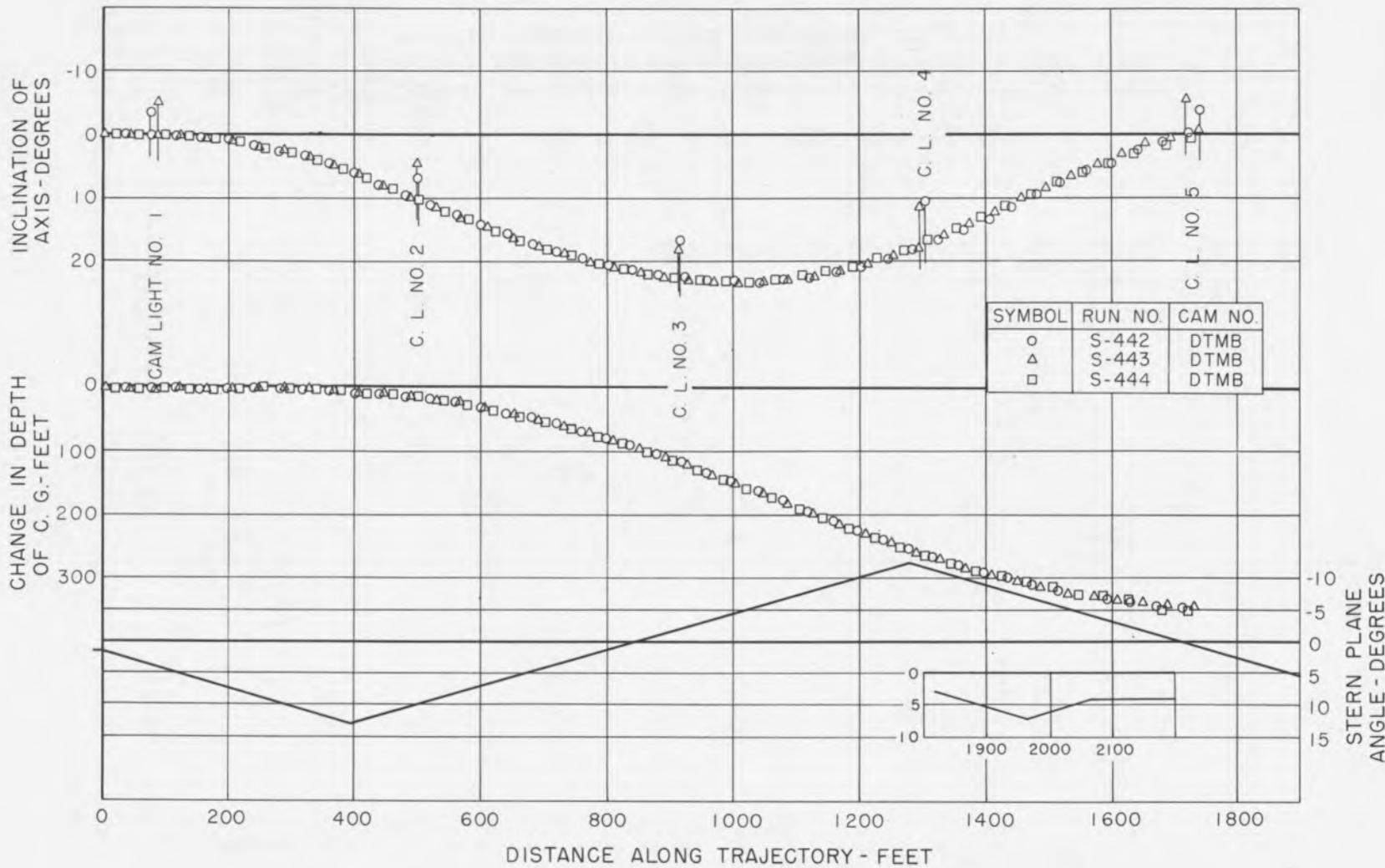


Fig. 5-29b Comparison of experimental and computed trajectories in depth changing maneuver for original configuration with 15 fps model speed and 95 knot prototype speed.

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Fig. 5-29c Trajectory response for three model test runs in a 95 knot full scale velocity depth changing maneuver showing consistency and reproducibility of data.

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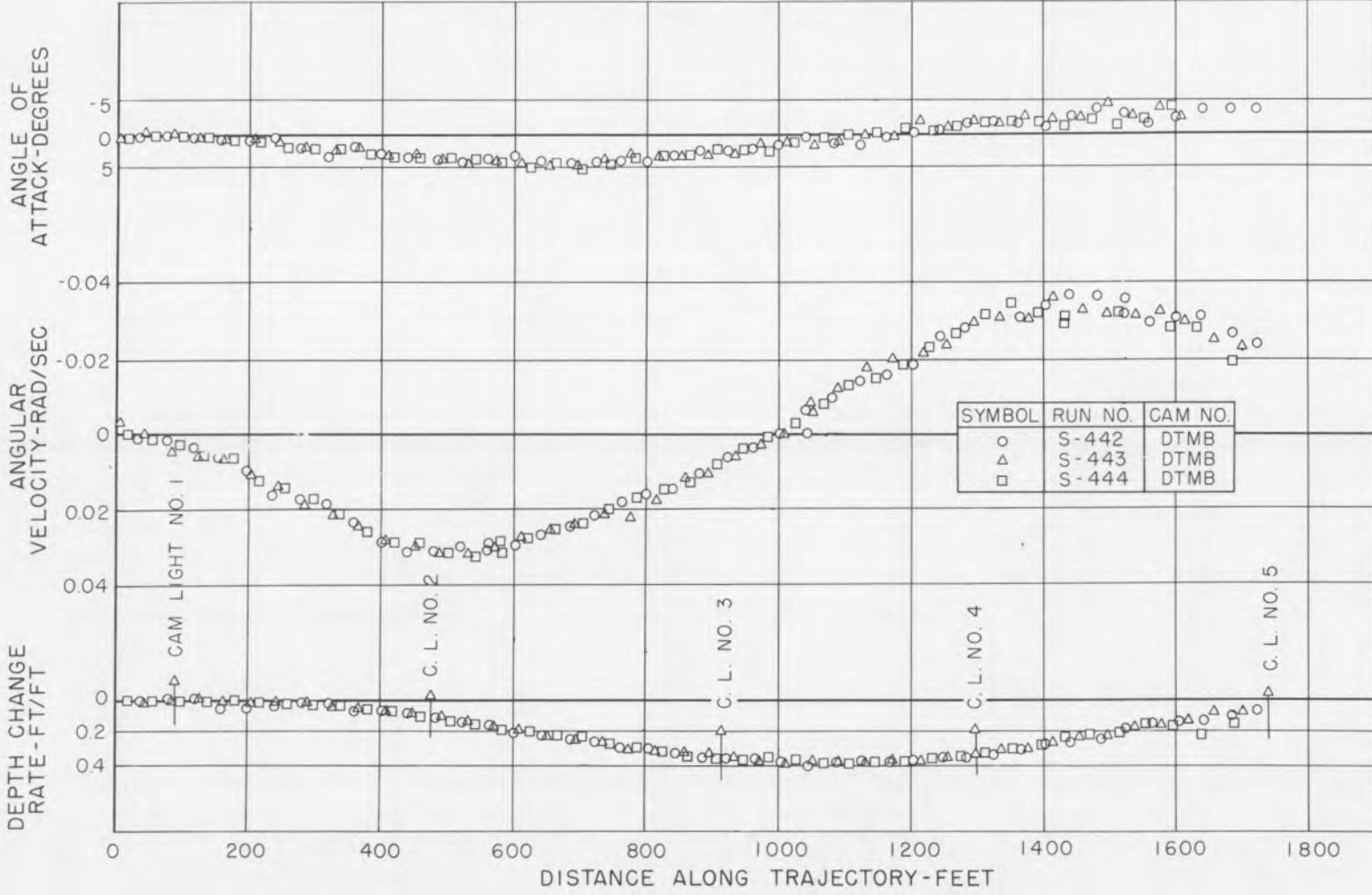
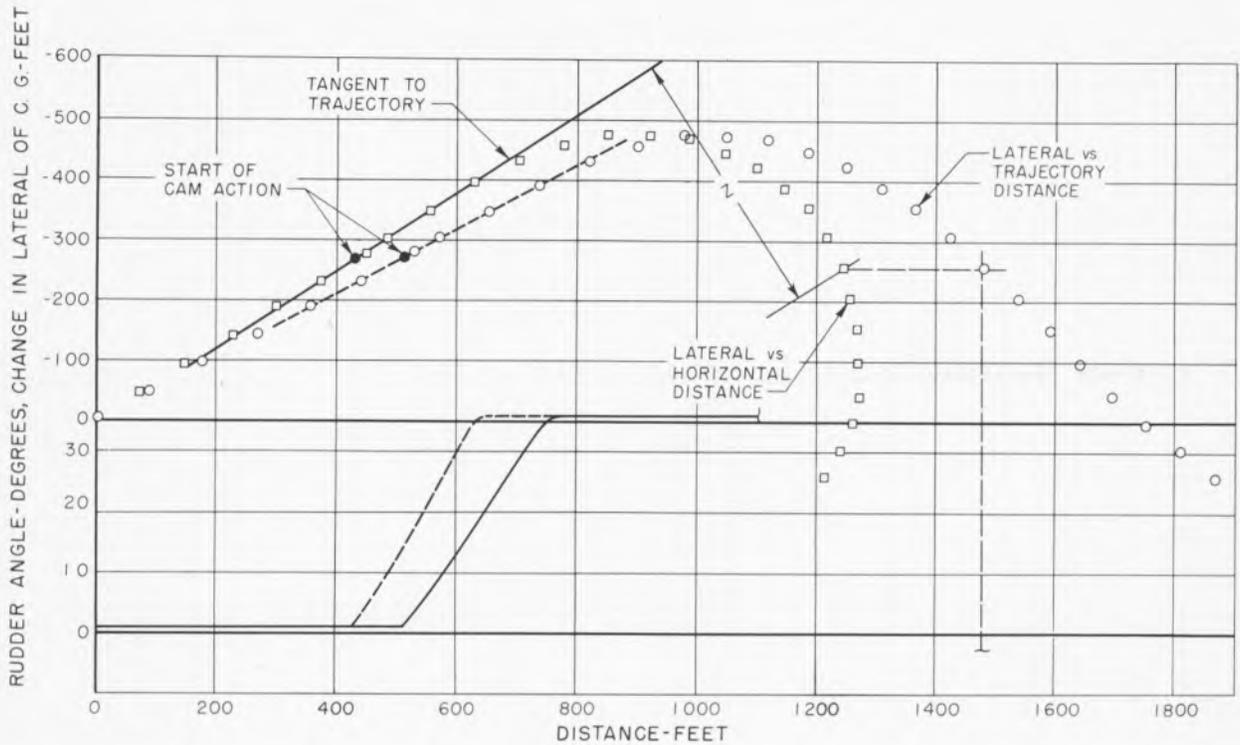
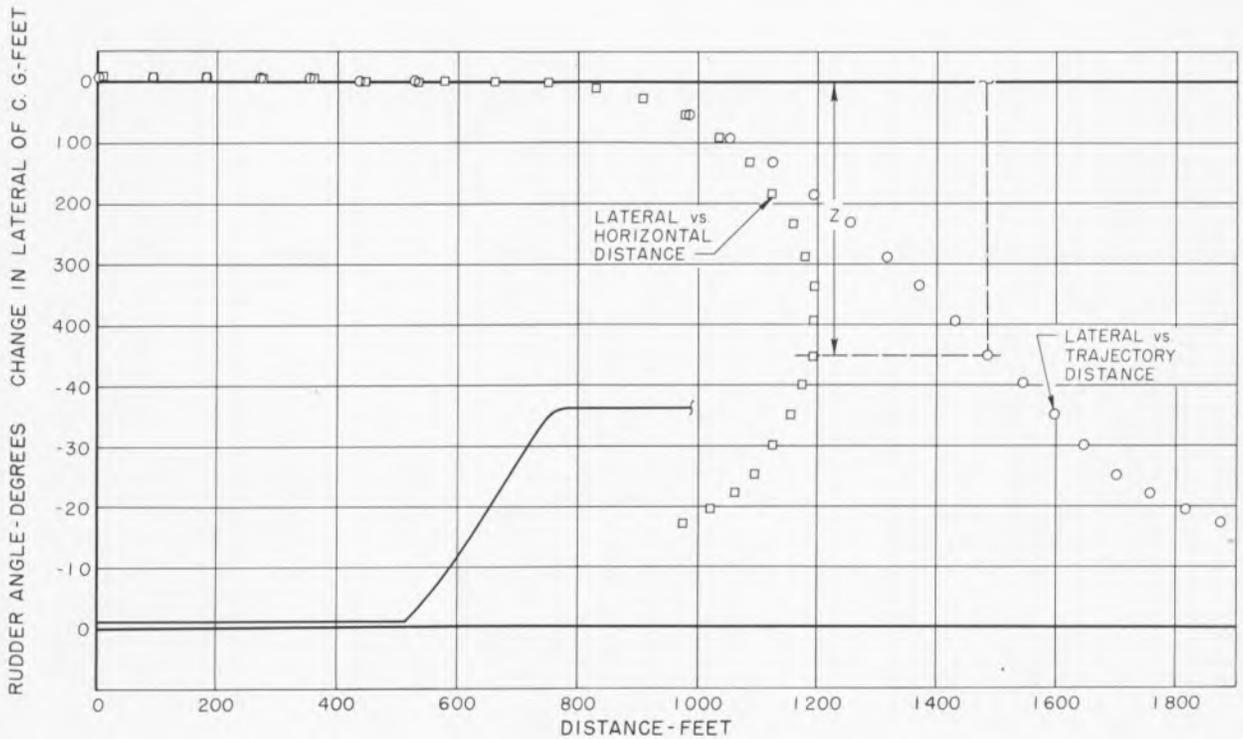


Fig. 5-29d Curvature response for three successive model test runs in a 95 knot full scale velocity depth changing maneuver showing consistency and reproducibility of data.



(a) Unrotated



(b) Rotated

Fig. 6-1 Technique of rotation of the trajectories in the horizontal plane.

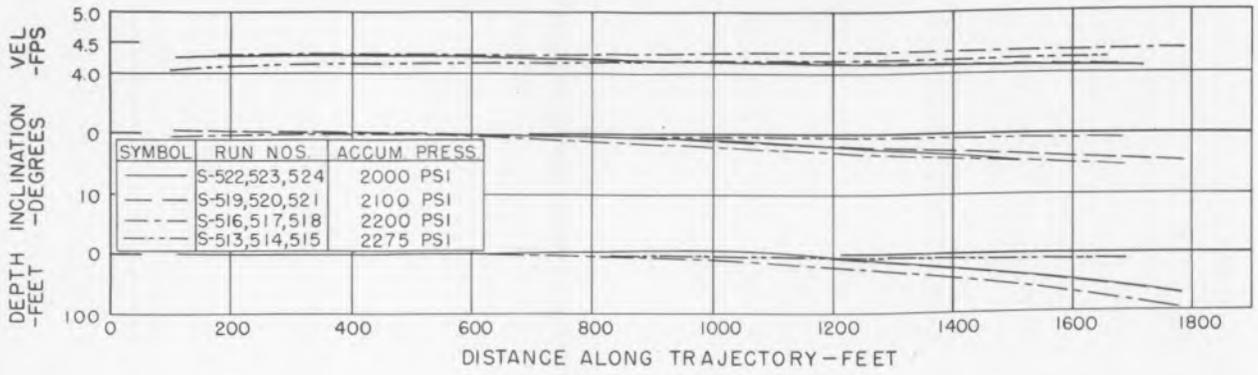


Fig. 6-2a Sensitivity of model response to variation of linear acceleration.

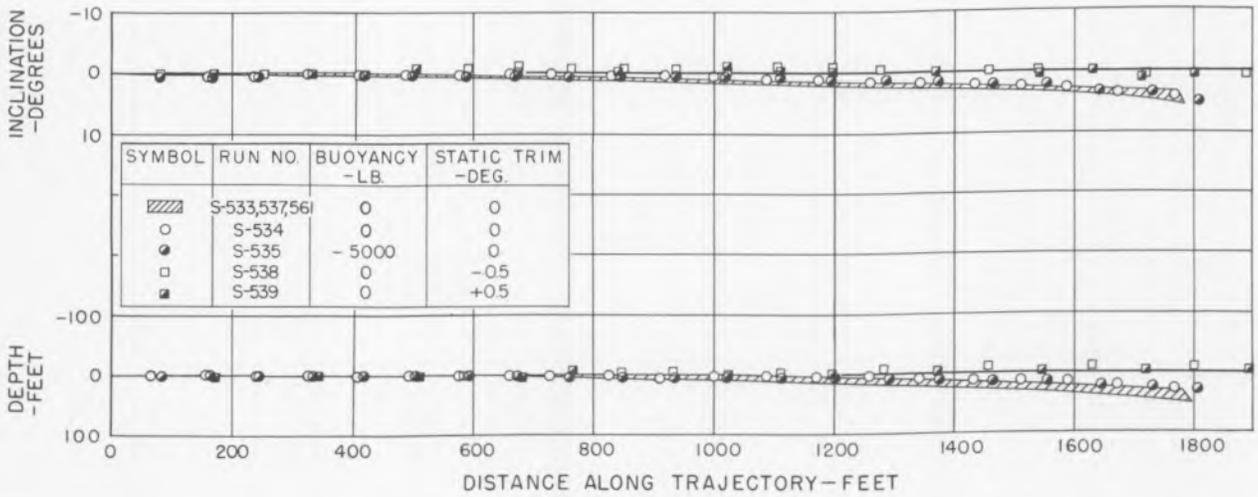


Fig. 6-2b Sensitivity of model response to variation of buoyancy and static trim.

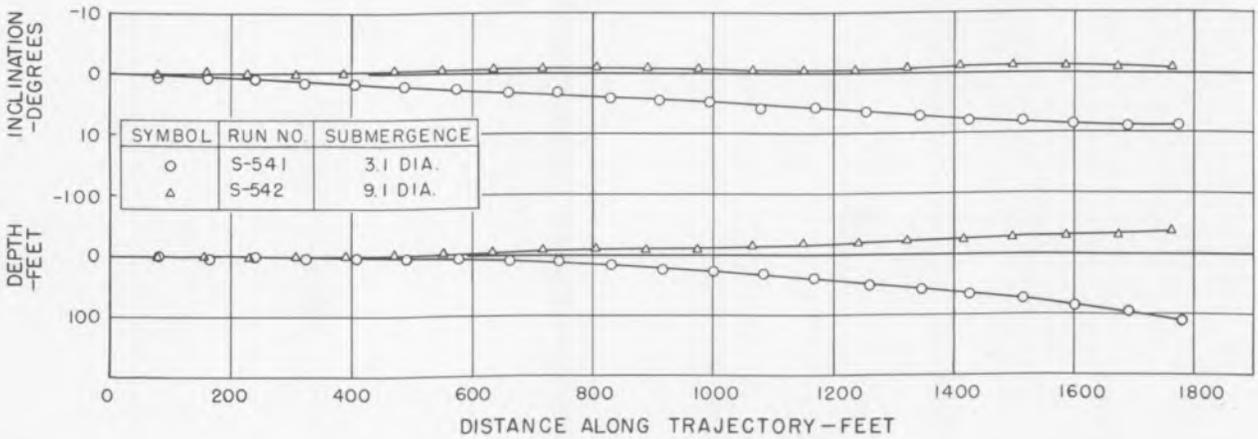


Fig. 6-2c Sensitivity of model response to the proximity of a free surface.

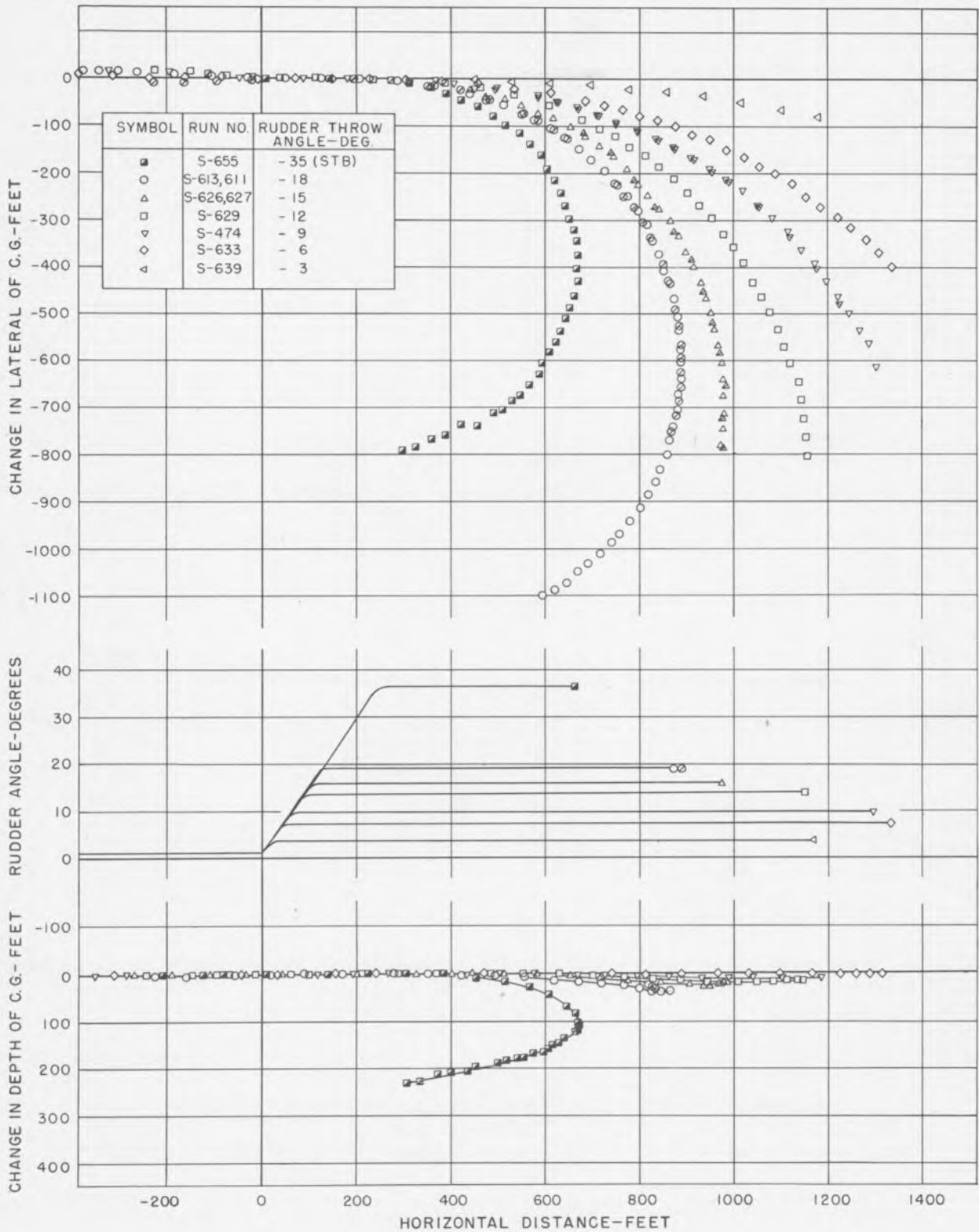


Fig. 6-3a Trajectory response for rudder control only in horizontal turning allowing depth change - horizontal and vertical projections of path of C. G.

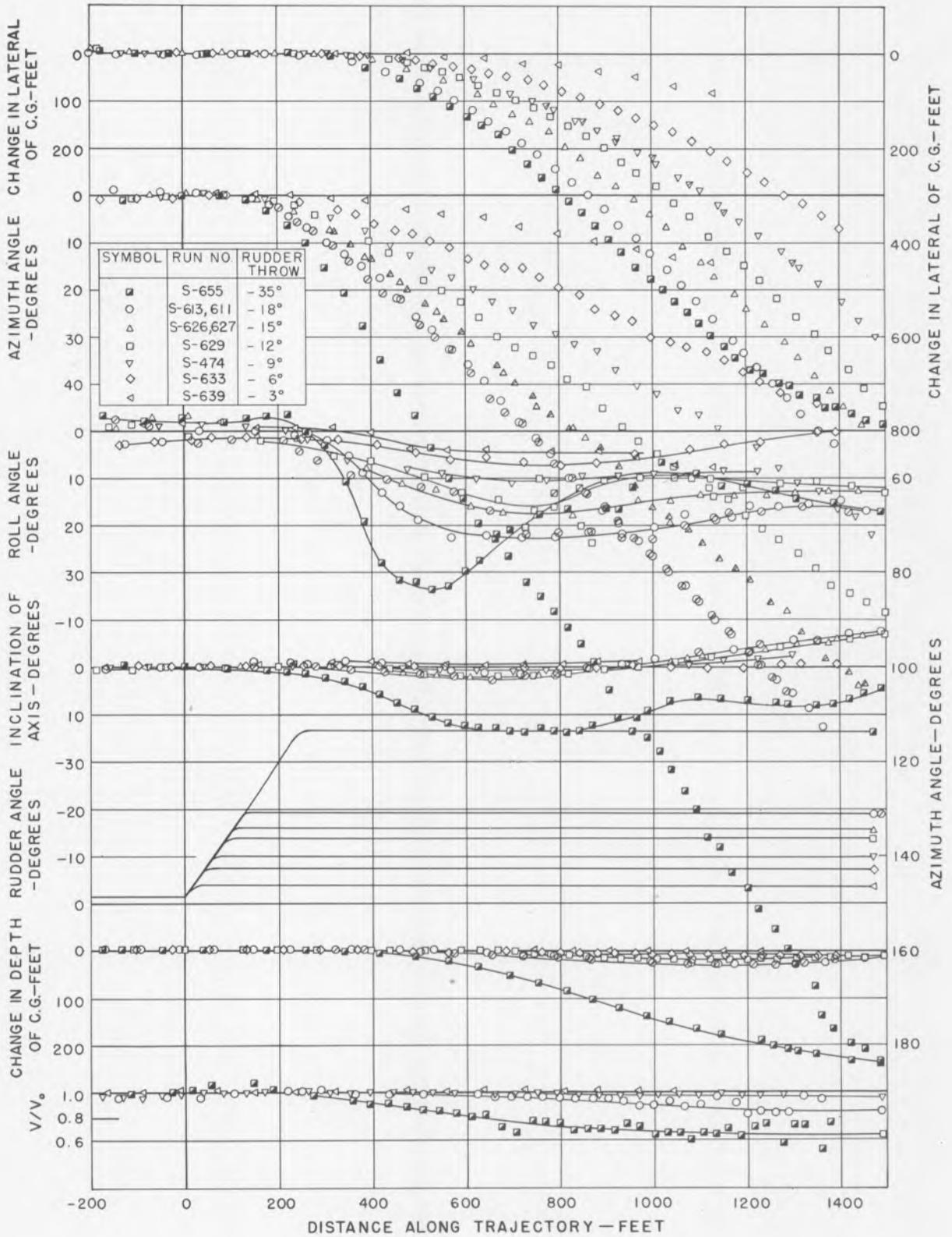


Fig 6-3b Trajectory response for rudder control only in horizontal turning allowing depth change.

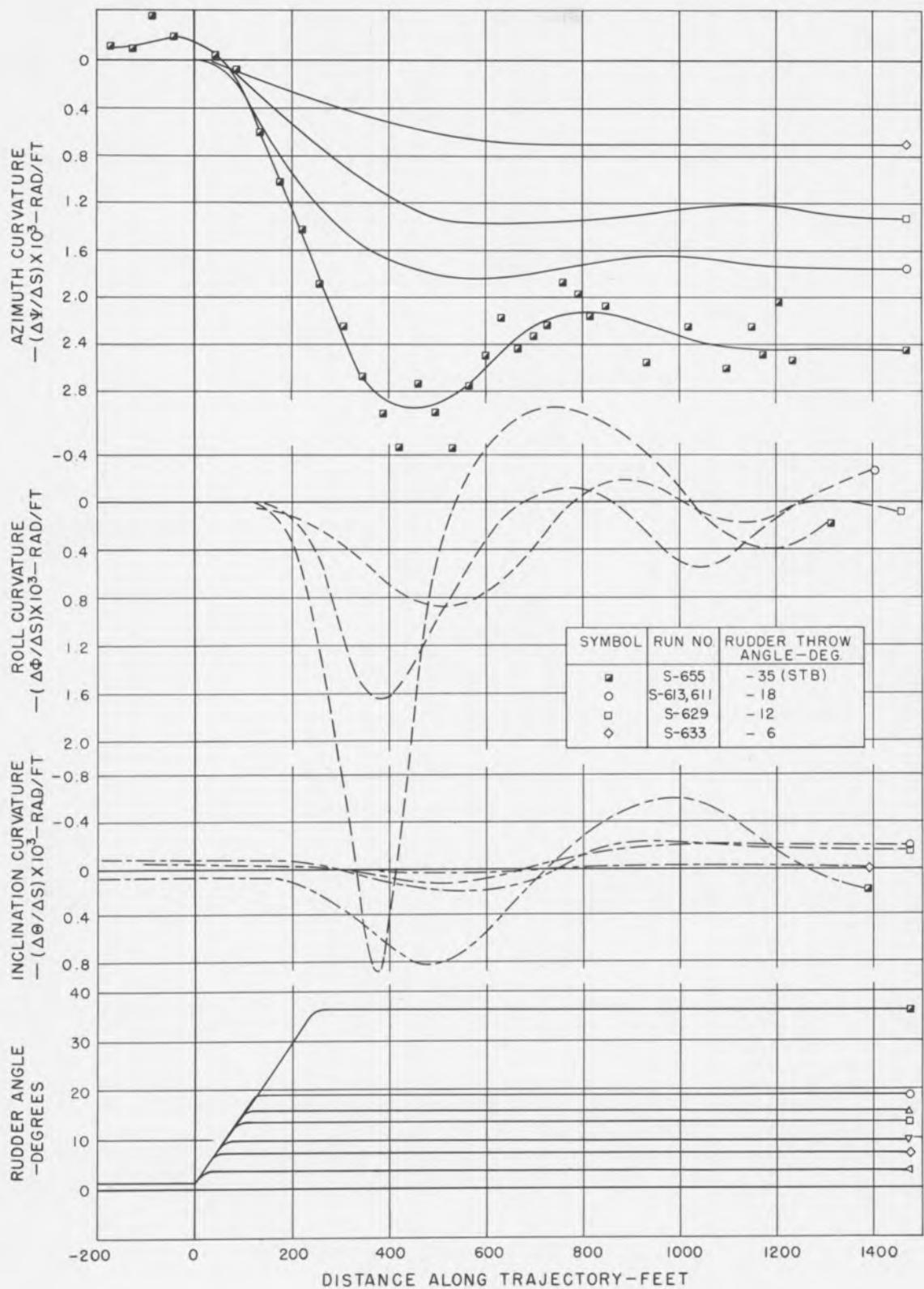


Fig. 6-3c Curvature response for rudder control only in horizontal turning allowing depth change.

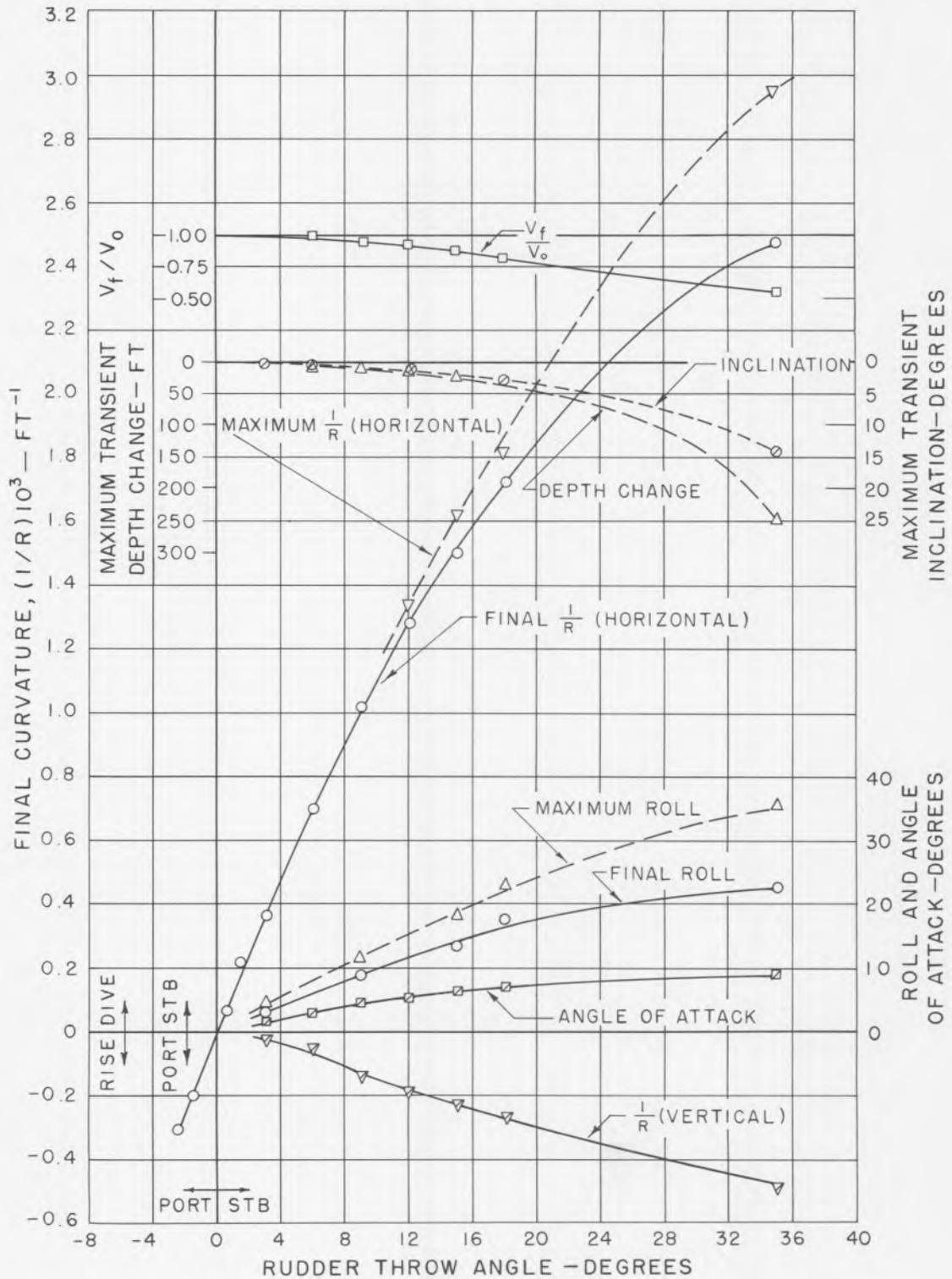


Fig. 6-3d Transient and equilibrium conditions in horizontal turning allowing depth change for rudder control only.

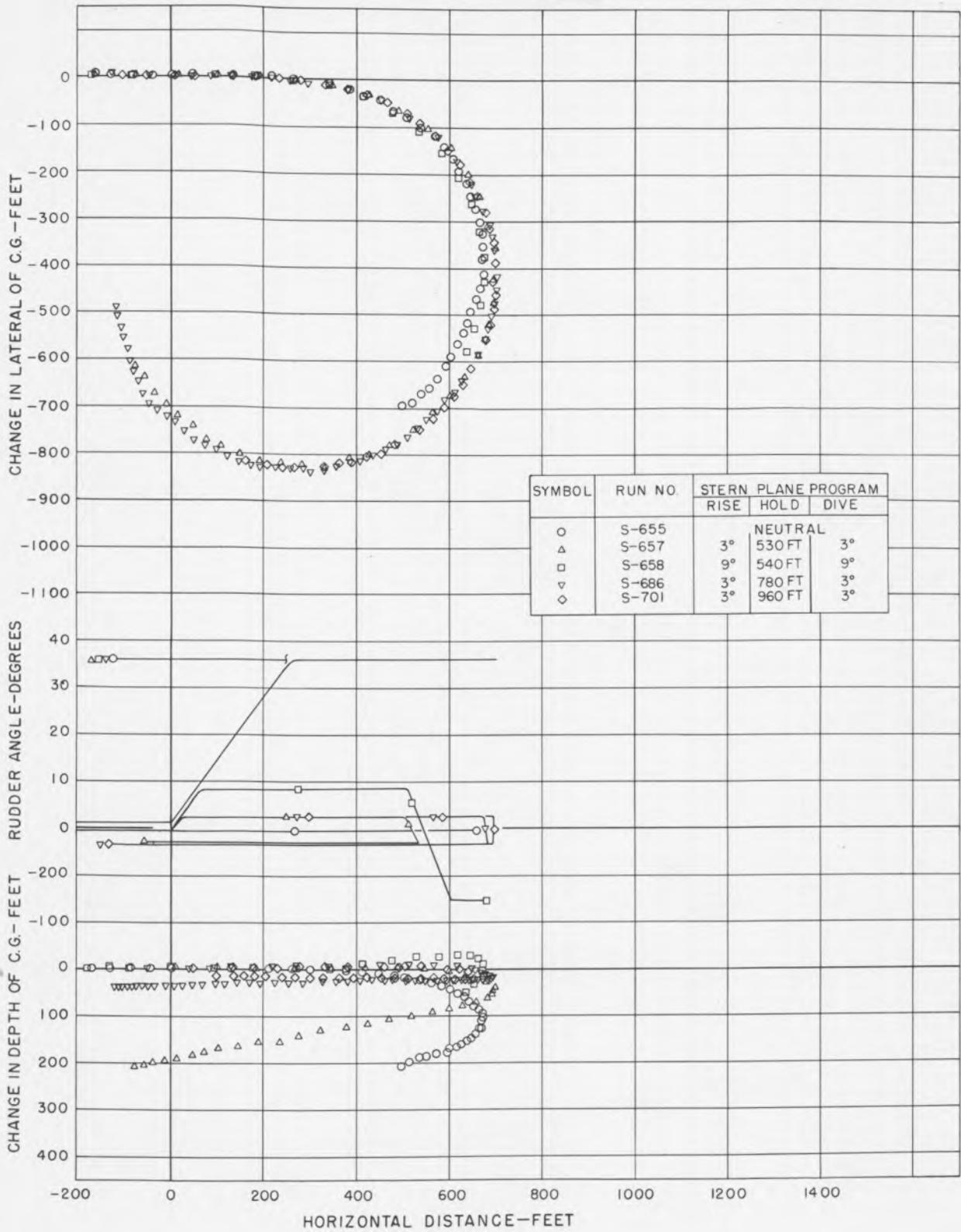


Fig. 6-4a Trajectory response for 35° rudder deflections in horizontal turning with depth control by means of stern planes - horizontal and vertical projections of path of C.G.

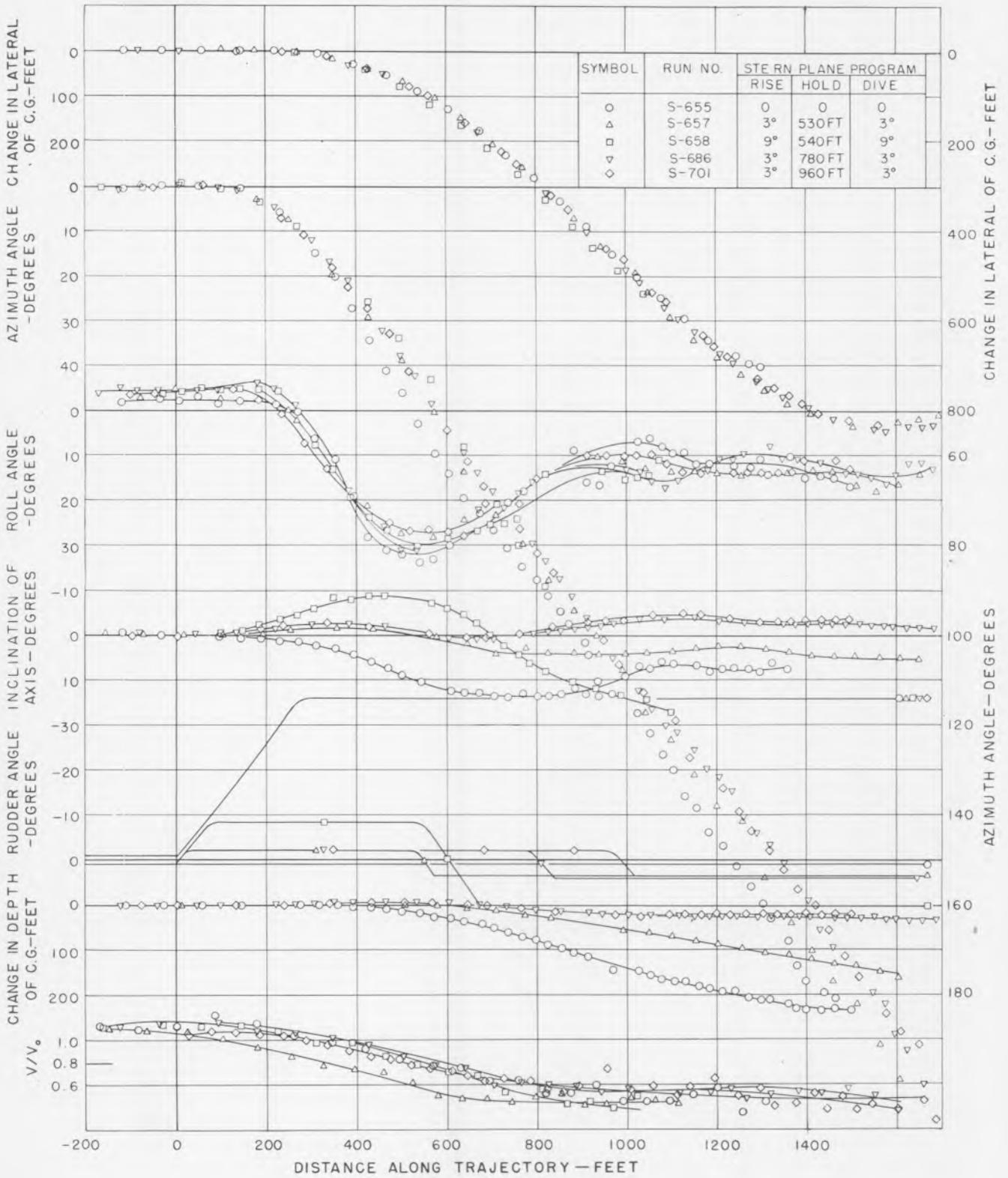


Fig. 6-4b Trajectory response for 35° rudder deflections in horizontal turning with depth control by means of stern planes.

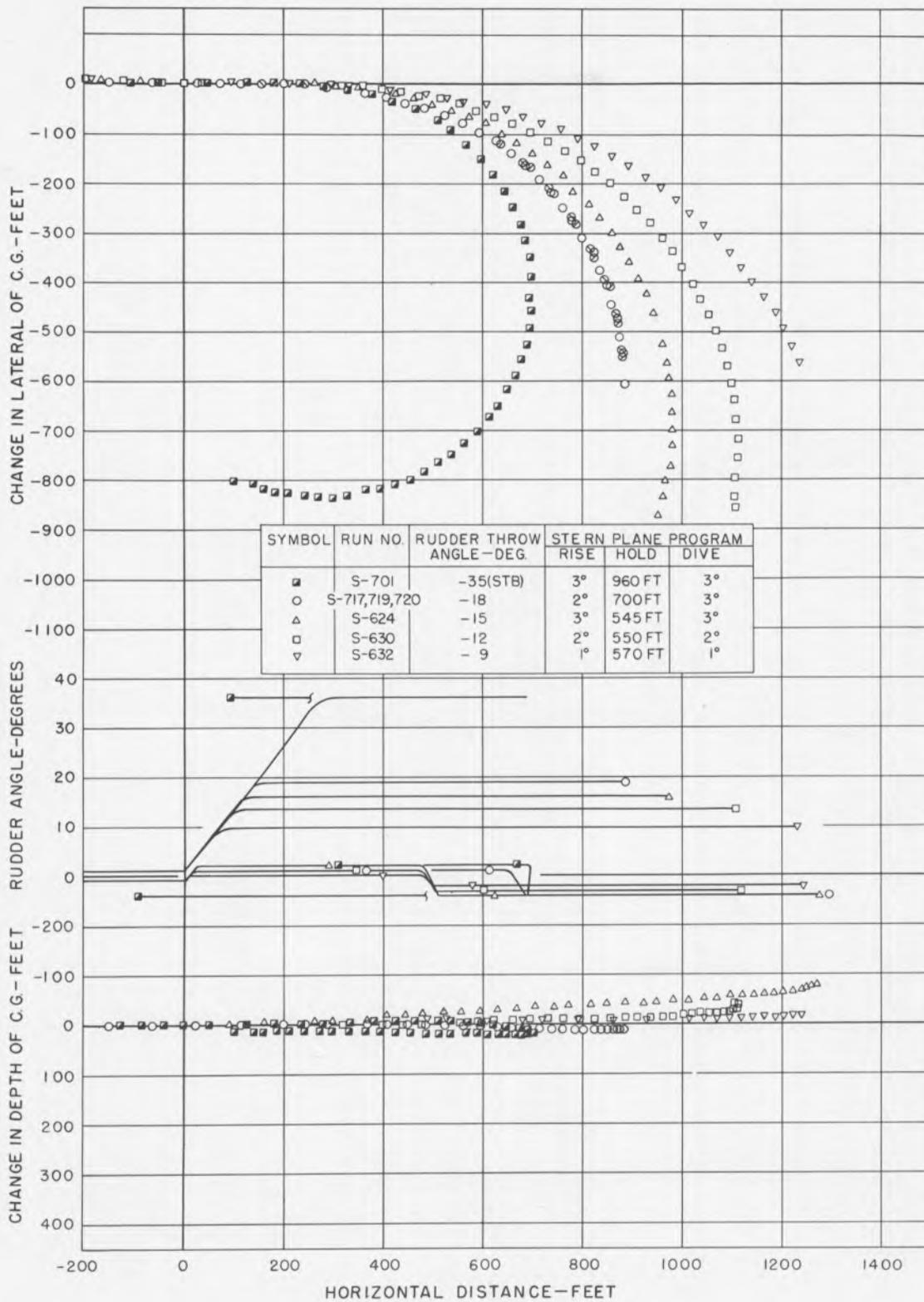


Fig. 6-5a Trajectory response in horizontal turning with depth control by means of stern planes - horizontal and vertical projections of path of C.G.

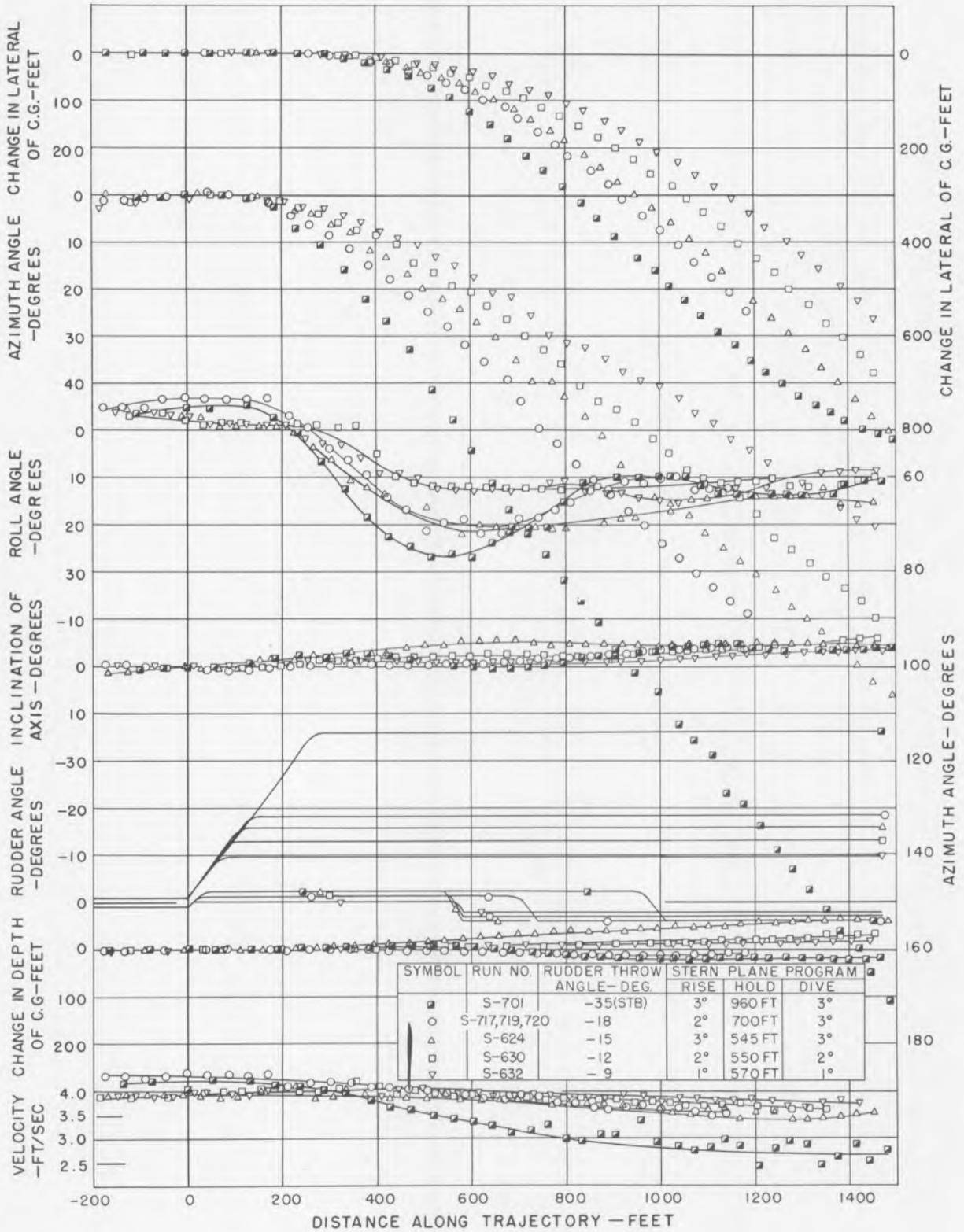


Fig. 6-5b Trajectory response in horizontal turning with depth control by means of stern planes.

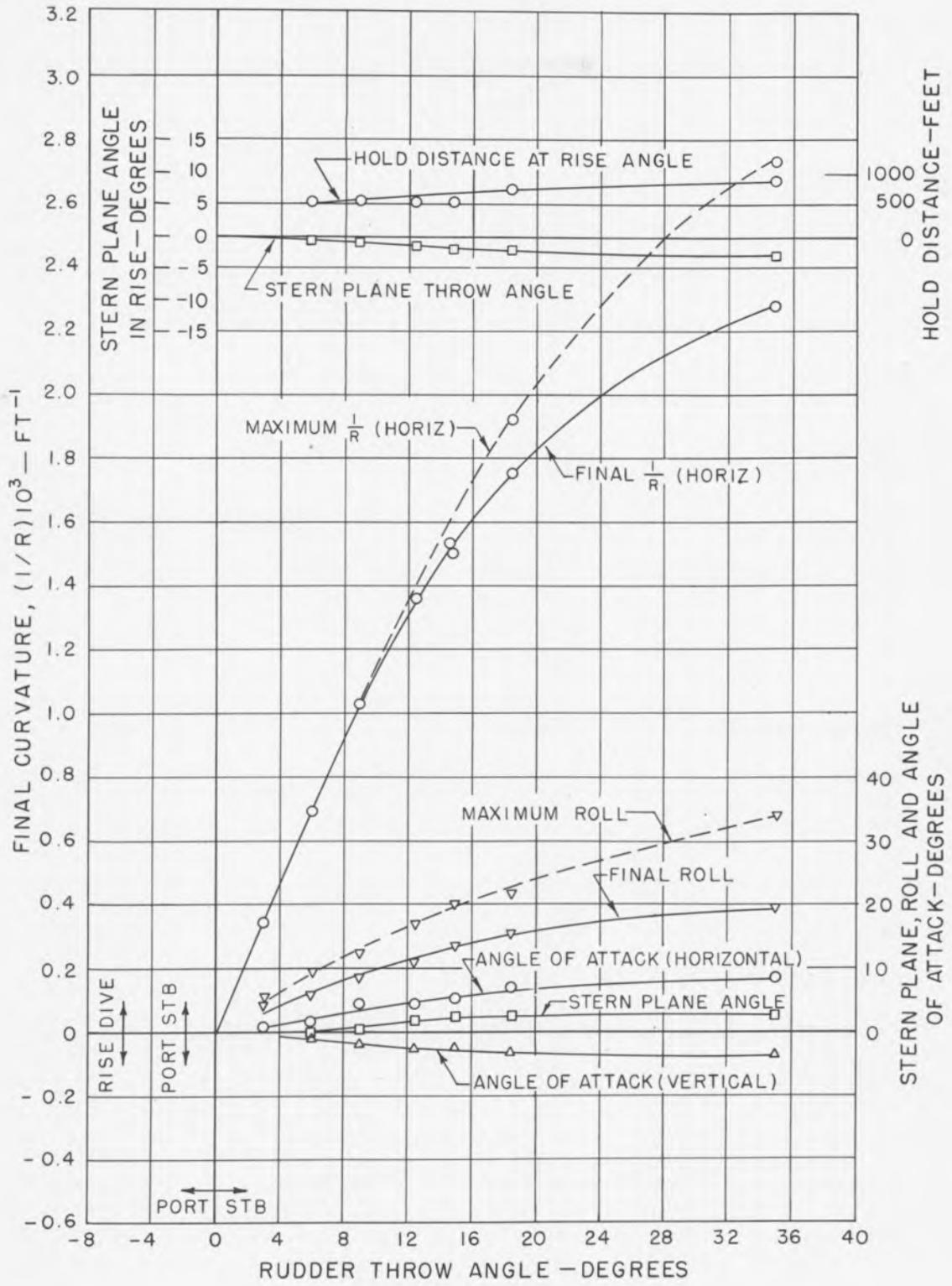


Fig. 6-5c Transient and equilibrium conditions in horizontal turning with depth control by means of stern planes.

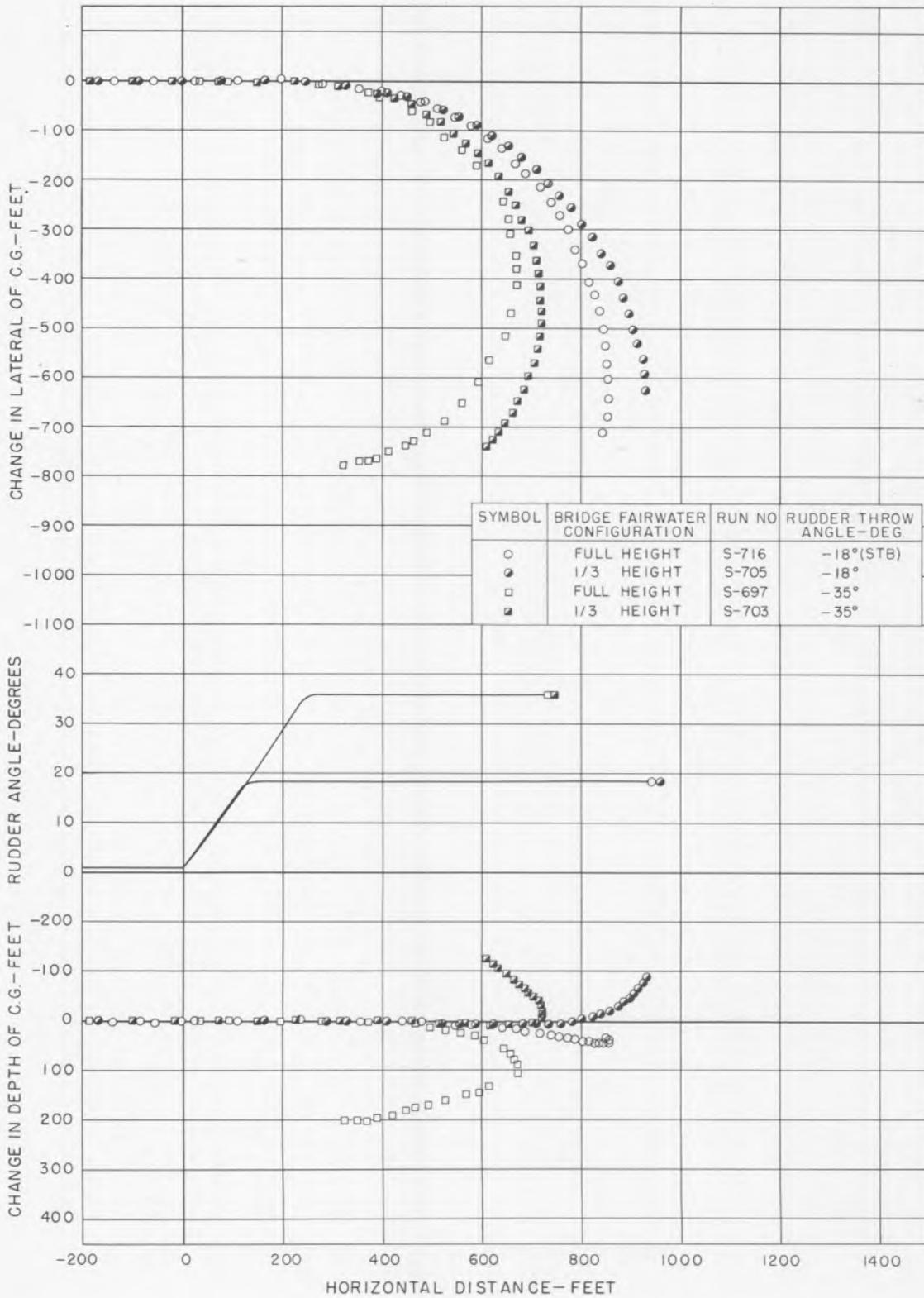


Fig. 6-6a Comparison of trajectory response in horizontal turning allowing depth change for reduced and full height bridge fairwater - horizontal and vertical projections of path of C.G.

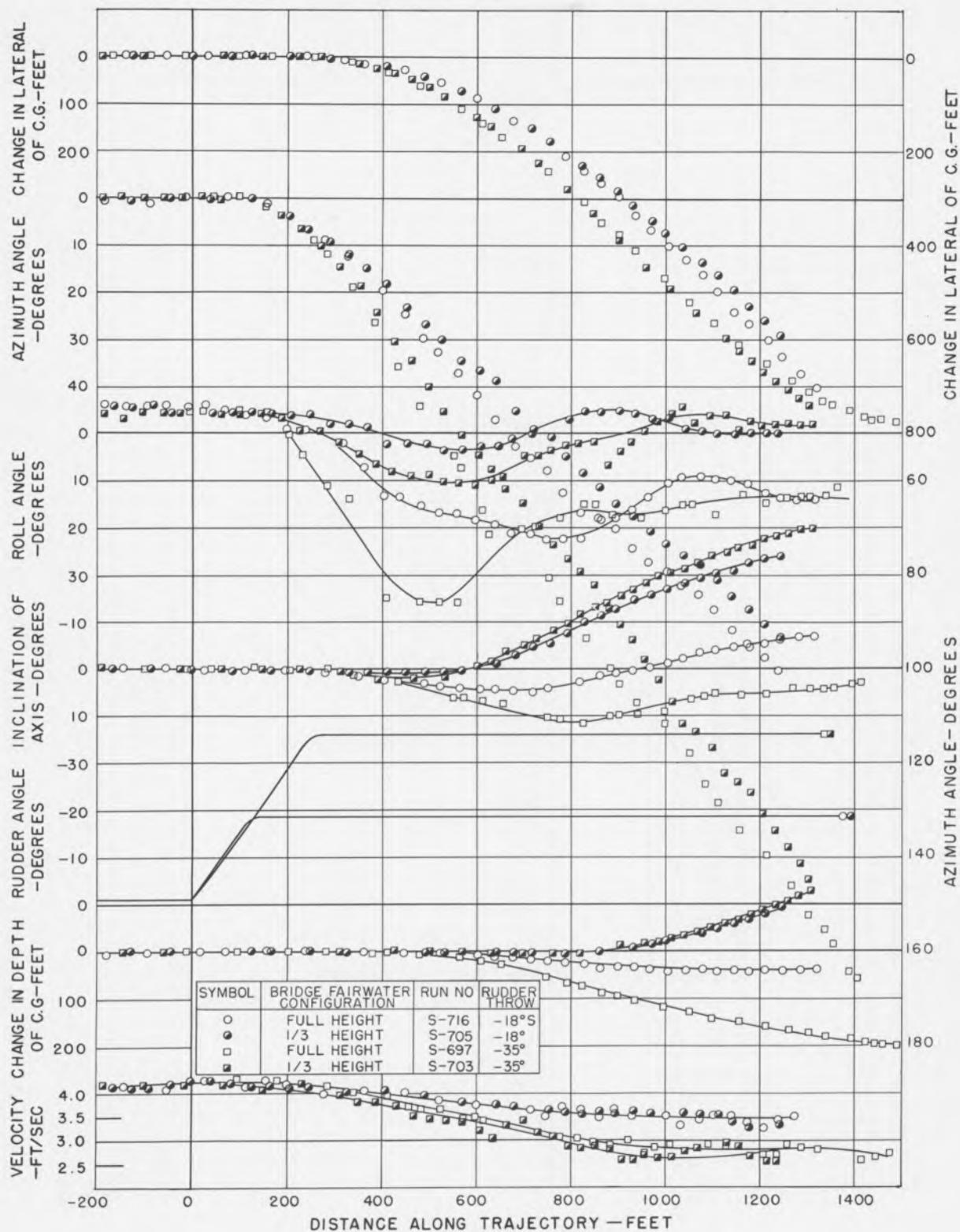


Fig. 6-6b Comparison of trajectory response in horizontal turning allowing depth change for reduced height and full height bridge fairwater.

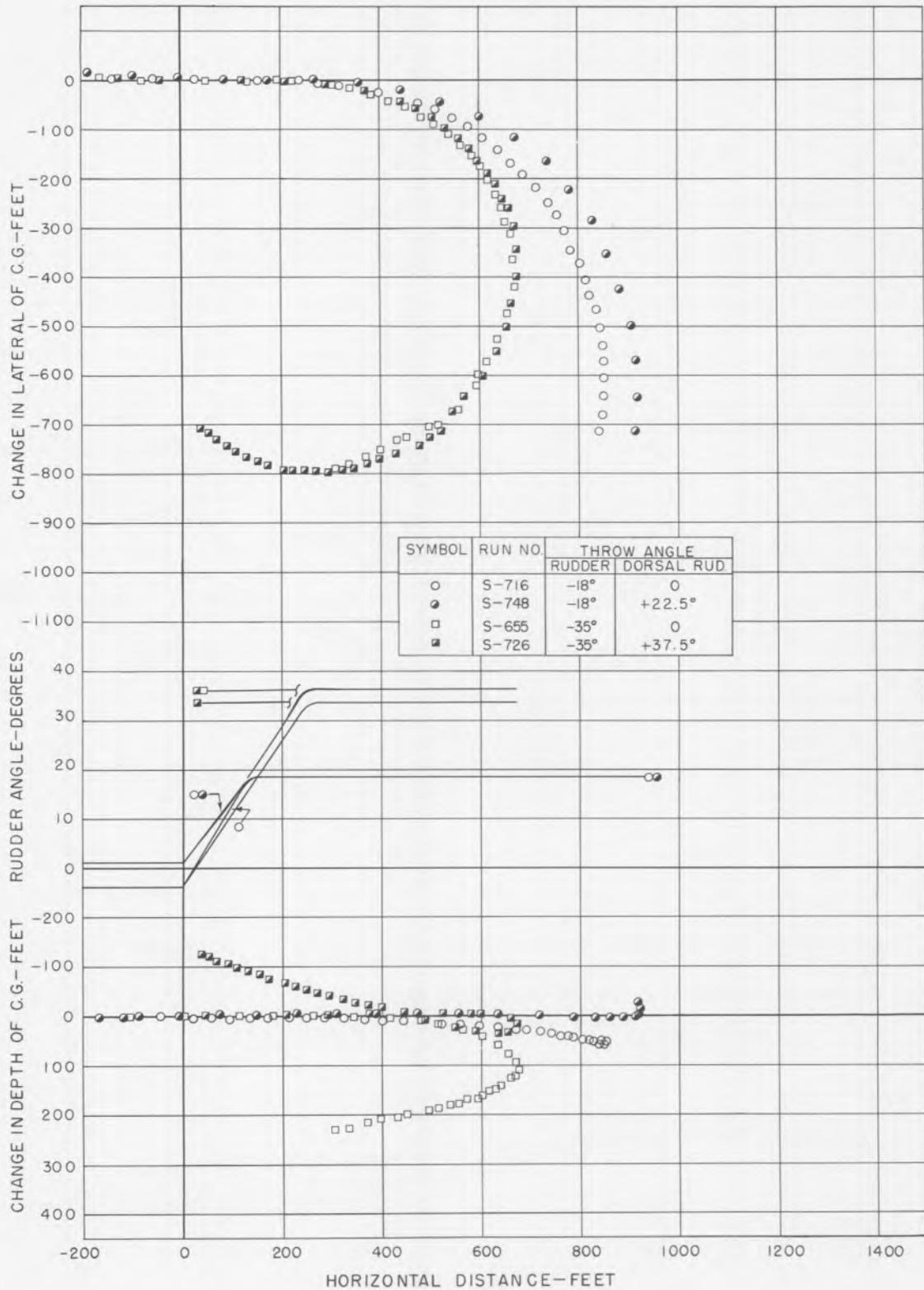


Fig. 6-7a Effect upon trajectory response in horizontal turning allowing depth change of roll control by means of dorsal rudder - horizontal and vertical projections of path of C. G.

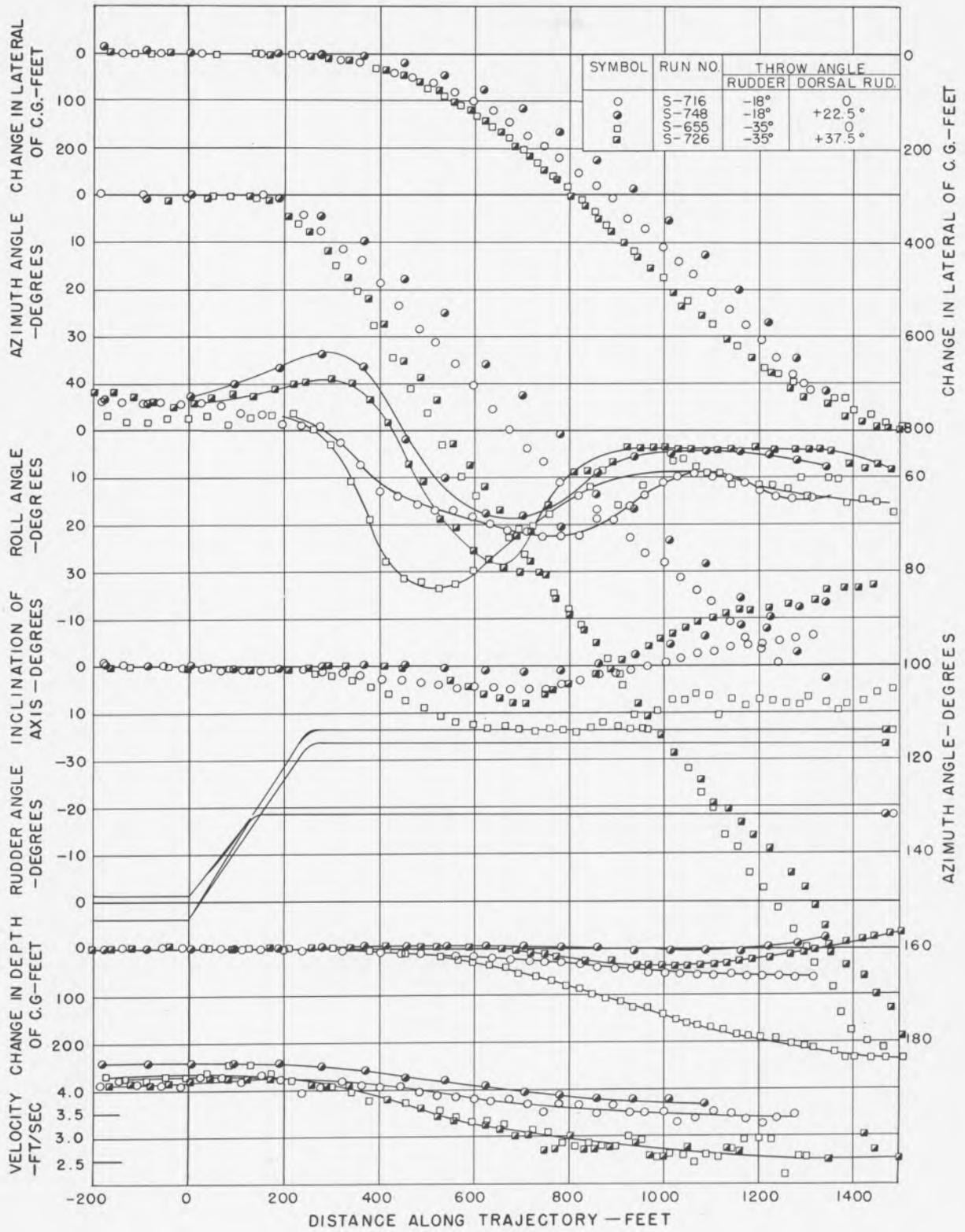


Fig. 6-7b Effect upon trajectory response in horizontal turning allowing depth change of roll control by means of dorsal rudder.

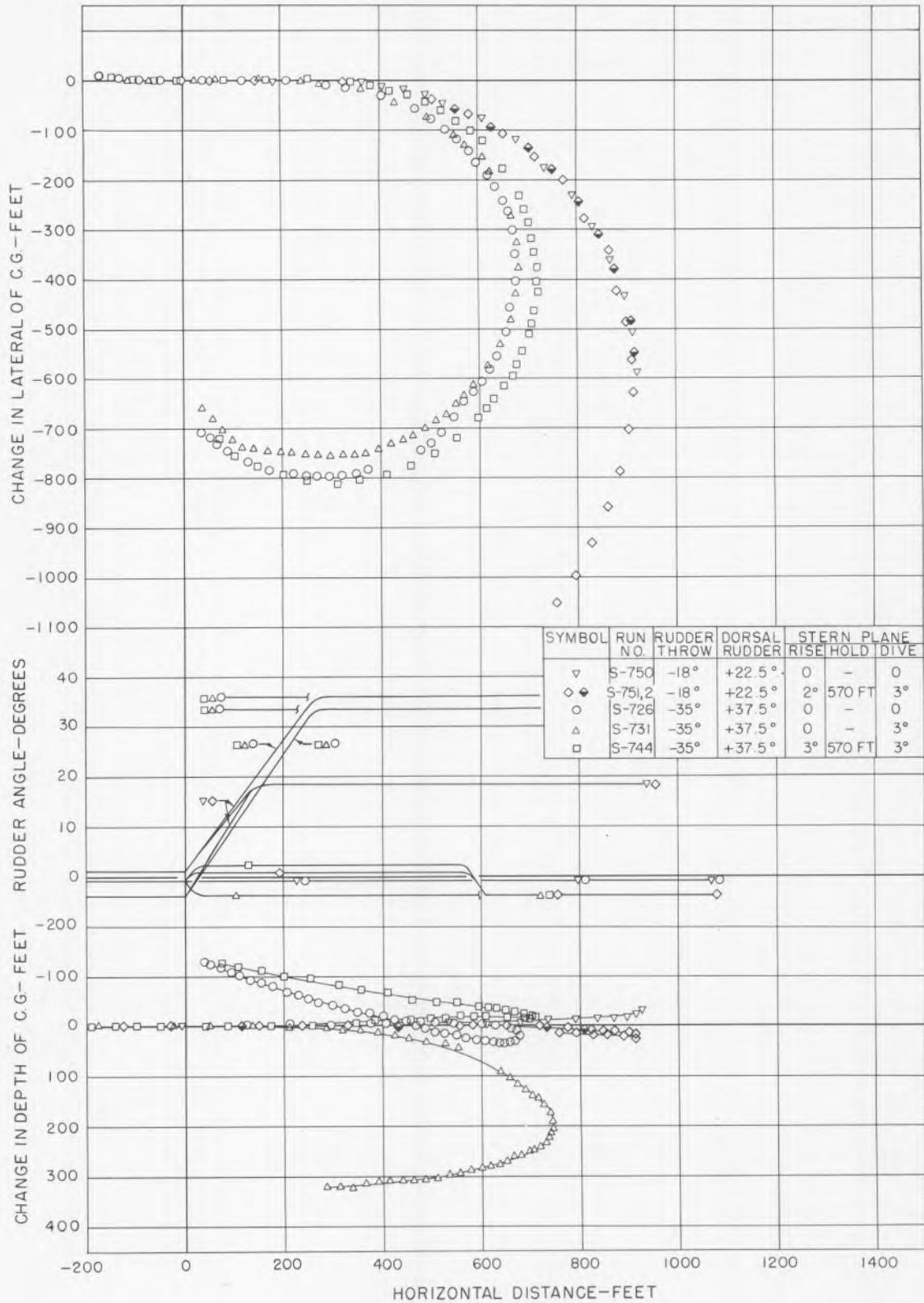


Fig. 6-8a Trajectory response in horizontal turning with depth control by means of stern planes and roll control by means of dorsal rudder - horizontal and vertical projections of paths of C.G.

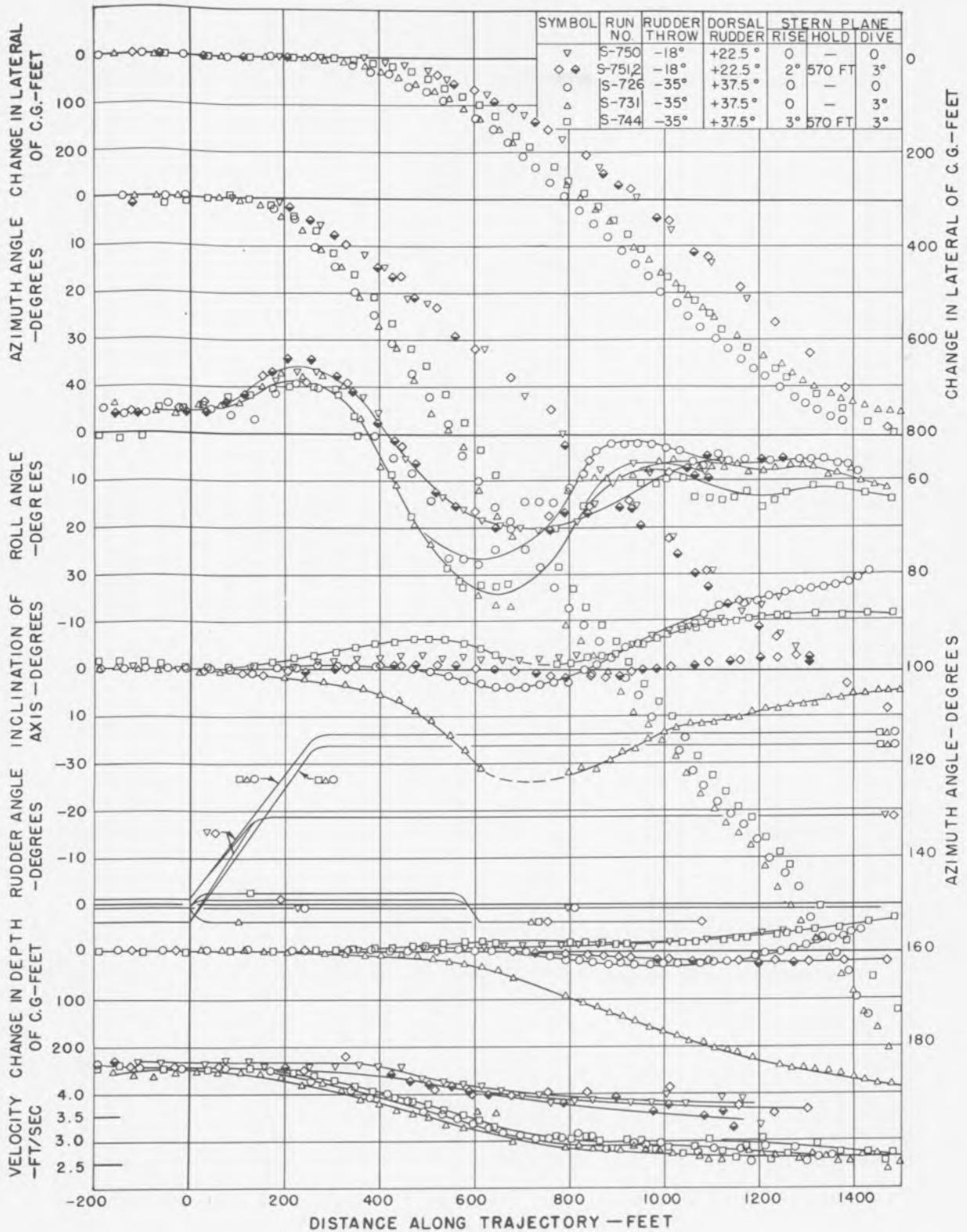


Fig. 6-8b Trajectory response in horizontal turning with depth control by means of stern planes and roll control by means of dorsal rudder.

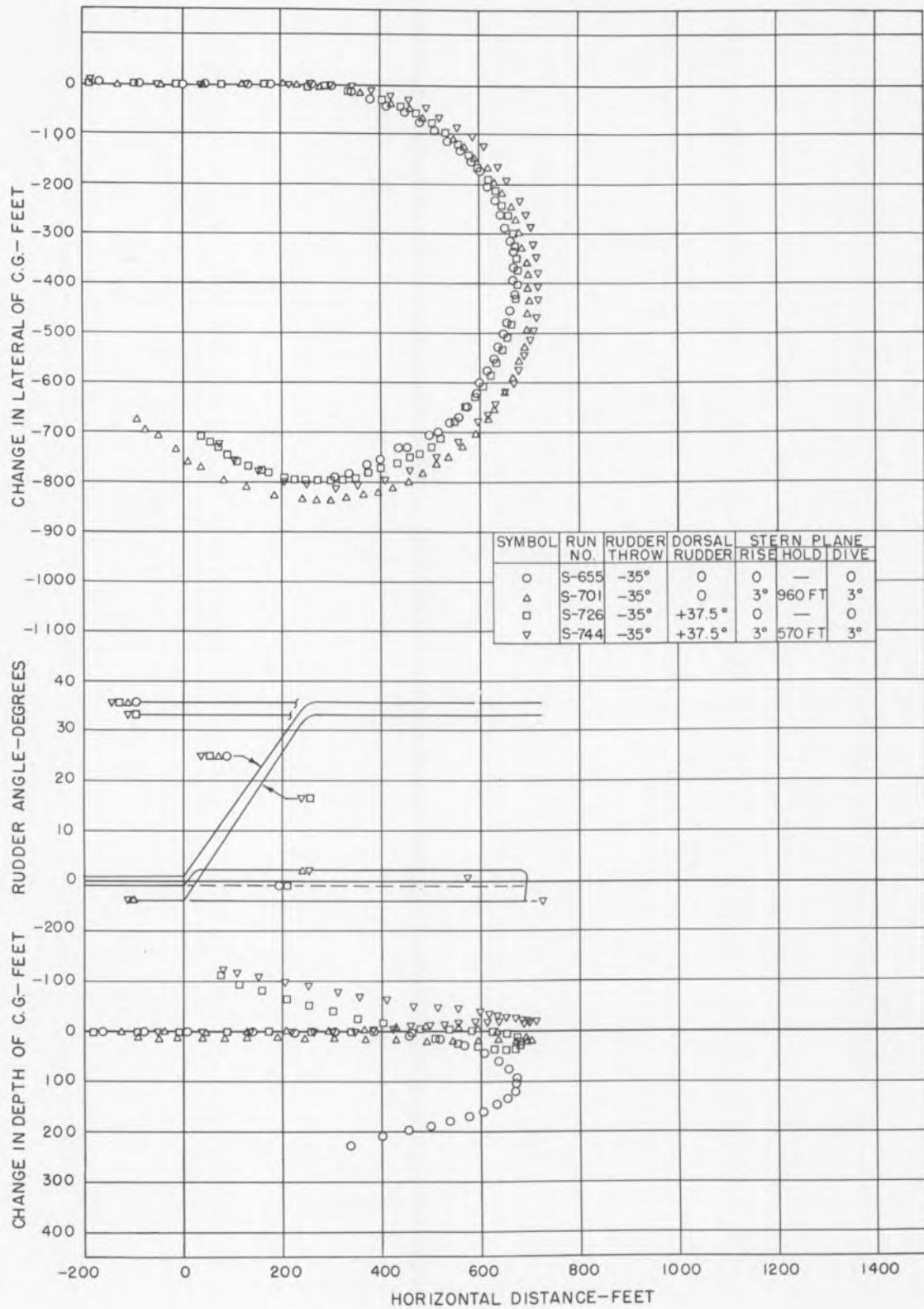


Fig. 6-9a Relative trajectory response in horizontal turning for various combinations of control actions for 35° rudder deflections - horizontal and vertical projections of path of C. G.

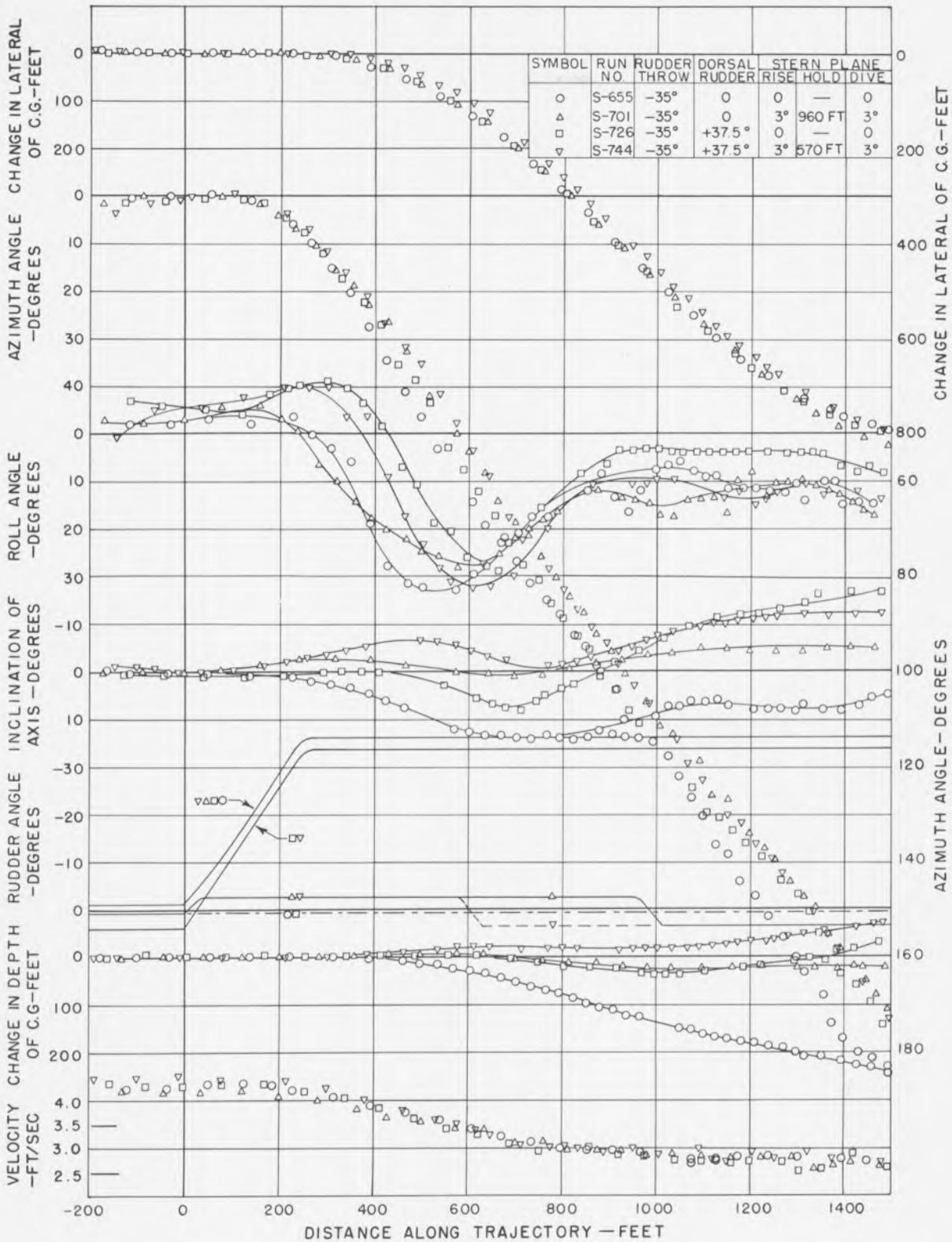
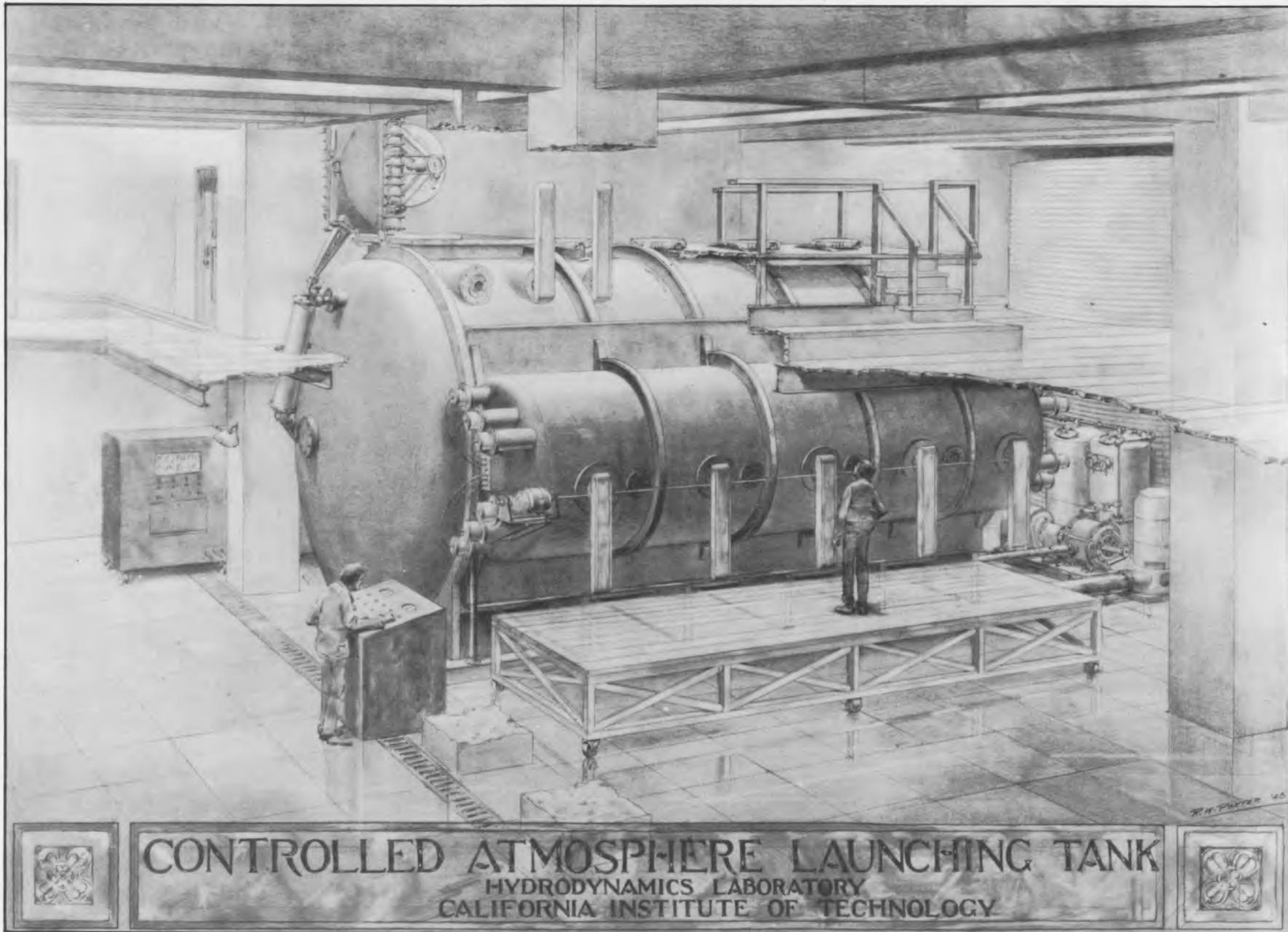


Fig. 6-9b Relative trajectory response in horizontal turning for various combinations of control actions for 35° rudder deflections.

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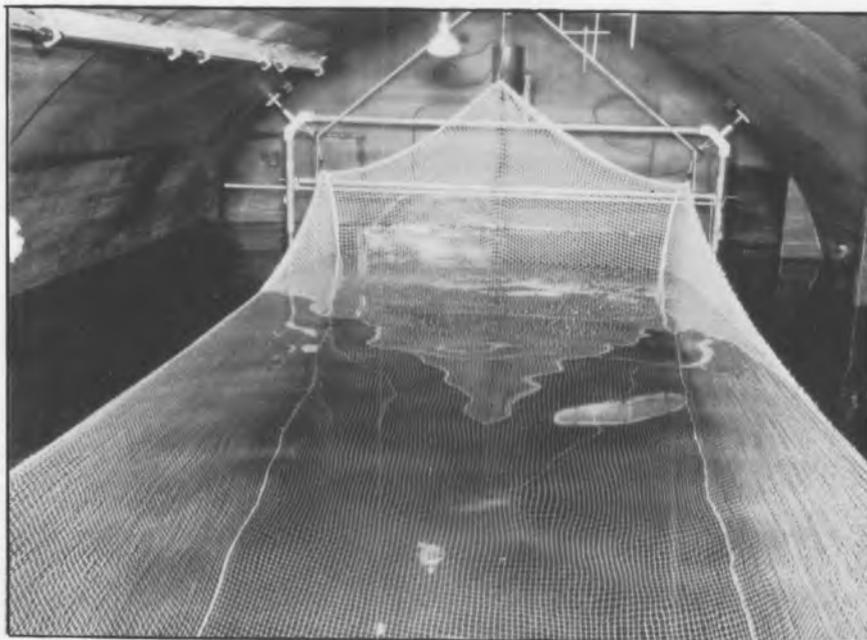
CONTROLLED ATMOSPHERE LAUNCHING TANK
HYDRODYNAMICS LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY

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Fig. B-1 Artist's sketch of the Controlled Atmosphere Launching Tank.

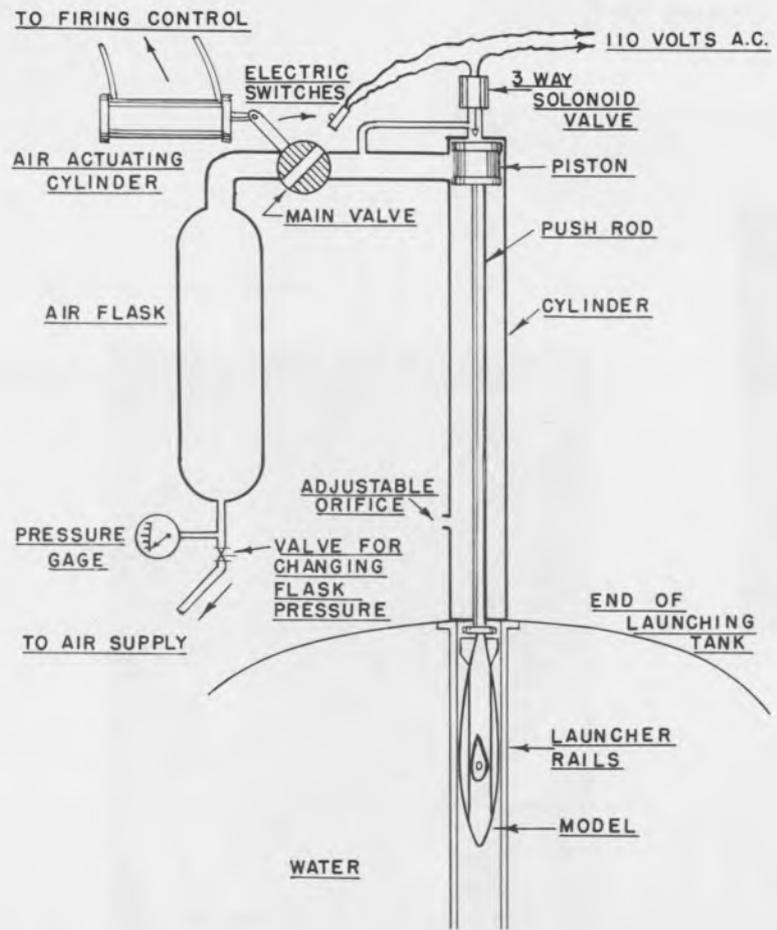


(a) Tank bulge after draining

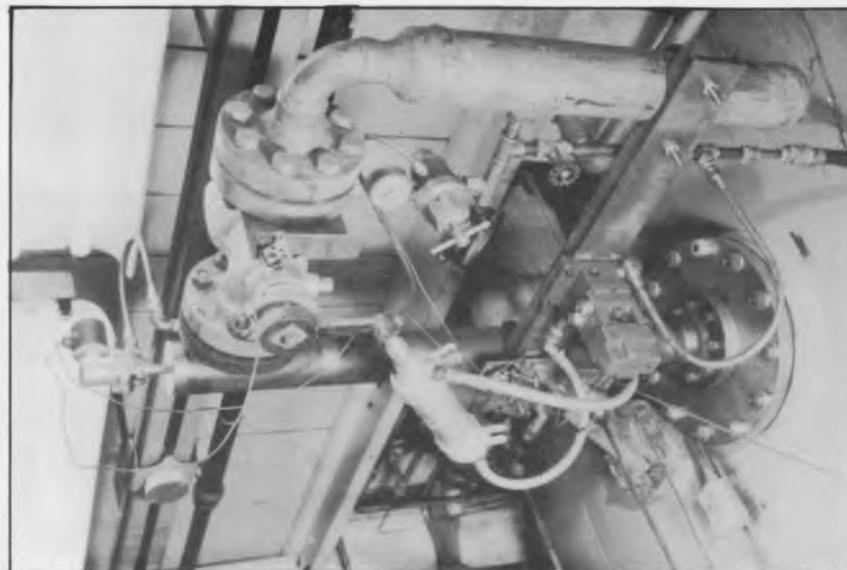


(b) Protective net in place

Fig. B-2 Interior arrangements.



(a) Schematic arrangement of linear launcher



(b) Mechanism mounted on tank

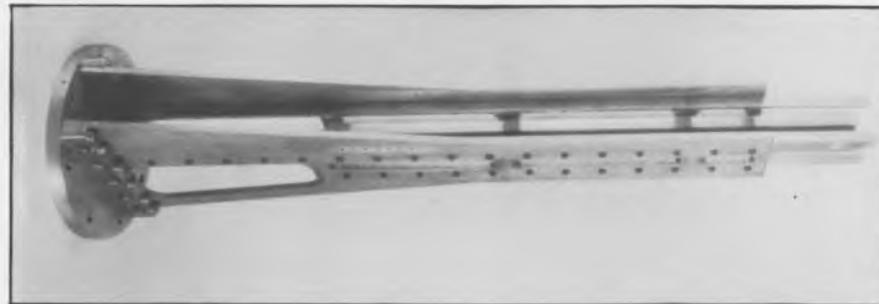


(c) Piston and rod

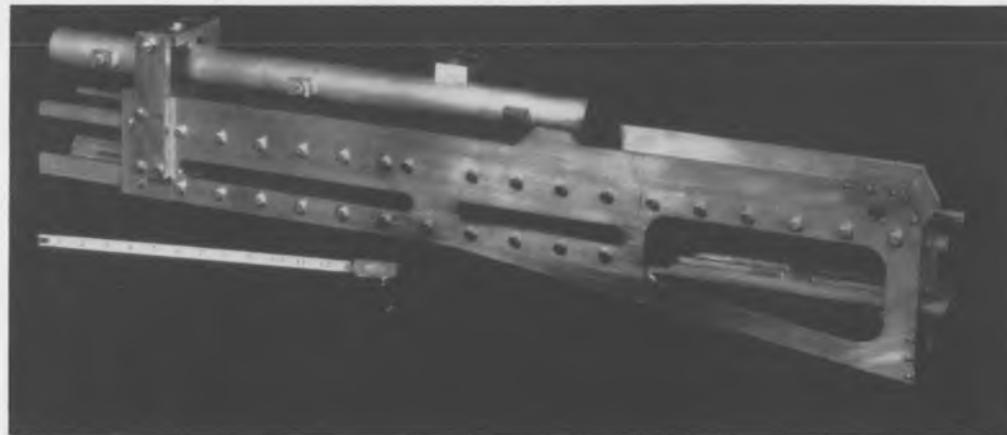
Fig. B-3 Linear launcher mechanism.



(a) Mechanism with guide rails attached



(b) Guide rails for Odax model



(c) Guide rails for Albacore model

Fig. B-4 Model guide rails for linear launcher.

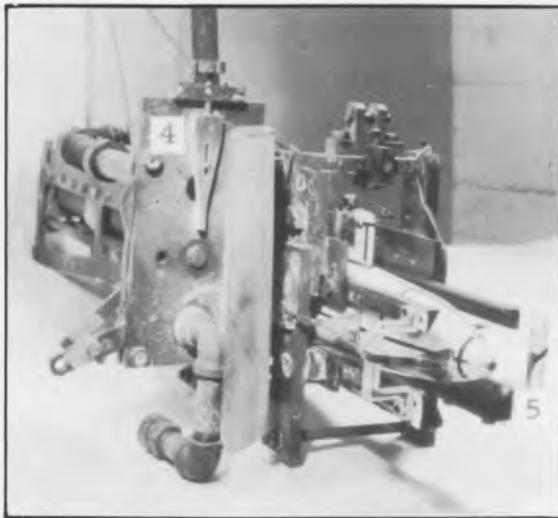
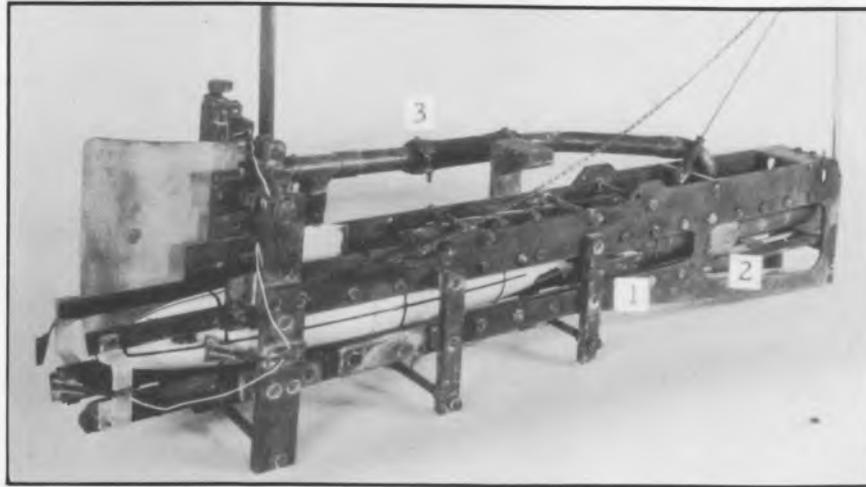


Fig. B-5 Launcher guide rail and mechanism for horizontal turning maneuvers.
(1) Spring and pusher, (2) Damper unit, (3) Exhaust line,
(4) Adjustable orifice, (5) Velocity contacts, (6) Support tube.

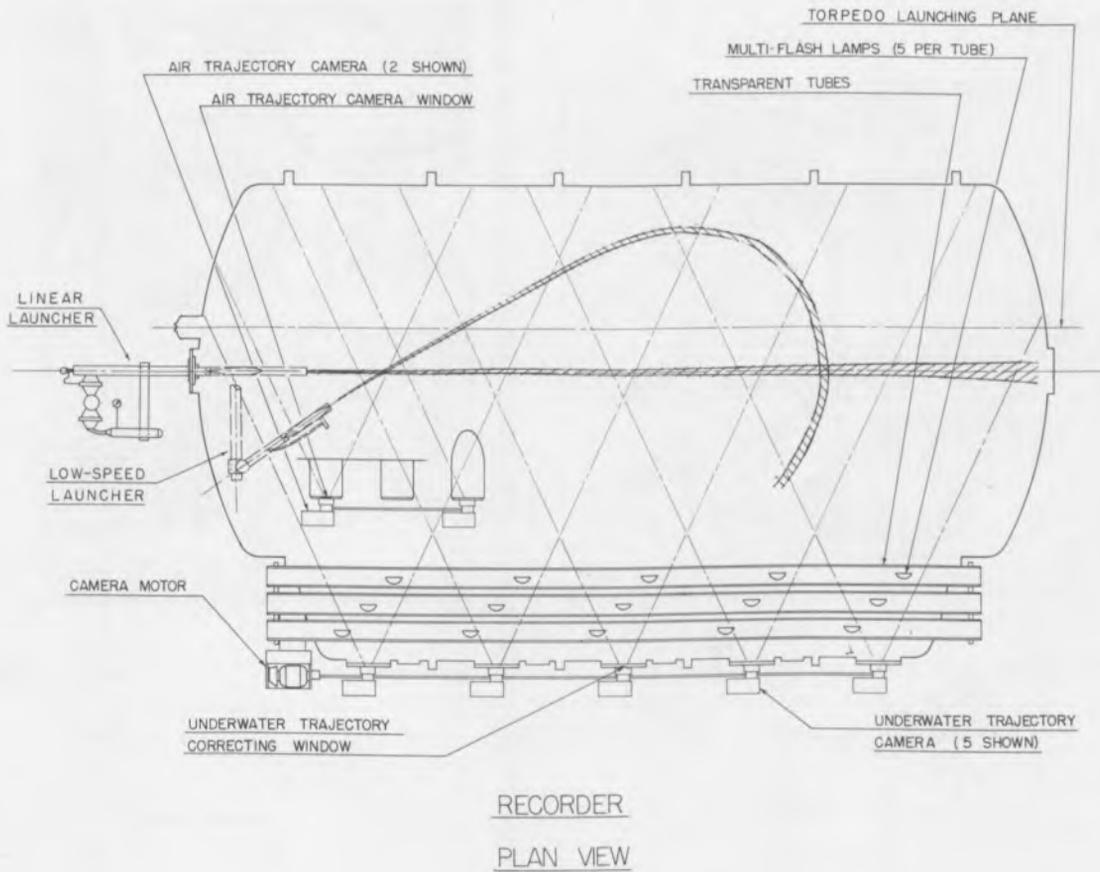
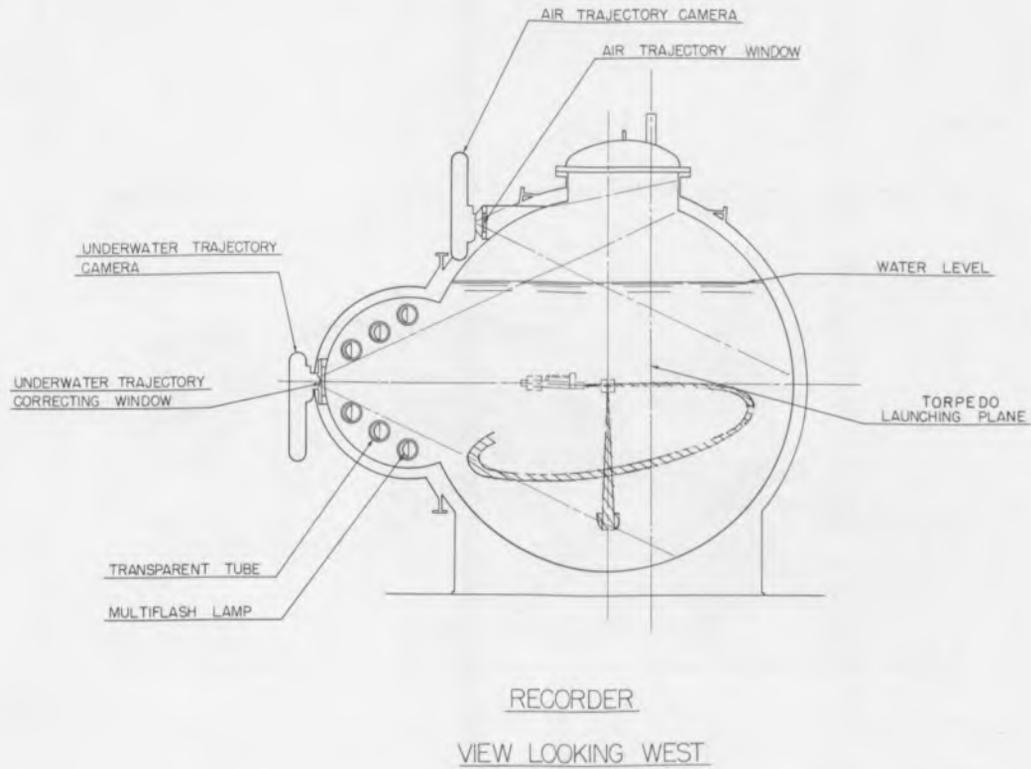
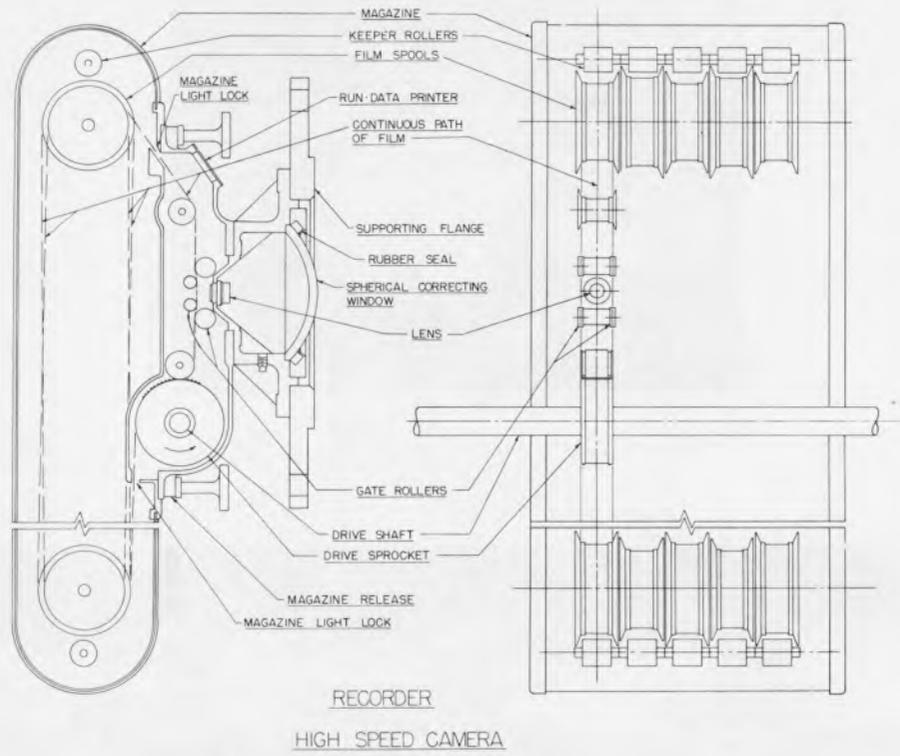


Fig. B-6 Trajectory recording system arrangement.



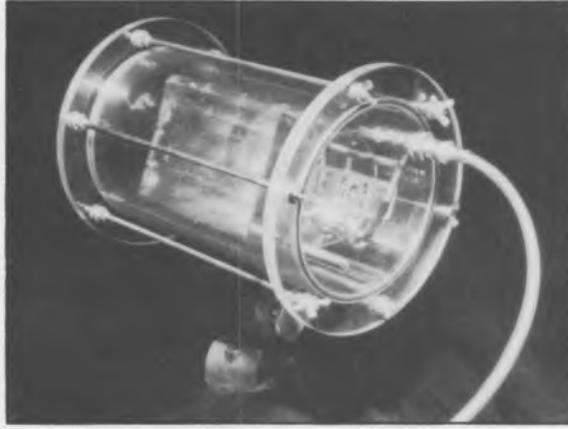
(a) Section view of camera and magazine



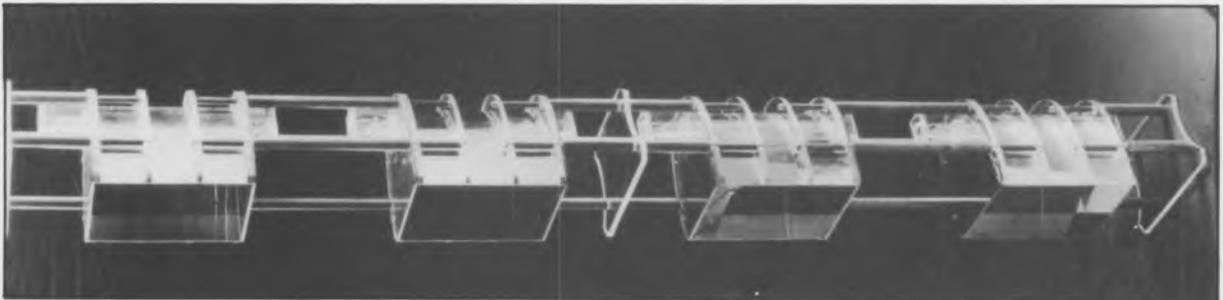
(b) Roller guides

Fig. B-7 High-speed movie cameras.

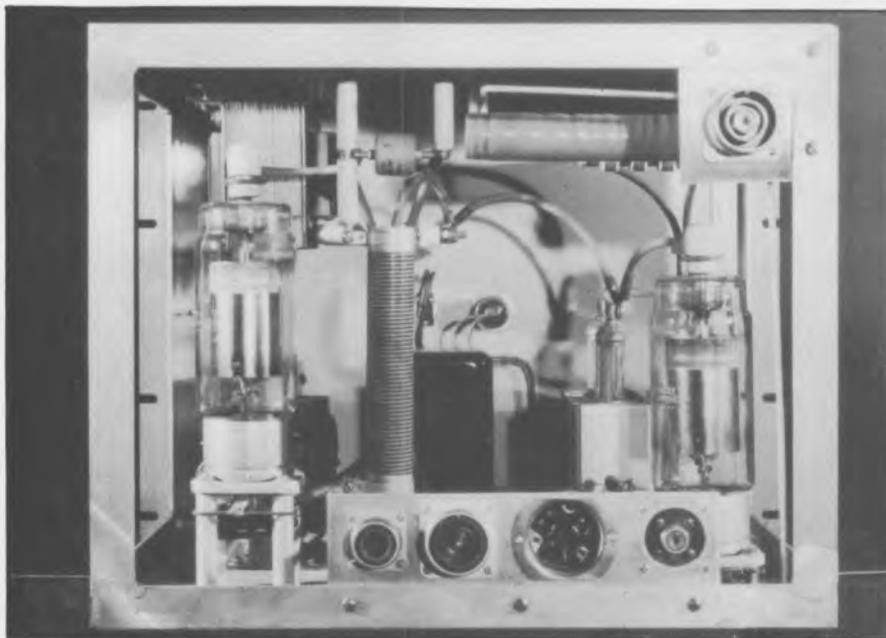
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(a) Auxiliary submersible unit



(b) Bank of lamps and reflectors
for mounting in lucite tubes



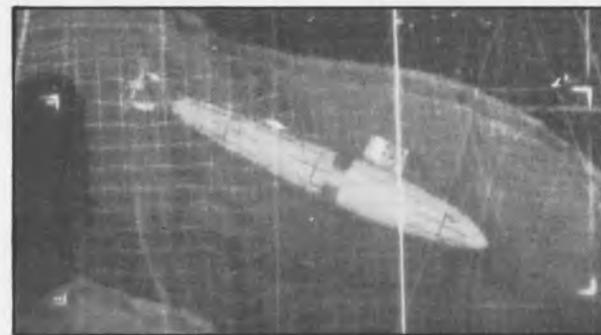
(c) Improved power pulse unit
for individual flash lamps

Fig. B-8 High-speed flash lamp equipment.

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(a) Background X emulsion with general lighting only



(c) Linograph ortho. with a general lighting only



(b) Background X emulsion with spotlighting

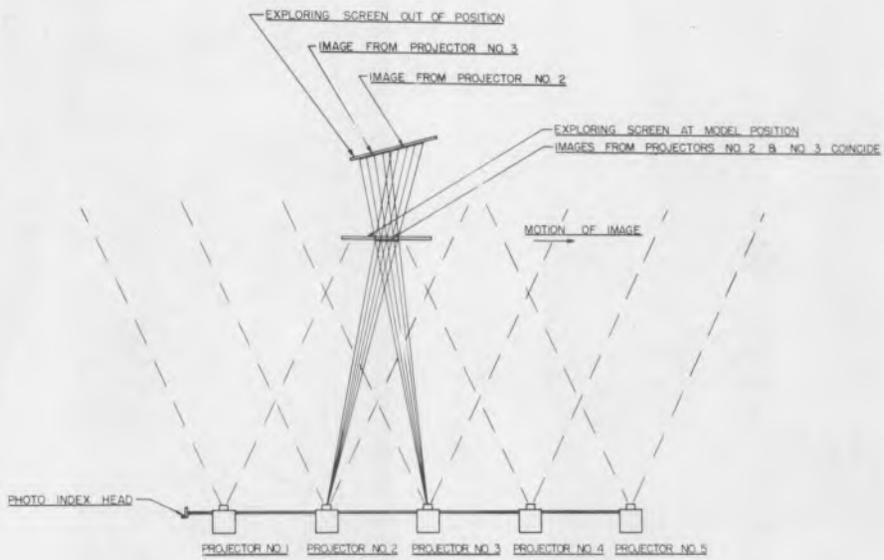


(d) Tri-X panchromatic with general lighting (horizontal maneuvers)

Fig. B-9 Model images with various Eastman Kodak emulsions.

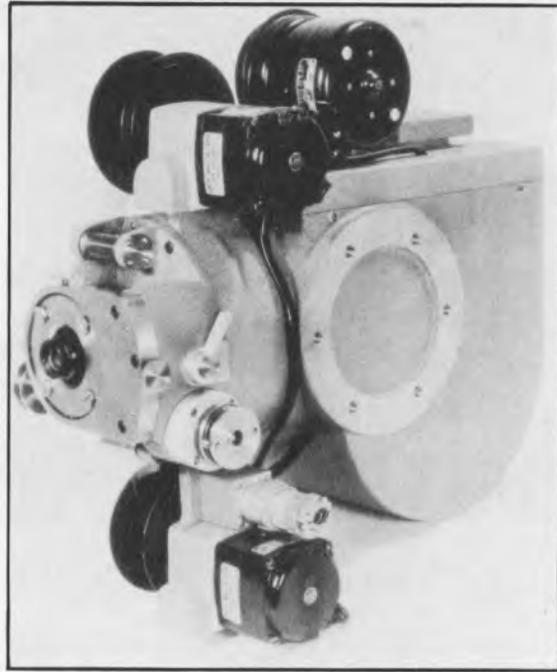


(a) Data analyzing room

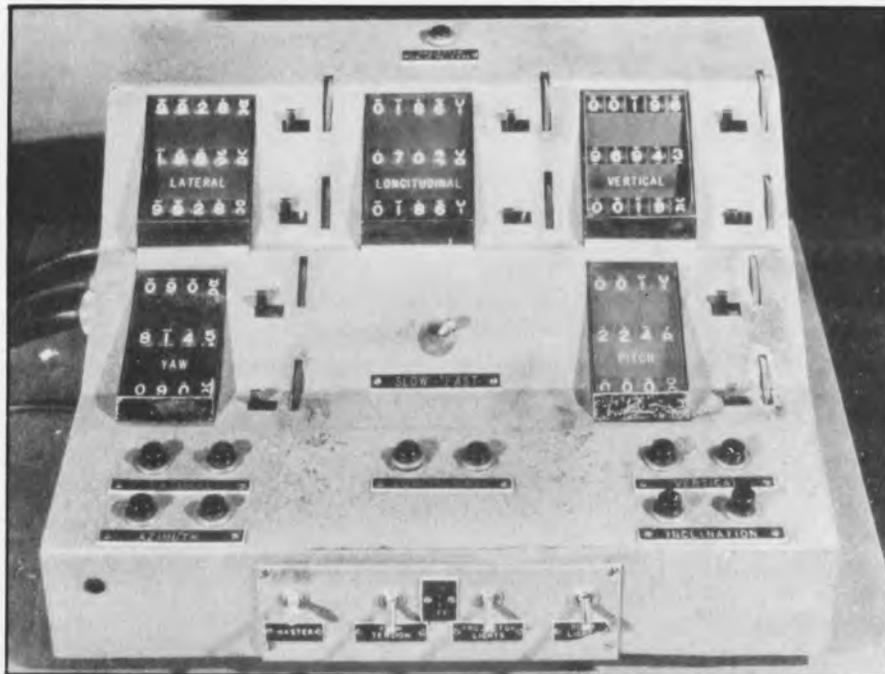


(b) Line diagram of analyzer

Fig. B-10 Trajectory mapping system

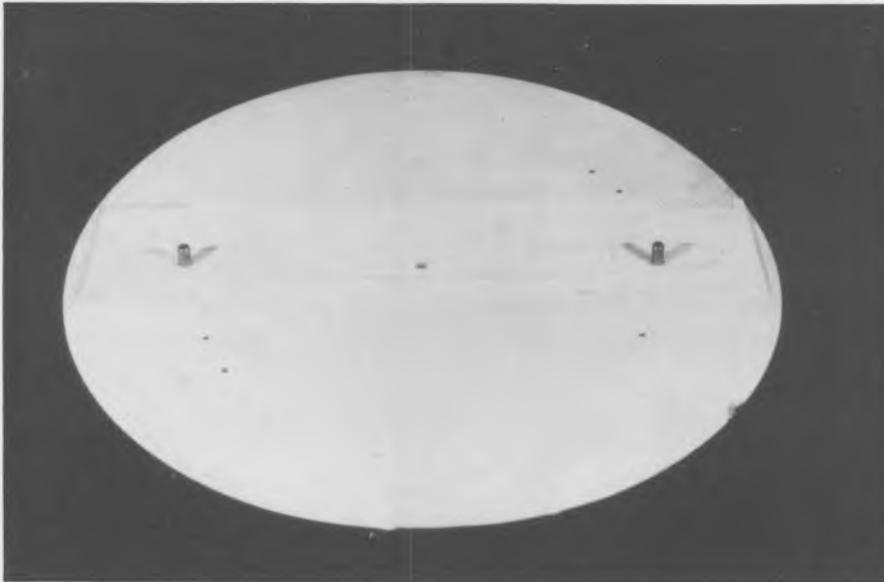


(a) Projector

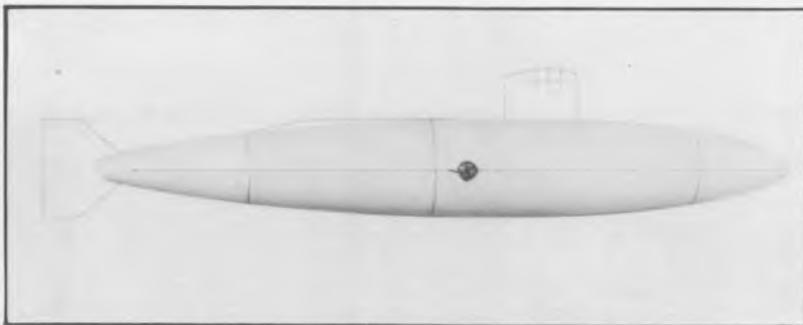


(b) Control panel

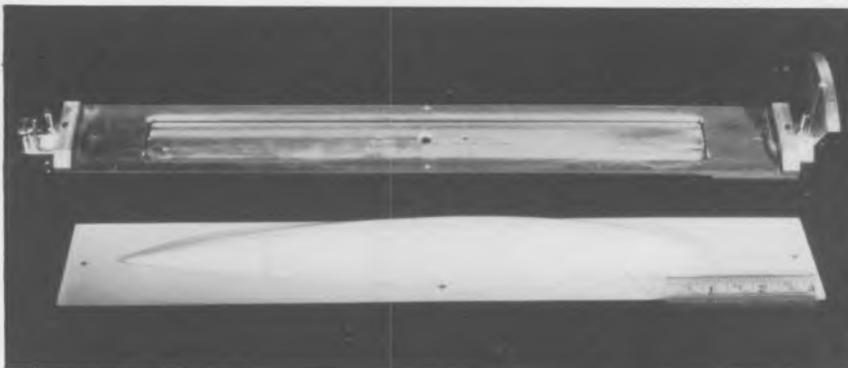
Fig. B-11 Trajectory mapping system coordinates



(a) Odax silhouette target and shield



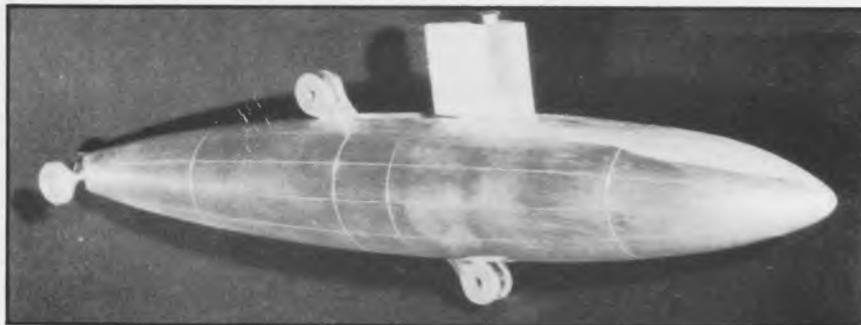
(b) Albacore half-model target



(c) Albacore half-model target with roll measuring attachment

Fig. B-12 Model targets for trajectory analyzer.

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(a) Showing forward deck construction



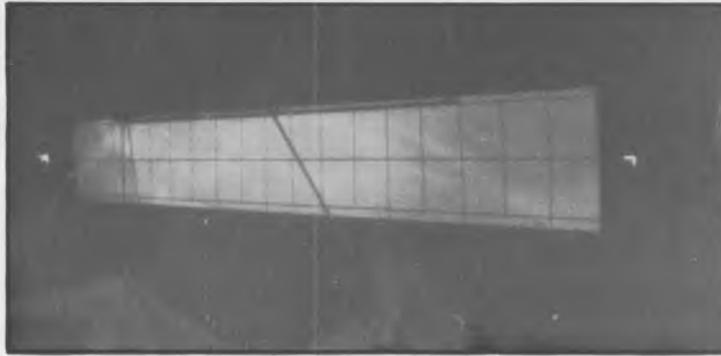
(b) Painted target with reference crosses



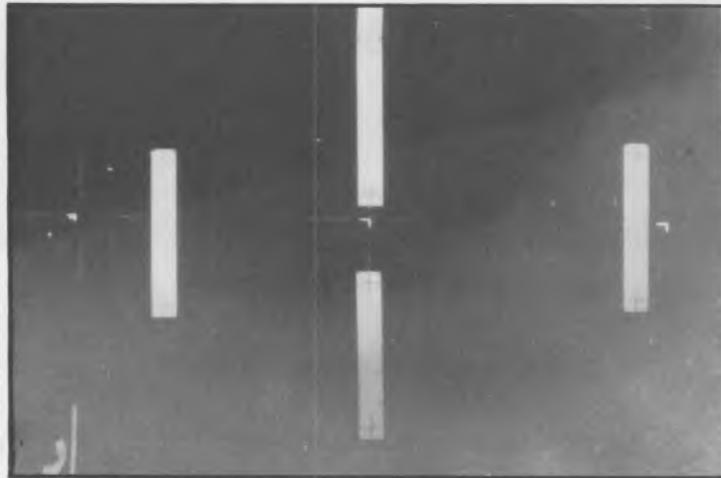
(c) Assembly mounted on
analyzer carriage

Fig. B-13 Full model analyzer target for horizontal turning maneuvers.

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(a) Image of 6-inch square grid



(b) Image of aligning targets and reference crosses in tank



(c) Target arrangement for film curvature tests

Fig. B-14 Targets for alignment of tank and analyzer optical systems.

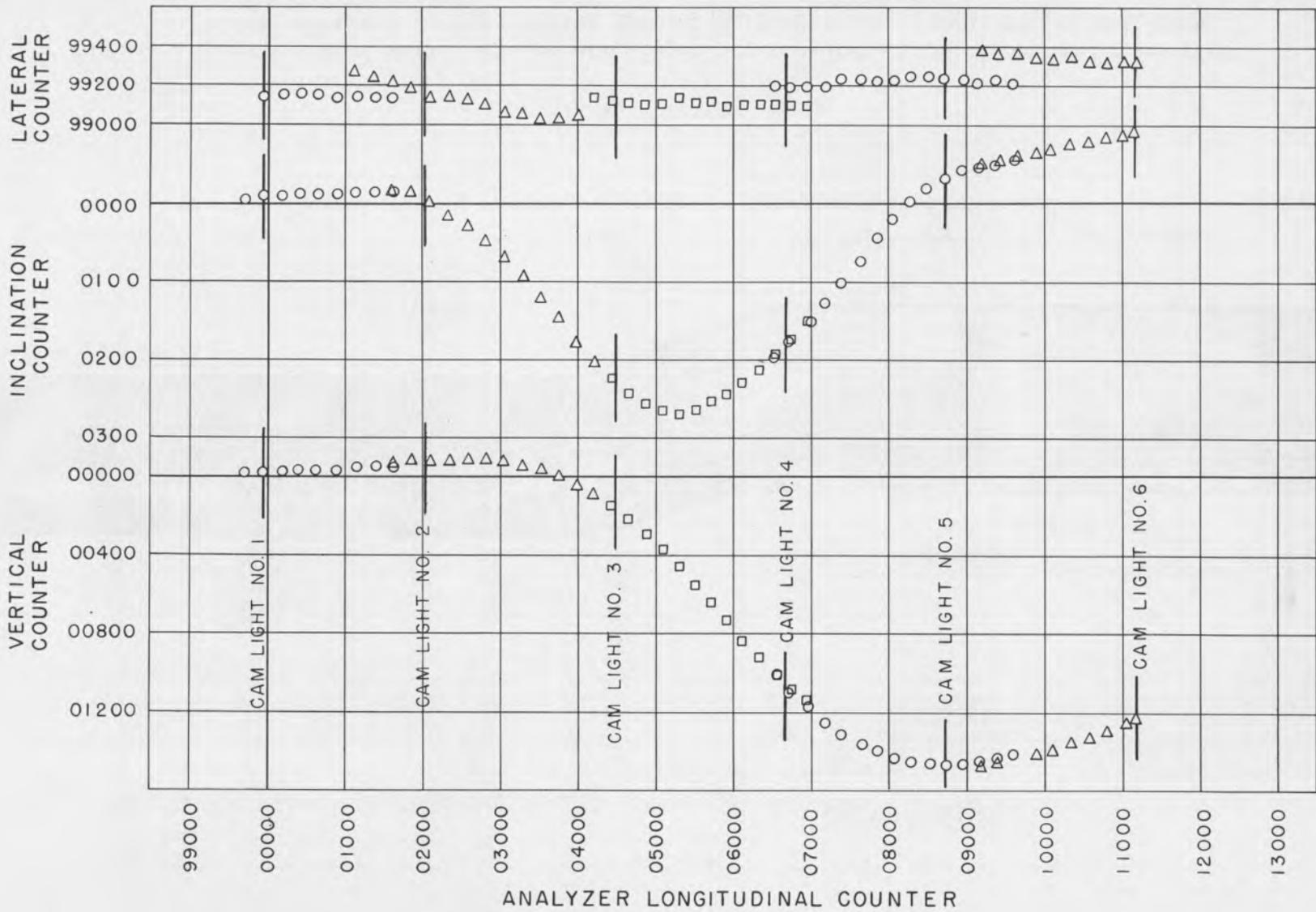


Fig. C-1 Plot of the tabulated data from the analyzer for a typical vertical maneuver of the Albacore model.

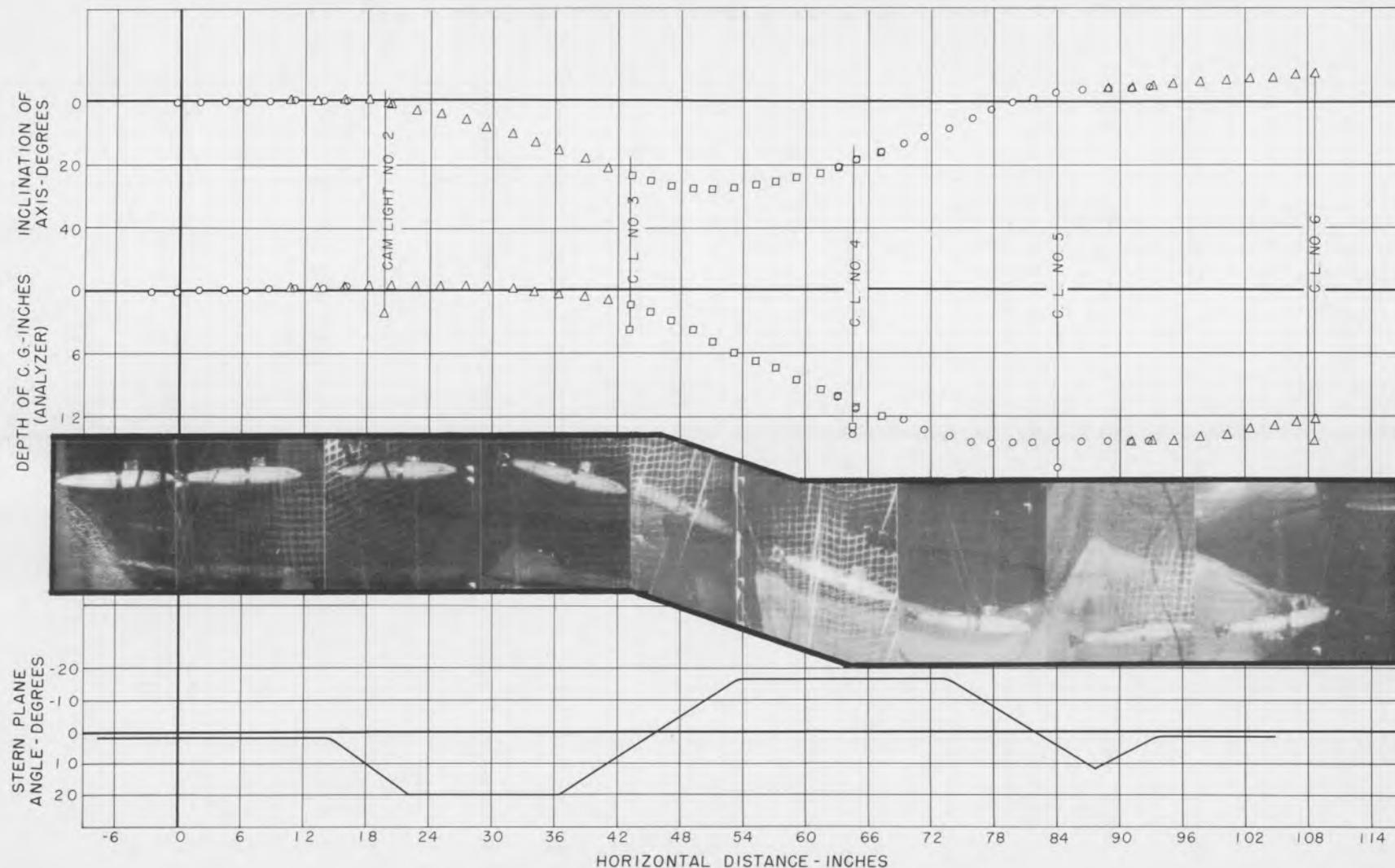


Fig. C-2 Composite of model images and trajectory plot for a typical vertical maneuver of the Albacore model showing quality of images for various model positions in the launching tank.

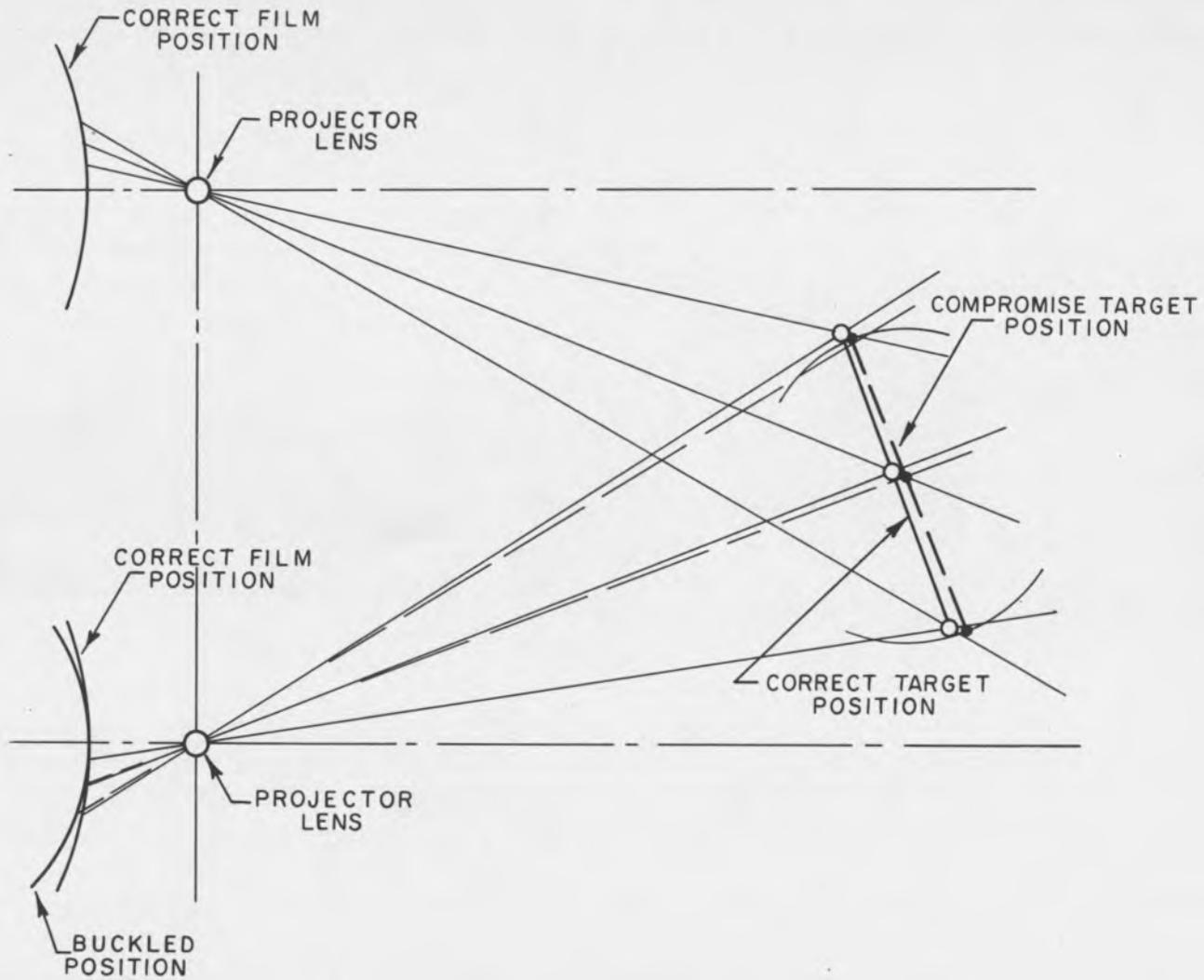


Fig. C-3 Line diagram showing the effect of variation of film curvature in the analyzer projectors.