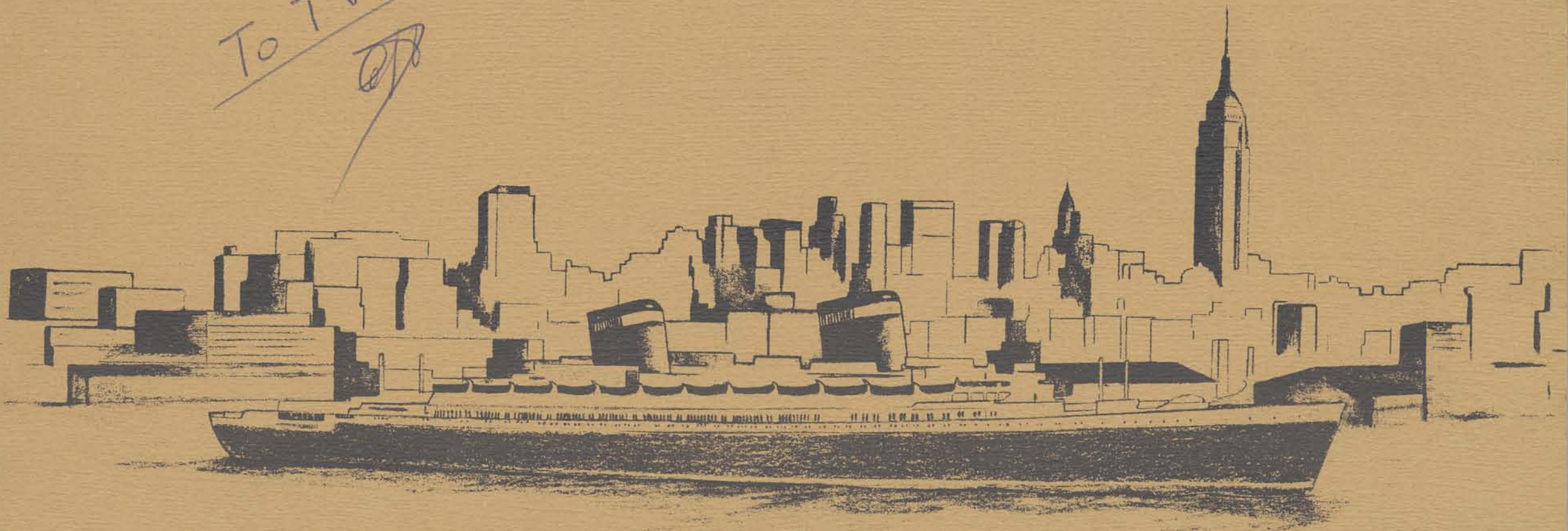


Research 1964

DAVIDSON LABORATORY
STEVENS INSTITUTE OF TECHNOLOGY

To T Walker
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View of the Manhattan skyline from the Stevens
campus as the *SS United States* moves down the Hudson

STEVENS INSTITUTE OF TECHNOLOGY

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President

HOWARD E. OREM
Director of Research

DAVIDSON LABORATORY

JOHN P. BRESLIN
Director

HUGH W. MacDONALD
Deputy Director

ALLAN B. MURRAY
Assistant Director

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Hugh W. MacDonald
Daniel Savitsky
I. Robert Ehrlich
P. Ward Brown

Personnel Committee

Albert Strumpf
Stephen J. Lukasik
Irmin O. Kamm
Edward Numata

Consultants

Louis Landweber
Karl E. Schoenherr
Paul D. Ritger
Jumpei Shioiri



Over the years, Davidson Laboratory has followed a work pattern which outlines its over-all function as the orderly, connective evolvment of theory and experiment, to achieve results immediately applicable to current engineering problems. This bridging of the chasm between pure science and hardware engineering constitutes a service which, though vital, is not readily available in our technological society.

The Laboratory's emphasis on such an approach is transmitted to the Stevens graduate curricula. Senior staff members are assigned to research professorships at the Institute; a limited number of graduate research assistantships are supported by the Laboratory; and tuition costs are paid for full-time staff members working toward advanced degrees at Stevens. There are at present eleven doctoral and six masters-degree candidates among members of the Staff, men who appreciate the need for excellence in both science and engineering.

During 1964 the Laboratory has continued to broaden into fields quite apart from the traditional one of ship hydrodynamics, and is currently working in several areas of applied mechanics and physics. Areas of intensive study now encompass many facets of hydrodynamics, vehicle dynamics, highway safety, internal-combustion engines, continental-shelf oceanography, properties of plasmas, rarefied-gas dynamics, and high-intensity-magnetic-field effects. The year of 1964 was indeed a busy one; and the current year, it is hoped, will offer opportunity for even greater service.

JOHN P. BRESLIN, Director



HUGH W. MacDONALD
Deputy Director

DAVIDSON LABORATORY IN 1964

The Davidson Laboratory is situated on the campus of the Stevens Institute of Technology, in the heart of the great Port of New York. It is an integral part of the Stevens Research Department, of which Vice Adm. Howard E. Orem, U. S. Navy (ret.), is Director and Hugh W. MacDonald Assistant Director. Col. MacDonald, who is also the Deputy Director of Davidson Laboratory, came to Stevens in 1945. In the early forties, he had served in England as Executive Officer of the Ordnance and Armament Section of the 8th Air Force and, in 1944, at Wright Field with the Ordnance and Armament Development Research Group.

Under general policies calling for vigorous encouragement of research at Stevens, the Laboratory continues to receive assistance for the improvement and expansion of facilities and for the enlargement of staff potential. As a privately owned, non-profit organization, it is able to move in any direction. Programs are undertaken which require access to many engineering capabilities, in such large areas as oceanology and land transportation; and it is hoped that these programs will continue to grow in usefulness to government and industry.

Davidson has been staffed and equipped to assure a balanced and economical operation. Fifty-two scientists and research engineers are assisted by a staff of sixty. Experimental facilities consist of two towing tanks, a maneuvering tank equipped with a rotating arm and oblique-sea test equipment, a shallow-water wave tank, a laboratory for

motor-vehicle studies, and a fluid-dynamics laboratory which includes a wind tunnel, a water tunnel, and several advanced electronic devices.

The following staff members of the Laboratory taught graduate and/or undergraduate courses at Stevens Institute of Technology during 1964:

JOHN P. BRESLIN, Research Professor in Mechanical Engineering

STEPHEN J. LUKASIK, Research Associate Professor in Physics

EDWARD NUMATA, Research Associate Professor in Mechanical Engineering

DANIEL SAVITSKY, Research Associate Professor in Mechanical Engineering

STAVROS TSAKONAS, Research Associate Professor in Mathematics

EARL M. URAM, Research Associate Professor in Mechanical Engineering

CHARLES A. COLOMBO, Visiting Lecturer in Mathematics

CHESTER E. GROSCH, Visiting Lecturer in Mathematics

GEORGE W. ZEPKO, Visiting Lecturer in Mathematics

The following staff members were enrolled in the Graduate School of Stevens Institute, as candidates for advanced degrees:

YOUNG H. CHEY

CHARLES A. COLOMBO

RICHARD J. DELL

HOWARD J. DUGOFF

KING S. ENG

GERARD FRIDSMA

CHESTER E. GROSCH

CHARLES J. HENRY

JOEL W. HOLLENBERG

GEORGE HULING

JOHN A. MERCIER

BENJAMIN J. PERNICK

PAUL H. RANK, JR.

CONRAD J. SEDLAK, JR.

EARL M. URAM

DOGAN UYGUR

GILBERT WRAY

Chu-Yung Chen is working toward a doctorate in Applied Mathematics at New York University, and Howard J. Dugoff and Joel W. Hollenberg are studying for qualification by the New Jersey Board of Professional Engineers.

Members of the research staff continue to be active in various study groups and organizations. Director Breslin serves on the SNAME (Society of Naval Architects and Marine Engineers) Hydrodynamics Committee and on that organization's Panel H-5 on Analytical Ship Wave Relations, Panel H-8 on Propeller Vibration and Hydroelasticity, and Panel H-11 on Flow Study. Assistant Director Murray is a member of the H-2 Panel on Resistance and Propulsion of the SNAME Hydrodynamics Committee. Daniel Savitsky is a member of the H-12 Panel on Planing Boats, and Anthony Suarez and C. Lincoln Crane, Jr. are members of Panel H-10 on Maneuverability and Controllability. Mr. Crane and Charles J. Henry work as members of the H-8 Panel on Hydroelasticity; Mr. Crane also belongs to Task Group HS-2-3 on Slamming. Edward Numata is a member of the H-7 Panel on Seakeeping Characteristics, and of Task Group HS-1-2 on Wave Loads — Great Lakes Vessels.

Dr. Breslin is Chairman of the Propeller Committee of the International Towing Tank Conference. Anthony Suarez, in addition to his SNAME activities, works as a member of the Maneuverability Committee of the American Towing Tank Conference and of the Maneuverability Committee of the International Association of Navigation Congresses, and is active on the Bureau of Weapons Hydroballistics Advisory Committee (BOWHAC). I. Robert Ehrlich, in 1964, was National Secretary for the United States, International Society for Terrain-Vehicle Systems, and Chairman of the Society's Armed Forces Liaison Committee and of the Standardization Committee. Albert Strumpf served as a member of BOWHAC and was BOWHAC Monitor for Activities in Stability and Control; he also was technical

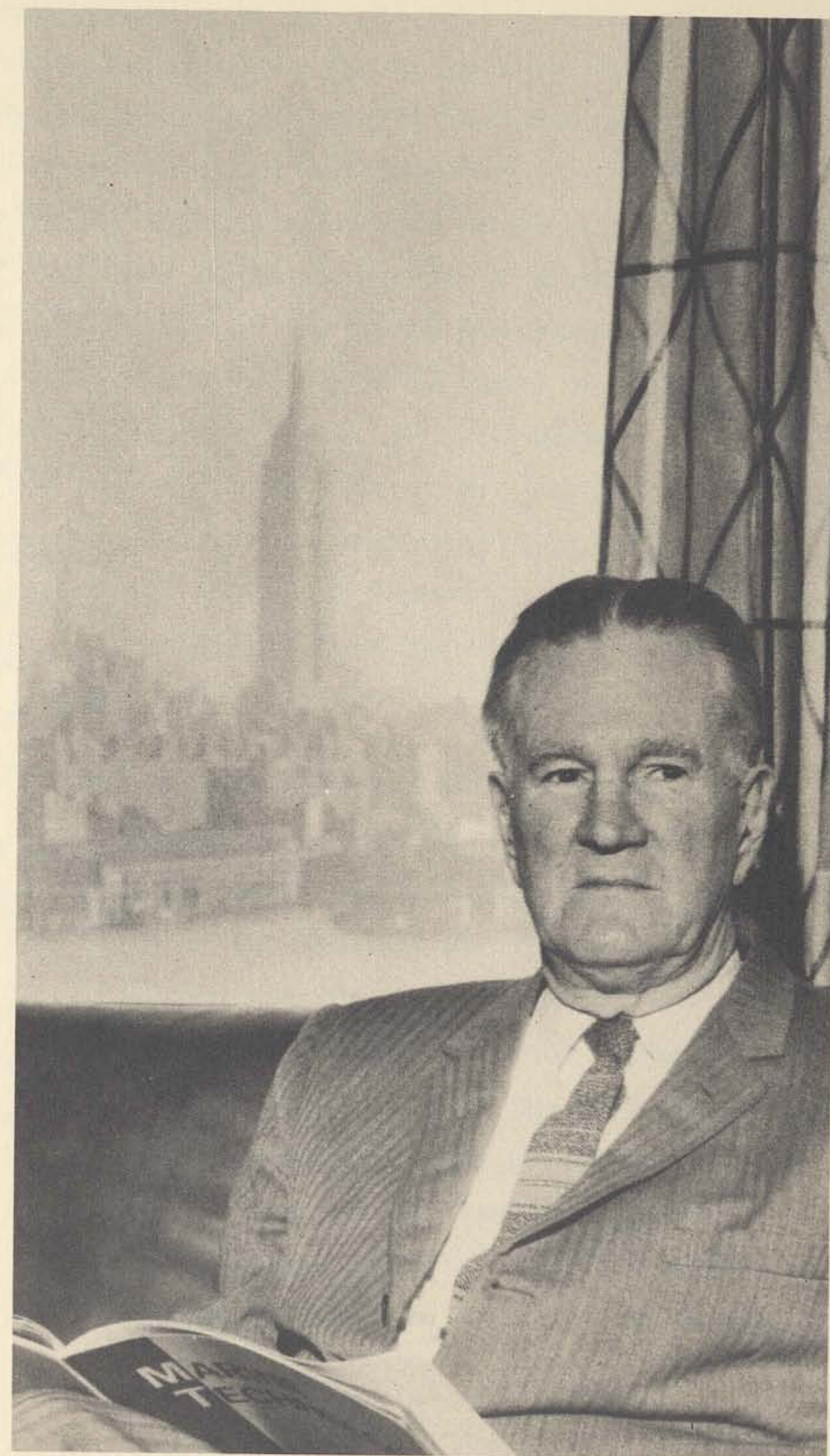
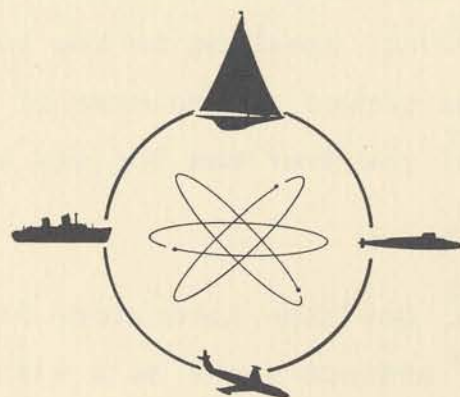
reviewer of the Bureau of Weapons Hydroballistics Handbook dealing with stability and control. Robert B. Schwartz continues as a member of the Highway Research Control.

In June, Daniel Savitsky received the Vice Admiral E. L. Cochrane Award from the Society of Naval Architects and Marine Engineers, for a paper on the design of planing hulls; and Stephen J. Lukasik and Chester E. Grosch received the Ottens Research Award in recognition of the excellence of their work and of their dedication to the ideals of teaching and research.

In August, I. R. Ehrlich spent a week as guest lecturer at the United States Military Academy at West Point, speaking on the subject of "Land Locomotion." In December he served as Chairman of the Space Sciences Session at the meeting of the American Society of Mechanical Engineers.

In the fall of 1964, Pung Nien Hu, Davidson Laboratory Staff Scientist, returned from a two-year leave of absence spent as a visitor at the Courant Institute of Mathematical Sciences, New York University. While at the Institute, he worked in the field of plasma dynamics, magnetohydrodynamics, and kinetic theory of gases. Upon his return to the Laboratory, he was appointed Chief of the Flow Phenomena Division.

ALLAN B. MURRAY
Assistant Director



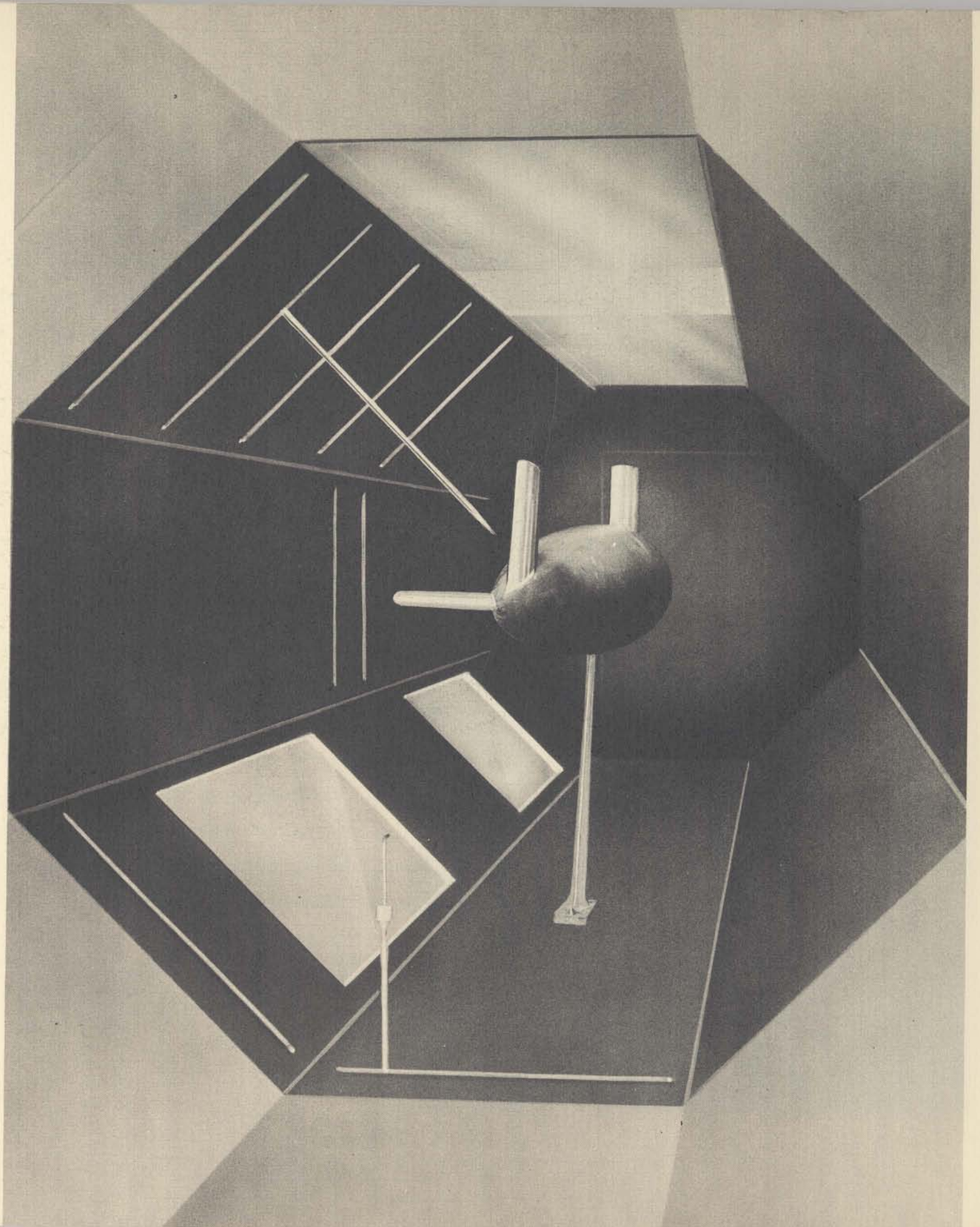
ENCOMIUM

Four years before the beginning of War II, at a time when few scientists foresaw the emergence of the new science of oceanology and the future importance of ship research, the late Dr. Kenneth S. M. Davidson, with our present Assistant Director, Allan B. Murray, founded Davidson Laboratory to extend the narrow frontiers of hydrodynamic research. Their initial contribution to the research community was the establishment of methods for investigating nautical problems through the use of ingeniously simple devices and models. These methods have eliminated the extravagantly high costs formerly associated with the building and use of model-testing facilities.

Through the years, Allan Murray has been a forceful influence in the organization, guiding the steady development of test facilities and test techniques, helping to increase the experimental capabilities of the Groups, and earning the respect and recognition of the international community which is concerned with research- and development-engineering as related to the hydrodynamic performance characteristics of merchant ships, power boats, sailing vessels, hydrofoil boats, and various other non-military vehicles.

In 1965 Mr. Murray retires, but he will continue his association with the Laboratory, as consultant.

INSTALLATION FOR
DETAILED STUDIES
OF FLOW
ABOUT A TYPICAL
SUBMARINE MODEL



APPLIED MECHANICS GROUP

The Applied Mechanics Group presents an analytical and experimental capability in the steady and unsteady hydrodynamics of lifting and non-lifting bodies — submerged, surface-piercing, or in the presence of a free surface. Studies are made of the interaction of hydrodynamic forms with the disturbances from regular and irregular ocean waves. Continuing effort is directed toward research in plasma flows developed by the interaction of detonations with electric and magnetic fields.

STAFF SCIENTISTS

Under the supervision of staff scientists, a variety of research investigations are conducted, some of which involve divisional personnel on temporary assignment; all laboratory investigations which require use of the Wind Tunnel and the new Water Tunnel are under the supervision of a staff scientist.

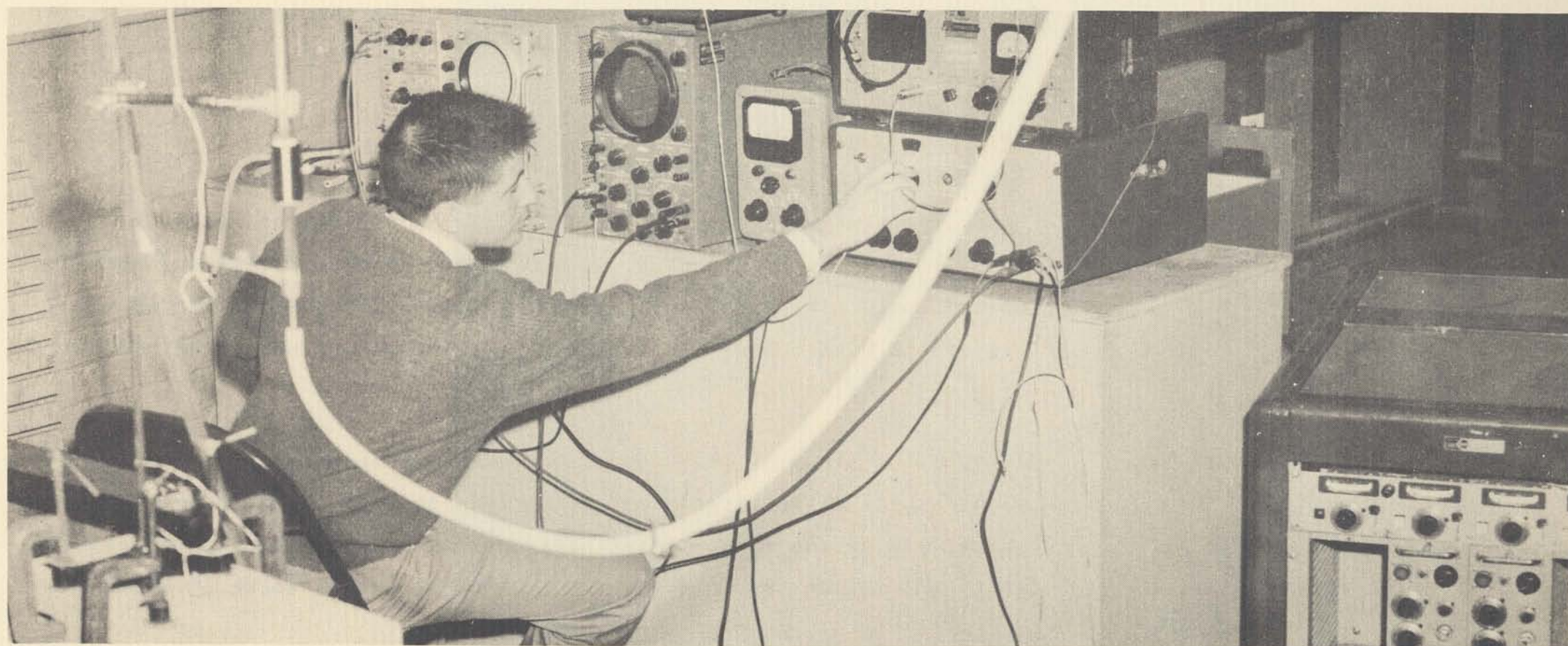
Novel Ship

In 1964 the study of the novel Hydrofoil Semi-Submarine was completed with results which clearly establish this ship as superior to other novel ships, and to the conventional destroyer as well, in horsepower requirements and motion response to wave systems at speeds above 35 knots.

Motion Equations

Also completed was the program to develop, for use in the design of a contemplated training device, the motion equations applicable to the mooring and docking maneuvers of a typical destroyer-class ship. Wind effects, current effects, and realistic ship-personnel-system time lags

ADJUSTING THE PASS BAND IN AN
UNDERWATER ACOUSTICS EXPERIMENT



are factors included in the motion equations and structured into the suggested computer program. The experimental phases of this program (model tests and sea trials) have made available, for the first time, information concerning low-speed, twin-screw-ship response to maneuvering by engine-control combinations and real ship-personnel-system time responses.

Aerodynamics

Recently the staff scientists of this Group have been working on the wind-tunnel phase of a program associated with the flow and drag characteristics of cascaded flat plates. The investigation is an evaluation of the usefulness of such configurations for improving the propulsion (in water) of amphibious tracked vehicles. It will provide both basic and useful design information on gap-chord ratio, aspect ratio, and Reynolds-number effects on individual plate thrust for flow normal to the cascade (that is, along the cascade axis) as well as through the cascade.

The Wind Tunnel is also being used to investigate the effects of surface roughness on the friction drag of flat surfaces. The surface roughnesses under study are those resulting from sand grains, from some typical paints, from actual corrosion of hull plates, and from typical shipyard refinishing procedures applied to corroded surfaces. It is already apparent that current empirical procedures for predicting these effects, and the data used for their development, need revision. The roughness-introduced turbulence and its effect on the momentum balance in the boundary layer — not previously accounted for — have been found to have appreciable influence on skin-friction determination.

Use of the Wind Tunnel was also involved in the following work: an investigation of 12-meter-yacht rigging-wire characteristics, in which it was demonstrated that certain combinations of ordinary cylindrical rigging wires can reduce the rigging-wire drag contribution by approximately 20 percent; exploratory tests related to a submarine-towed antenna system; and calibration of Stauscheibe instruments.

Fluid Mechanics

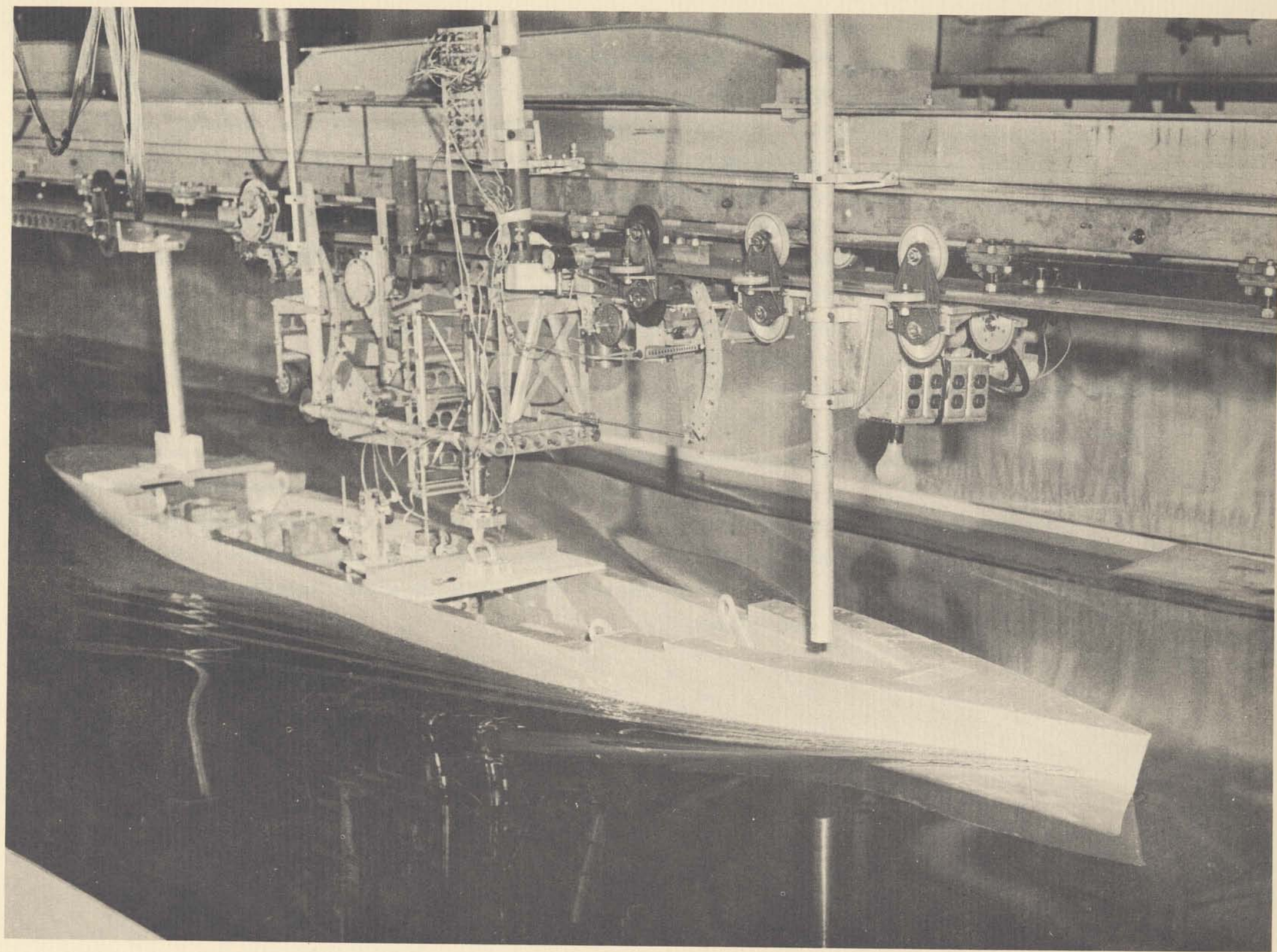
One of the 1964 projects was the design and fabrication of a new and unusual water-tunnel facility, presently in use for a study on the feasibility of, and the requirements for, the establishment and maintenance of a captured air film or pocket on a submerged flat surface. It is planned to assess the use of this concept for reducing the drag of barges or other vessels having extensive flat bottom areas over which the longitudinal pressure variations are negligible.

Oscillating Cylinder

Other scientific work has concerned theoretical and experimental research on the viscous damping of an oscillating cylinder, with application and extension of a formula (derived by C. E. Grosch and simplified by J. P. Breslin) which, in a laminar flow condition, connects the damping characteristics of the rotational oscillation of a cylinder with the Reynolds number when the usual boundary-layer approximation is used. This calculation successfully explained experimental results obtained at the Davidson Laboratory and by another researcher abroad. In the course of the study, an experiment was performed involving the use of several kinds of turbulence stimulators.

Tankers and Amphibians

During 1964 a preliminary experiment was also conducted on the resistance characteristics of specific new tanker forms. In addition, work was done on the propulsive performance of the hydrotracks of amphibious vehicles, and the above-mentioned experimental wind-tunnel study on the cascade of flat plates was made, with a simplified model considered to be in conformation with actual full-size construction. The ultimate purpose of the cascade study is to determine interference effects among plates.



FLUID DYNAMICS DIVISION

Activities in the Fluid Dynamics Division relate in particular to evaluation of the unsteady hydrodynamic forces and the study of hydroelasticity, flutter, propeller-induced vibration, propeller-noise mitigation, and drag reduction of a surface ship.

Unsteady Lifting-Surface Theory

Considerable effort is devoted to systematic study of unsteady and steady-state hydrodynamic loading on three-dimensional lifting surfaces under a variety of conditions. Unsteady-lifting-surface theory has been applied to the marine propeller and to the hydrofoil craft, and surface integral equations have been derived for each case. Owing to the complicated structure of the kernel functions, which relate the downwash distribution boundary required to meet the condition on the lifting surface with the unknown loading, and whose integral forms have "Hadamard" type singularity, approximate solutions have been obtained.

Propeller Loading and Vibratory Thrust

Two methods have been applied to marine propellers to estimate vibratory thrust — a modification of the Weissinger mathematical model and a model with chordwise loading given by the first term of the Birnbaum distribution. The second model is more complicated but contains as a nucleus the exact solution of the unsteady two-dimensional problem.

FOURTEEN-FOOT LONG MODEL OF SERIES 60, $C_B=0.60$ BEING SELF-PROPELLED IN TANK 3, AS PART OF A RESEARCH PROJECT ON BLOCKAGE EFFECTS IN RESISTANCE AND PROPULSION TESTS OF SHIP MODELS

Predictions of the vibratory thrust and torque of a propeller behind a ship, and of the sound pressure signal at a large distance from the propeller, are a great improvement over those based upon the unsteady two-dimensional approach applied in stripwise fashion.

A series of calculations, obtained by a numerical procedure adaptable to high-speed computers, indicates the special importance of the three-dimensional flow field and the inadequacy of two-dimensional steady and unsteady flow theories applied in stripwise manner for the evaluation of the propeller loading. Work is being pursued to improve the mathematical model by including more realistic loading conditions.

Pressure Radiation

A study of the radiation from an infinitely long elastic cylinder and plate of the pressure waves generated from a marine propeller indicates that no distortion of the harmonic content of the incident wave occurs; what does occur is a magnification or reduction in amplitude, depending upon the mechanisms of sound transmission, the geometry and elastic properties of the boundary, and the wave number.

Propeller Singing

The propeller-singing phenomenon, or self-excited vibration system, has been investigated. A mathematical model has been devised which exhibits and interprets the well-known step-and-jump characteristics in the singing-frequency-versus-flow-velocity diagram. The singing system was simulated by a "closed loop" composed of a blade, which acts as a mechanical vibration system, and the mechanism which is responsible for the shedding of vortices in synchronization with blade vibration. The numerical calculations made for several types of blade-vibration mode shape showed that the criteria for the stability of the synchronized shedding of vortices, together with the criterion for

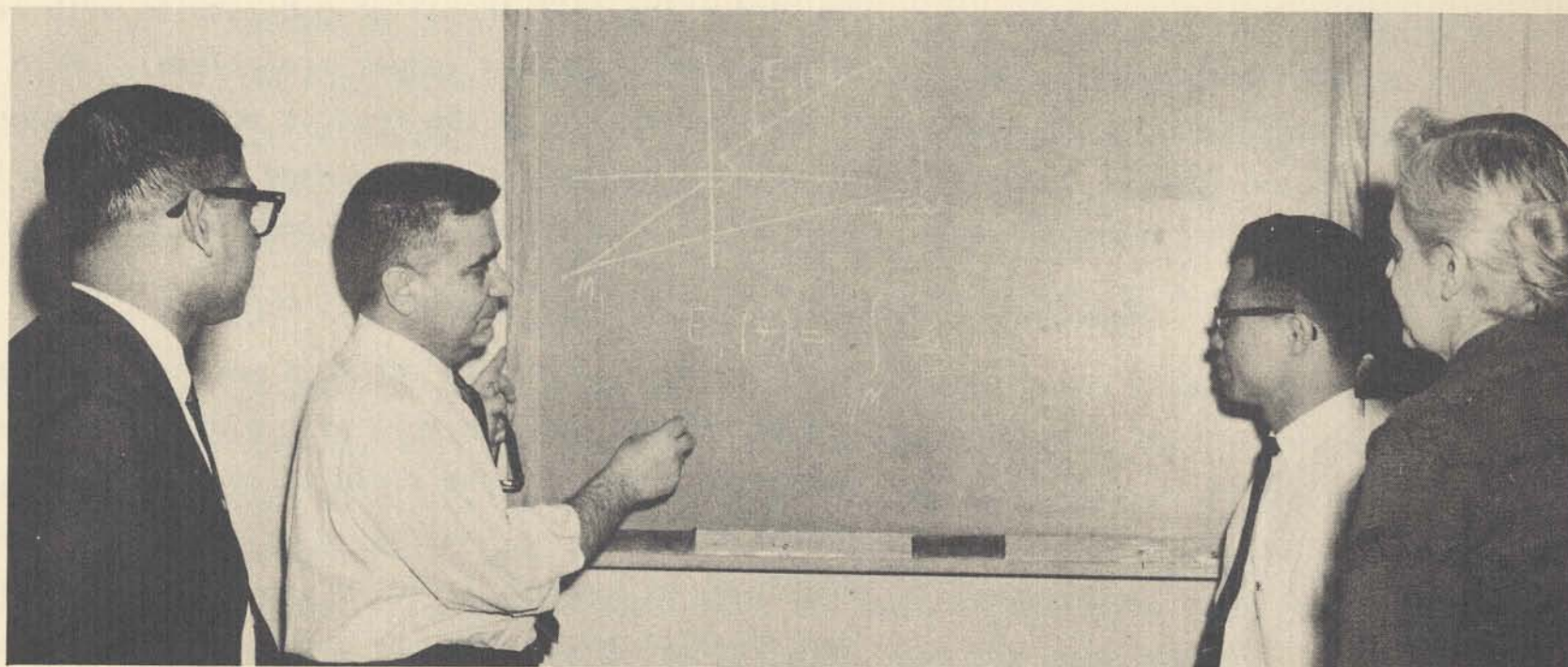
the phase relation favorable to positive work done by the hydrodynamic reaction force of the shed vortices upon the blade vibration, can interpret the step-and-jump phenomenon.

Self-Propelled Models

Also under way is an experimental study of related problems encountered in conducting self-propelled-model tests with relatively large-size models (and therefore larger propellers), which will result in greater precision in the results and an avoidance of propeller scale effects. The problem of blockage or flow restriction for large models in a relatively small tank becomes of paramount importance.

Hydrofoils

In the case of hydrofoil craft, current studies bear upon the surface-piercing strut, the foil moving near the free surface at high Froude number, and the foil with planform variation in the fully submerged case. In the field of hydroelasticity there is continuing effort to establish the region of validity of the airfoil flutter theory. The study of hydrofoils fully submerged, like the study of the surface-piercing strut, has shown that the non-conservative predictions based on the airfoil theory constitute a real danger. In the hydroelastic studies, the focus has been on determining the importance of unsteady three-dimensional effects in hydrofoil operation, and on extending previous flutter investigations to the study of the elastic response of a hull-appendage configuration moving in water. In another study, the measured forces and moments on teed hydrofoil models in oblique seas indicated the importance of aspect ratio, submergence, and interaction between the strut and foil components. Lifting-surface techniques were developed to analyze the effects of submergence, aspect ratio, and planform variations on the forces acting on horizontal foils in oblique waves.



MEMBERS OF THE FLUID DYNAMICS DIVISION
ENGAGED IN DISCUSSION

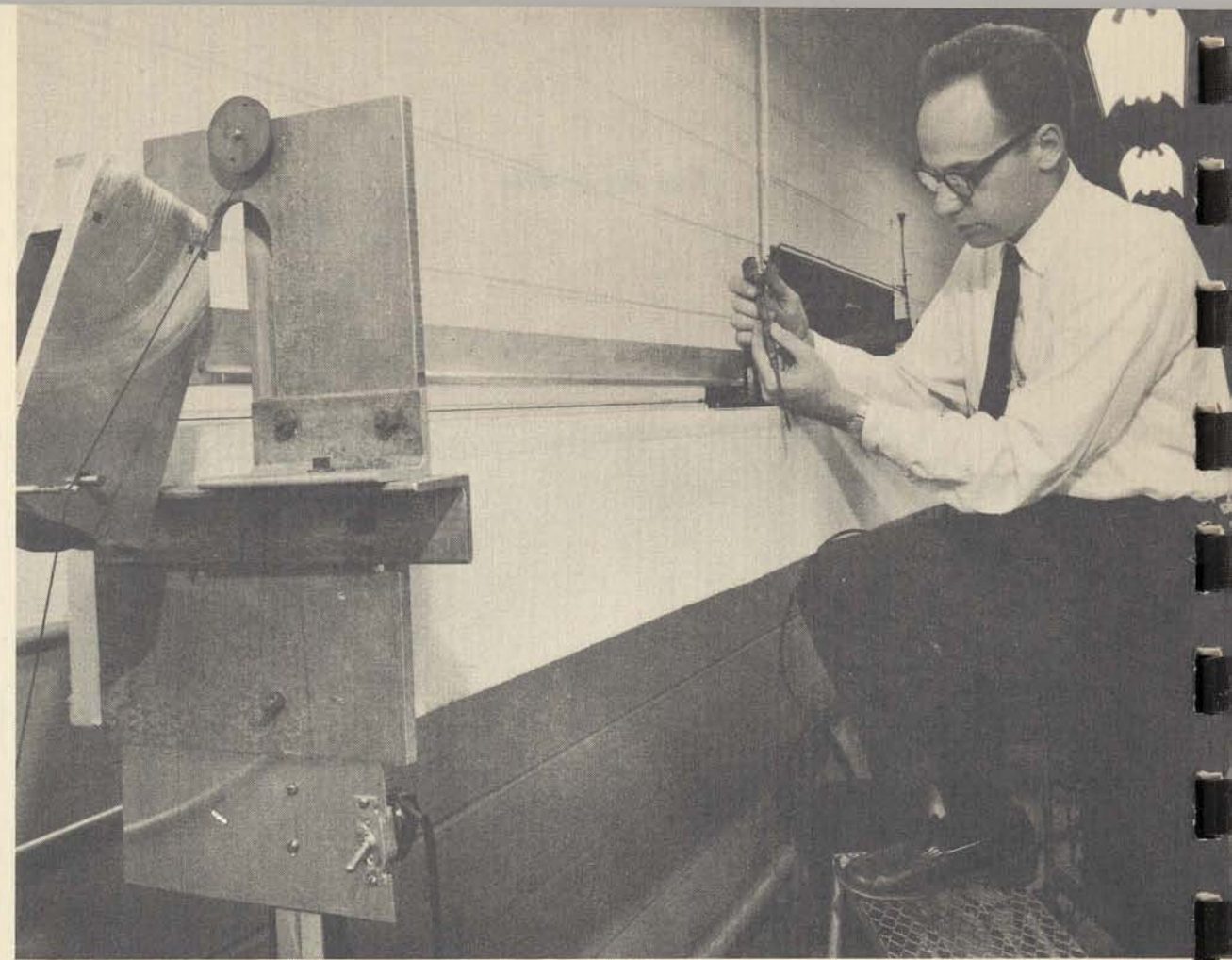
Cavity Flows

For axisymmetric cavity flows, a linearized theory is being developed in which expressions are derived for the cavity shape and its corresponding drag; a special case of a slender cone at finite and zero cavitation number has been studied in detail.

To develop a ship form with reduced wave-making resistance and improved seakeeping qualities, an exploratory theoretical study has been undertaken, coupled with detailed experimental work on wave resistance aimed at the reduction, and possibly the elimination, of the wave-making resistance of a displacement ship by the addition of a large bulb to the bow.

Course Stability

Some of the Division's activity is associated with the development of a rational method for predicting lateral forces and moments in yaw from the geometric characteristics of a surface ship and its skeg configurations. Such a method, based on aerodynamic wing theory and simplified potential-flow theory with empirical modifications for a real viscous fluid, has been applied with a high degree of success to twenty hulls, varying in block coefficient, beam-draft ratio, and displacement-length ratio, under different conditions. For the stable ship with large skegs reaching the water surface at the stern, the major form factors influencing course stability have been demonstrated to be block coefficient, beam-draft ratio, and average sectional inertia coefficients; and it has been shown that decreasing one or more of these factors will increase stability. In fact, a formula for the stability index σ_1 has been derived, in terms of these three factors, which fits the experimental results very well and should indicate what course stability can be expected, given the block coefficient, beam-draft ratio, and an easily calculated average sectional inertia coefficient.



A THERMISTOR VELOCITY SENSOR IS CALIBRATED IN THE LABORATORY BEFORE BEING USED IN THE FIELD. THE WAVE AND CURRENT VELOCITIES TO BE ENCOUNTERED ARE SIMULATED IN A SMALL TOWING FACILITY.

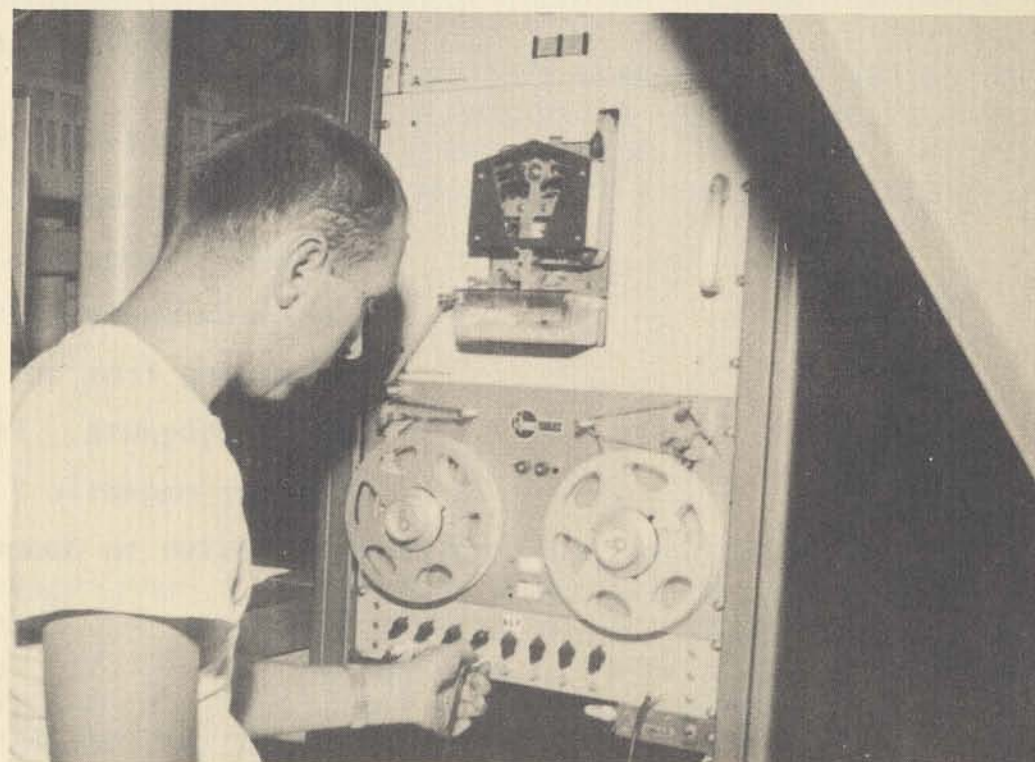
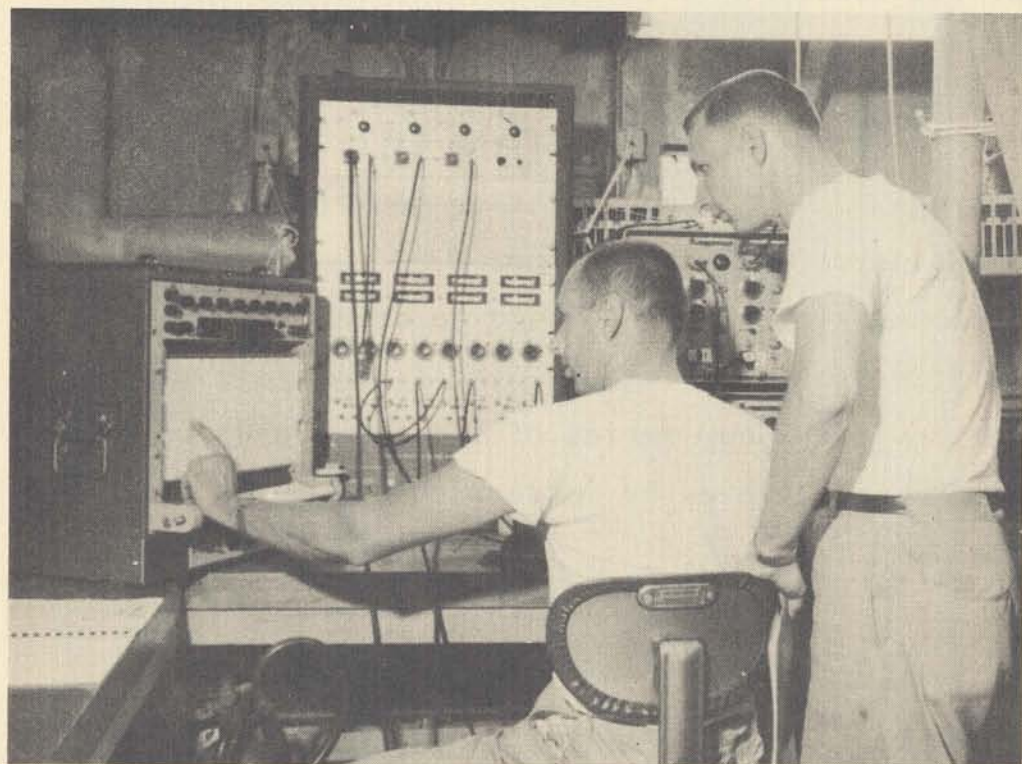
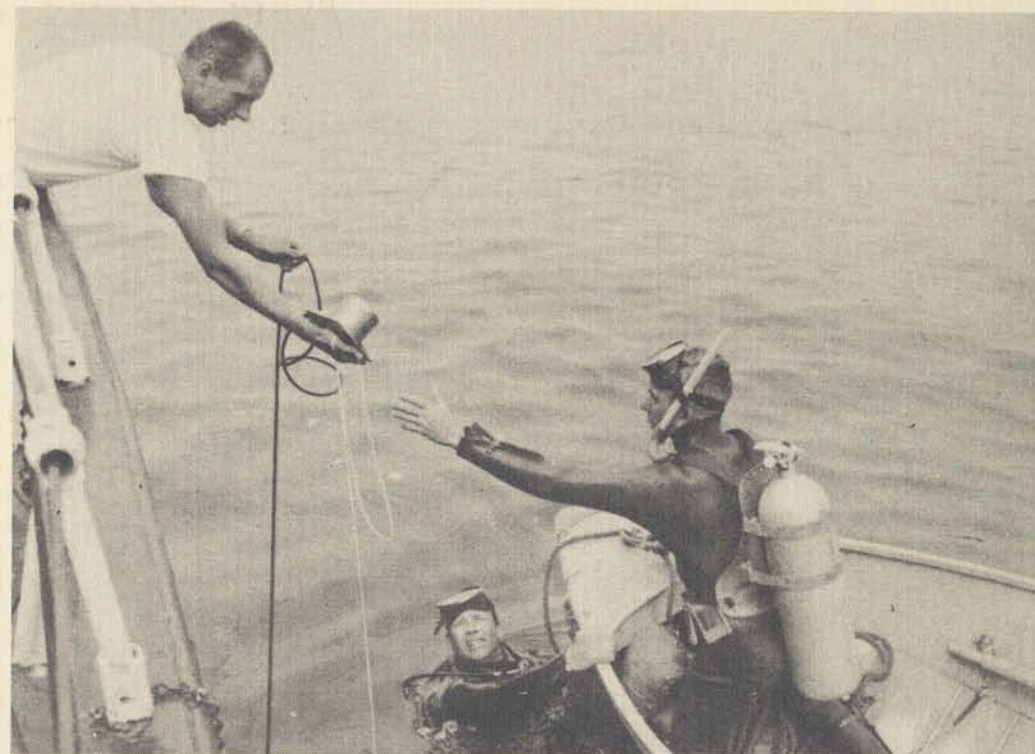
MEMBERS OF THE FLUID PHYSICS DIVISION MAKE PLANS FOR OCEANOGRAPHIC TRIP TO STUDY WAVES AND TO FIELD-TEST A NEW TRANSDUCER. HERE THE RESULTS OF PRELIMINARY LABORATORY TESTS OF THE WAVE SENSORS AND THE DIGITAL DATA SYSTEM ARE COMPARED, TO ENSURE THAT ALL OF THE COMPONENTS ARE OPERATING CORRECTLY.

FLUID PHYSICS DIVISION

High-Energy Fluid Dynamics

The expanding programs of this Division, both experimental and theoretical, are adding significant knowledge to various areas of fluid dynamics. A representative program concerns hypervelocity impact studies based upon the detailed analysis of time-resolved spectroscopic records obtained from shaped-charge jet collisions. Neutral atom and ion densities as functions of time have been obtained from line half-width and Stark shift measurements. These reveal that the copper plasma formed during the collision is about 1-percent ionized. Hydrodynamic and radiation-transport calculations indicate that the observed light arises from a thin region near the expanding plasma front. Several types of measurements show that at 6 microseconds after jet collision the electron temperature is about 10,000 K. The hydrodynamic theory, used to extrapolate backward in time, leads initially to substantially higher neutral and electron temperatures.

A major activity has involved the completion of the first set of magnetic-compression firings for which an explosion geometry was used. These firings employed explosive charges of about 0.39 pound. The maximum magnetic-field compression ratio achieved to date has been 22; starting from an initial field of 56 kilogauss, the final field was 1.3 megagauss. Preparations for a new series of firings are under way. Higher magnetic fields will be achieved by increasing the weight of explosive to about 1 pound.



During 1964 a new program was initiated to study the physical mechanism underlying the intense luminosity in explosively shocked argon. The "argon bomb" technique is a standard way of providing high-intensity illumination for the high-speed photography of non-luminous events. During the course of this program, time-resolved spectroscopic data will be obtained to provide a basis for the construction of a theoretical model of the process. The model can then be used to make detailed predictions on the feasibility of using argon-shock luminosity for various practical applications.

Oceanography

The recently acquired digital data system was put to field use for the first time on an oceanographic trip. Several experiments were performed to study the attenuation of shallow-water waves, particularly as they occur in ocean swell. Directional spectra were measured by means of an array of bottom-pressure gauges. At the same time, field testing of a new bottom-shear-stress transducer was initiated.

FOUR MAIN STEPS ARE INVOLVED IN MEASURING AND RECORDING THE DATA ON OCEAN WAVES. USING THE RESEARCH VESSEL AS A BASE OF OPERATIONS, PROFESSIONAL SCUBA DIVERS SET FORTH IN A DINGHY (UPPER LEFT) TO MARK OFF A 450-FOOT TRIANGULAR AREA WITH BUOYS.

RETURNING TO THE SHIP, THE DIVERS ARE THEN HANDED THE SENSITIVE INSTRUMENTS (UPPER RIGHT) WHICH THEY PLACE ON THE OCEAN BOTTOM AT THE APEXES OF THE TRIANGLE. CABLES RUNNING BACK TO THE SHIP CONNECT THE WAVE-INDICATING DEVICES TO AMPLIFIER AND RECORDER UNITS (LOWER LEFT). SIMULTANEOUSLY, A DIGITAL DATA SYSTEM (LOWER RIGHT) PRODUCES THE SAME INFORMATION ON A PUNCHED PAPER TAPE FOR TRANSMISSION TO THE WAITING COMPUTER.

AFTER THE RESEARCH SHIP DOCKS IN THE EVENING, THE RESEARCH TEAM TAKES PUNCHED TAPES PRODUCED ABOARD THE SHIP TO A DATA TRANSMITTER ON BLOCK ISLAND. WHILE BRIEF VOICE CONVERSATIONS ARE HELD WITH THE COMPUTER CENTER AT STEVENS INSTITUTE, TAPES ARE SELECTED AND INSERTED INTO THE TRANSMITTER.



AT THE COMPUTER CENTER, A RESEARCH ENGINEER GIVES THE FIELD TEAM ON BLOCK ISLAND A REPORT ON TAPE WHICH HAS JUST BEEN PROCESSED THROUGH THE UNIVAC COMPUTER. RESEARCHERS IN THE FIELD THUS HAVE A DAILY CHECK ON THE VALIDITY OF THEIR ACTIVITIES.



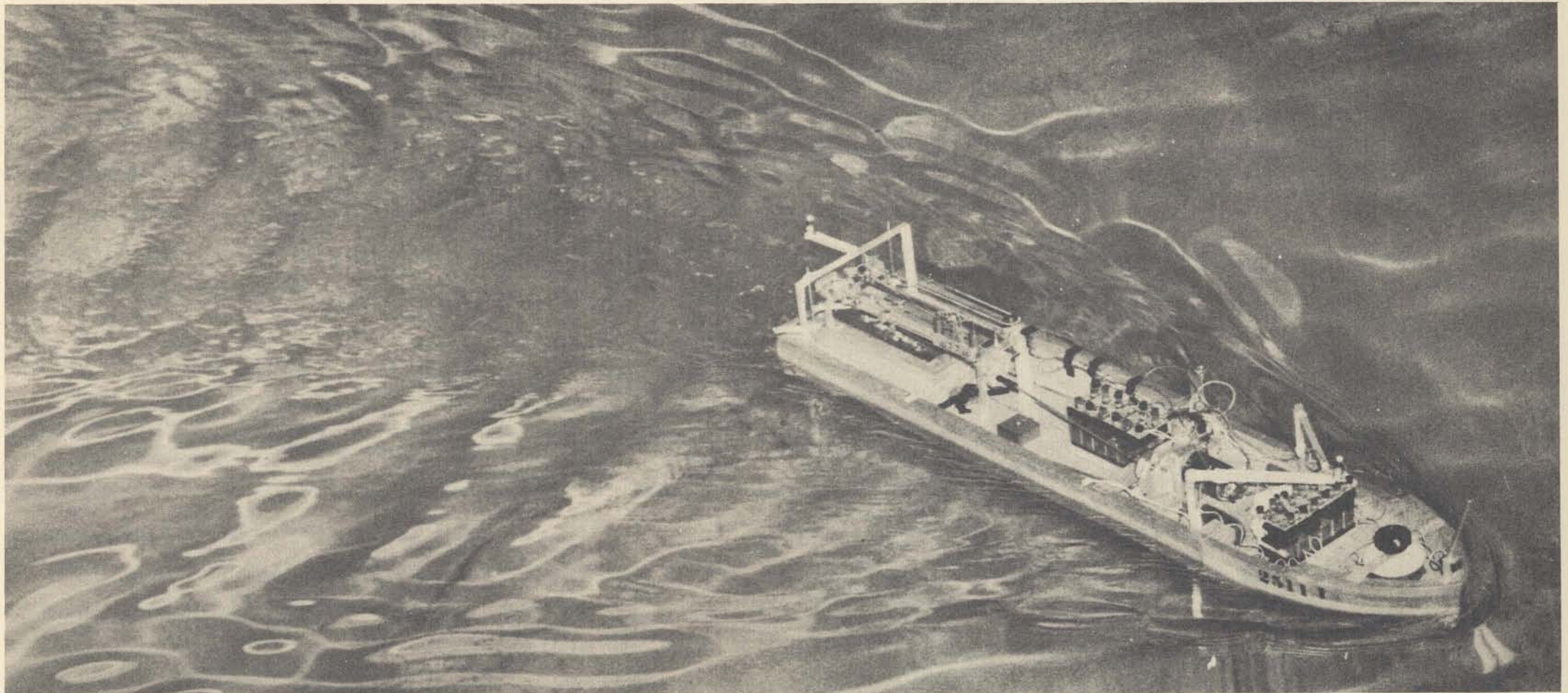
All of the data obtained on the trip were digitized in the field on paper tape in a form capable of direct entry into the Univac 1105 at the Stevens Computer Center. However, an additional and potentially significant experiment was undertaken — the establishment of a teletype datalink between Block Island and Hoboken, involving the use of commercially available telephone-company installations and services. The purpose of the work was to assess the feasibility of such a scheme for supplying oceanographic researchers with fast analysis of field data, and to determine the characteristics of data transmission from Block Island.

In 1964 a theoretical study was completed which has made it possible to extract power spectra and cross spectra from rectified data. The need for such a study derived from frequent use in the oceanographic work of thermistors for fluid measurements which are inherently non-directional. The technique that was developed requires application of a transformation to the covariance of the rectified data and reversal of the sign of the covariances at certain lags.

Potential Flows

The Division has also developed a theory of internal wave generation by a dipole moving in a medium characterized by an exponential density distribution. Such a density distribution is of practical interest because it commonly occurs in the Davidson Laboratory towing tanks and in the ocean as well. These theoretical results are being subjected to detailed comparison with experimental results recorded in earlier towing-tank studies.

SELF-PROPELLED 1/40-SCALE MODEL OF A 22-INCH PIPE
LINE DREDGE DURING A FREE-TURNING MODEL EXPERIMENT



The scattering of surface waves by underwater obstacles is being studied in another program which includes both experimental and theoretical investigations. Thus far, calculations have been of an exploratory nature, to assess relative magnitude of the near- and far-field contributions.

STABILITY AND CONTROL DIVISION

This division makes analyses of the stability and control of vehicles that move through fluids, and is concerned with the measurement and prediction of the external forces in terms of body shape and motion. Objectives are to improve the methods used to predict trajectories and to define design conditions leading to optimum performance.

New Design

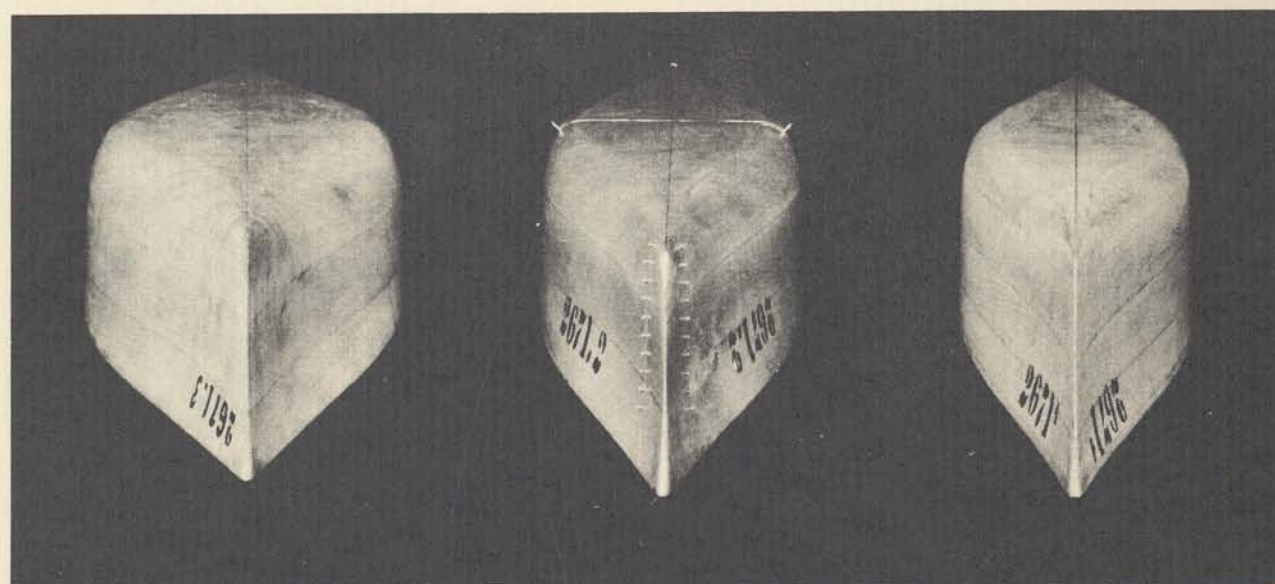
In 1964 a submarine-like vessel was designed on the basis of the linearized turning theory developed earlier. The theory indicates that this kind of design is hydrodynamically stable in both ahead and astern motions, has a high degree of turning ability with a very small stern rudder, and eliminates the strong yaw-to-roll and yaw-to-pitch coupled motions that are present with conventional designs. The theory also predicts that such a design will experience much smaller sideslip angles than are normally obtained during tight turns, thus permitting substantially higher turning speeds and making linearized turning theory more credible than in other cases. A model of the new design was constructed, and rotating-arm evaluation tests were made to check the theory. Preliminary analysis of the results indicates that the theory is confirmed by the experiments.

MODELS USED TO MEASURE EFFECTS OF VARIATIONS IN
(A) FULLNESS, (B) BREADTH, AND (C) LATERAL PROFILE,
IN CONTROLLABILITY TESTS TO STUDY SHIP MANEUVERING
AND COURSE-KEEPING QUALITIES

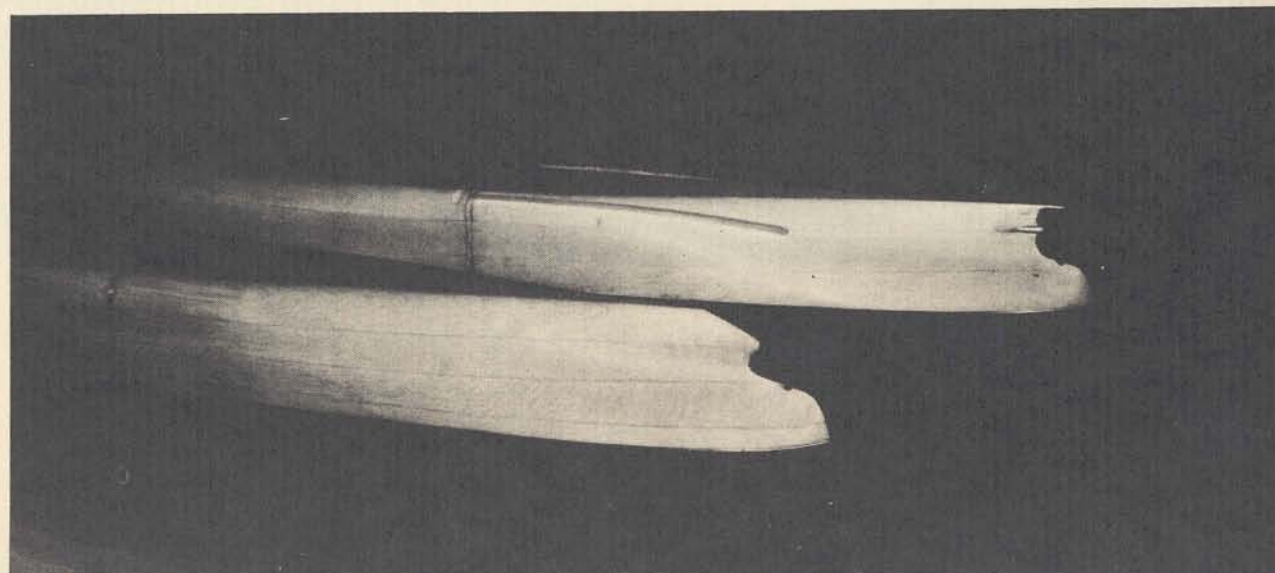
(A)



(B)



(C)



Automatic Control of Torpedoes

The directional stability and controlled horizontal turning characteristics of a finless torpedo were analyzed theoretically to determine whether proper design of a proportional control can yield good performance even in the case of extreme hydrodynamic instability. Although the study was part of a general appraisal of the fundamental relation between the performance characteristics obtained with and without automatic controls, it also was motivated by the desire to reduce hydrodynamic drag and noise due to propeller-fin interactions. The results show that the finless torpedo can be made directionally stable, but that it can recover only from low degrees of control saturation; to avoid oversaturated conditions which are characterized by uncontrollable motions, a control system must be used which prevents the finless torpedo from utilizing its potentially high rate of response. On the other hand, a directionally stable torpedo with tail fins can recover from highly saturated controls if it has a high degree of hydrodynamic stability. The latter case is characterized by sluggish response under unsaturated control conditions.

Surface-Ship Controllability

Toward the end of 1964, and in the third year of a five-year program, the studies of surface-ship controllability, previously conducted by the Transportation Research Group, were transferred to the Stability and Control Division of the Applied Mechanics Group. Work was continued on an experimental program designed to determine the influence of ship form and proportions on steering and maneuvering qualities. Six additional models were tested, using rotating-arm, towing-tank, and maneuvering-basin facilities. Good agreement was obtained between experimental results and theoretical predictions of the hydrodynamic stability derivatives. Analyses of the yaw and sway motions of ships in oblique waves were extended to the bow-sea range. As in the earlier quartering-sea tests, preliminary results for the bow-sea range indicate that measured forces and pitch plane motions can be predicted theoretically.

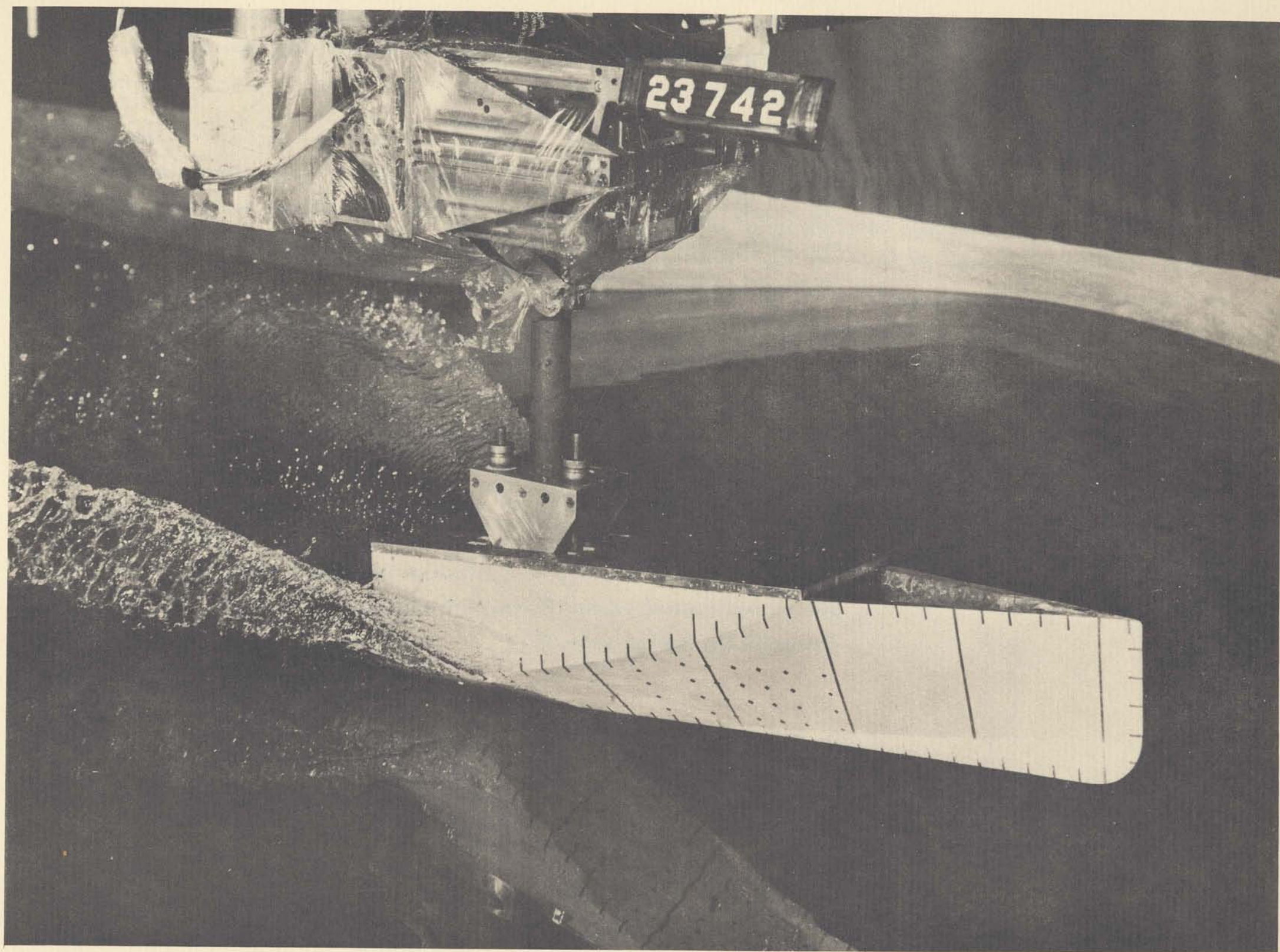
At the request of various naval-architecture firms, free-running model tests were made in 1964 of several surface ships whose performance characteristics were found to be wanting in some respects. On the basis

of the experimental results, the Division made recommendations for modifications of the ship forms to improve turning, maneuvering, and stability characteristics.

Other Programs

Work is continuing on the effect of a free-fluid surface on torpedo performance, on studies of the limitations of conventional analyses of the stability of submerged vessels with and without controls, and on the development of new techniques for the measurement of hydrodynamic force and moment derivatives in accelerated missile motions.

The following programs are nearing completion: a correlation of the hydrodynamic forces and moments that act on a tapered submerged body of revolution, as functions of its shape variables; an experimental and theoretical study of a surface-piercing hydrofoil system; and an investigation of the magnitudes of non-linear induced hydrodynamic roll moments and their influence on torpedo motions. Problems which have recently been initiated by the Division include research on the low-speed controllability of surface ships, the study and design of search and rescue submersibles, and the study and design of a fast-sinking homing vehicle.



FLOW PHENOMENA DIVISION

Established in October of 1964, the Flow Phenomena Division conducts theoretical and experimental studies of basic flow phenomena in incompressible fluids, non-uniform gases, and ionized gases.

Water Impact

An investigation of the hydrodynamic impact of rigid bow forms on regular water waves is being pursued, both theoretically and experimentally. A generalized strip theory, based on the concept of added mass, has been developed to evaluate the lift and drag on the bow forms. Numerical computations made for specific forms have been found in good agreement with preliminary experimental results.

Wave Resistance

In view of the fact that the usual method for estimating wave resistance of ships does not take into account the viscous effect which actually alters the wave pattern, a theoretical and experimental program is now under way to develop a new method which will lead to a more realistic assessment of wave resistance. Waves will be considered as

MODEL OF A TYPICAL BOW FORM FOR A HIGH-SPEED MARINE CRAFT
DESIGNED FOR OPERATION NEAR AND ABOVE THE WATER SURFACE.
IN ORDER TO OBTAIN DATA VITAL TO SOUND STRUCTURAL DESIGN,
THE IMPACT FORCES ON THE HULL ARE MEASURED AS THE MODEL
ADVANCES INTO WAVE CRESTS.

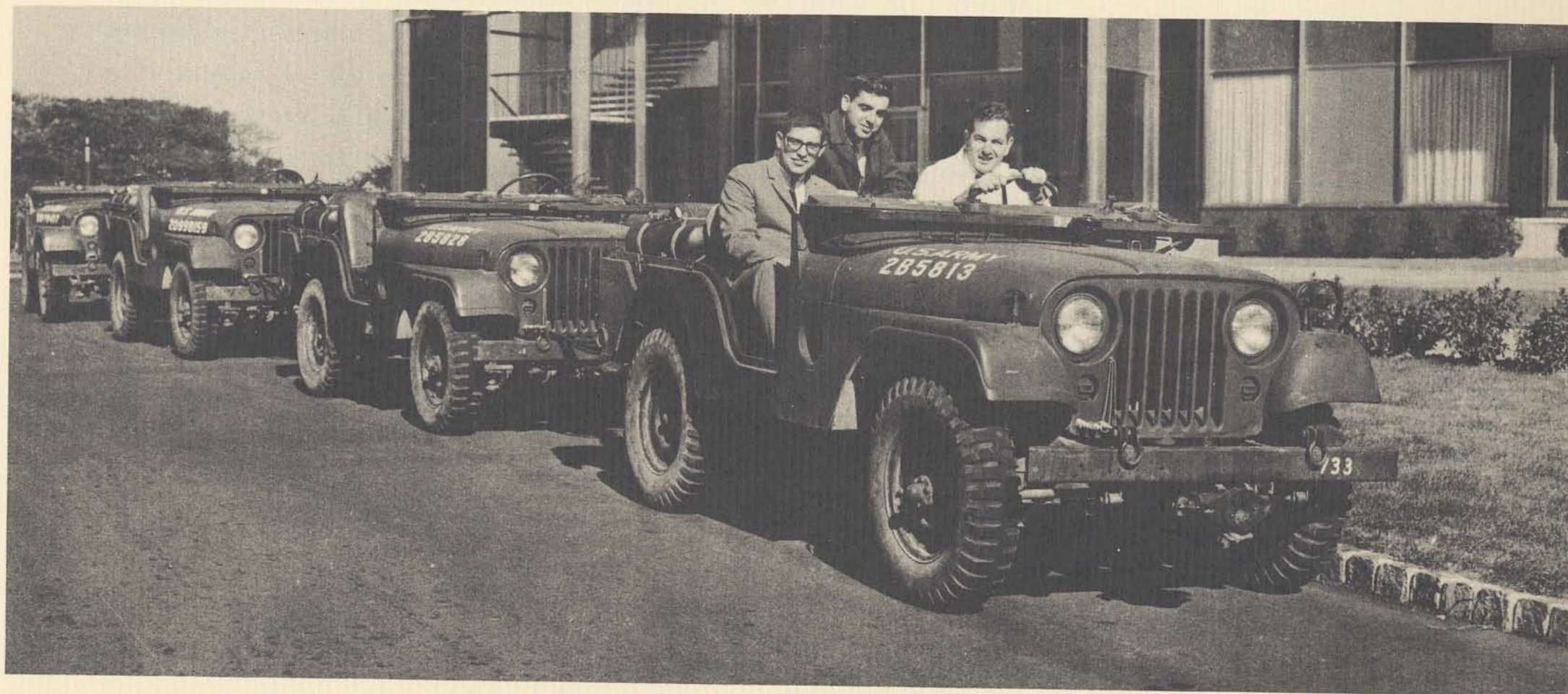
generated by a moving pressure distribution which will be obtained from measurements of the same form moving in a real fluid. Since the presence of viscosity alters the pressure distribution in the stern region, the singularity distribution, which can be obtained by solving an integral equation, will represent the flow pattern more accurately. Wave resistance thus calculated from the potential theory will then be compared with experimental results.

Drifting Force and Moment

The non-oscillatory force and moment acting on ships in waves, although of the second order as compared with the oscillatory force and moment, are very important in the study of ship motions, because they induce a steady drift to the ship. A theoretical method for evaluating such drifting force and moment has been developed and has been applied to thin ships in long waves. The analytical results, expressed in terms of simple elementary functions, exhibit many interesting physical interpretations.

Shock Waves in Plasma

A theoretical study is being undertaken which concerns formation of a shock wave in a fully ionized gas. With the presence of a magnetic field, the mechanism of shock formation is quite complicated. Preliminary study for the case of a weak shock wave with a magnetic field perpendicular to the flow direction has been made, based on the moment equation of the Boltzmann equations for electrons and ions. The system has been reduced to a pair of second-order partial differential equations, with the electron Larmor radius, the mean free path, the length of penetration, and the mass-ratio of electron and ion as parameters. Studies on the structure of shock waves in a plasma with an oblique magnetic field are also planned.



THE JEEP TRAIN — AN EXPERIMENTAL TRACKLESS VEHICLE TRAIN
COMPRISING FOUR MODIFIED M38A1 $\frac{1}{4}$ -TON MILITARY TRUCKS

TRANSPORTATION RESEARCH GROUP

The Transportation Research Group is concerned with all phases of transportation research, especially that associated with the performance of ships, yachts, and low-speed aircraft, with vehicular traffic, with off-road mobility, and with the integration of all land-, sea-, and air-transportation facilities. The need for more emphasis on these studies becomes pressing as we continue to travel at higher speeds and in environments never before attempted; and the phenomenal congestion on our highways plainly underscores the urgent requirement for studies which will help solve this national dilemma.

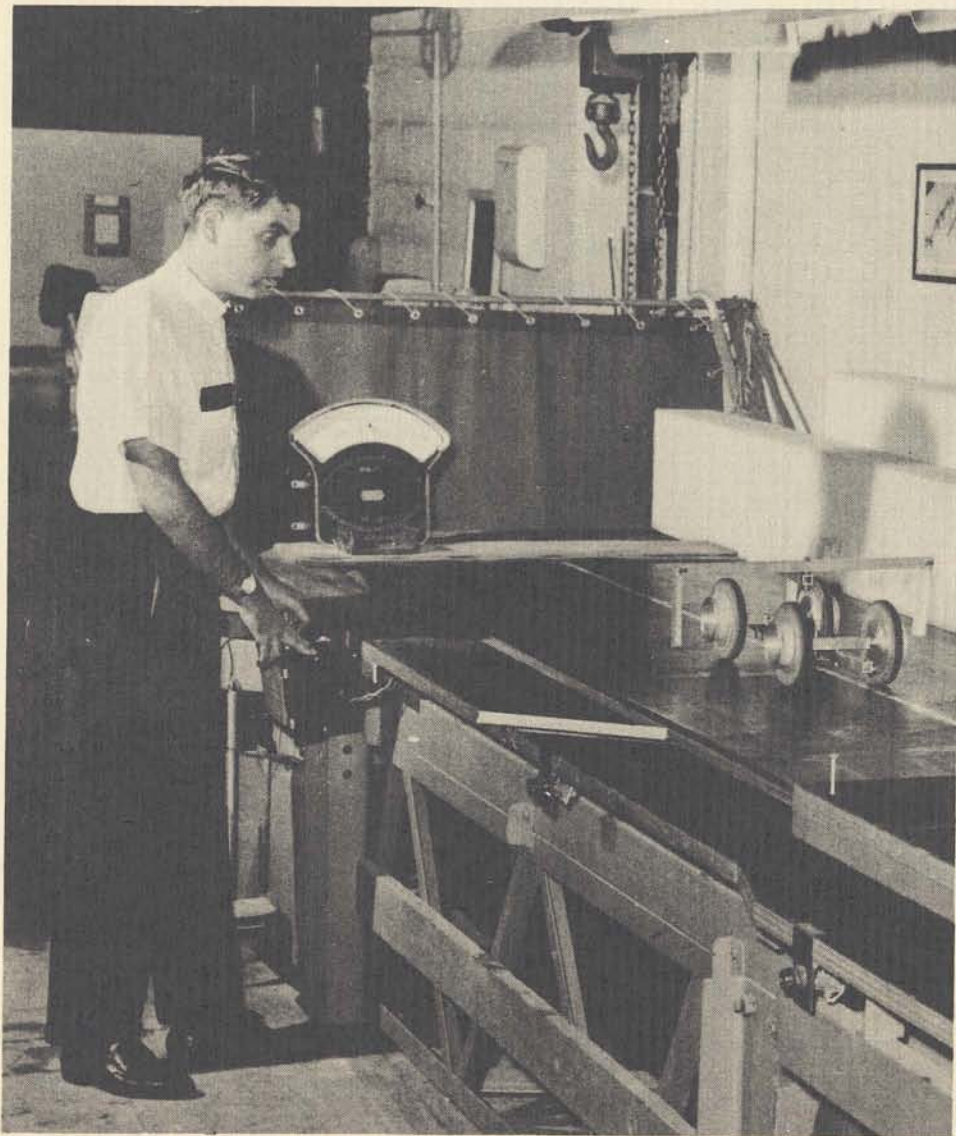
MOTOR VEHICLE RESEARCH

The Motor Vehicle Research Division is concerned with many aspects of the behavior of both on- and off-road vehicles. During 1964 work ranged from studies of internal-combustion-engine performance through analyses of vehicle dynamics and highway safety to programs in various fields of vehicle mobility research.

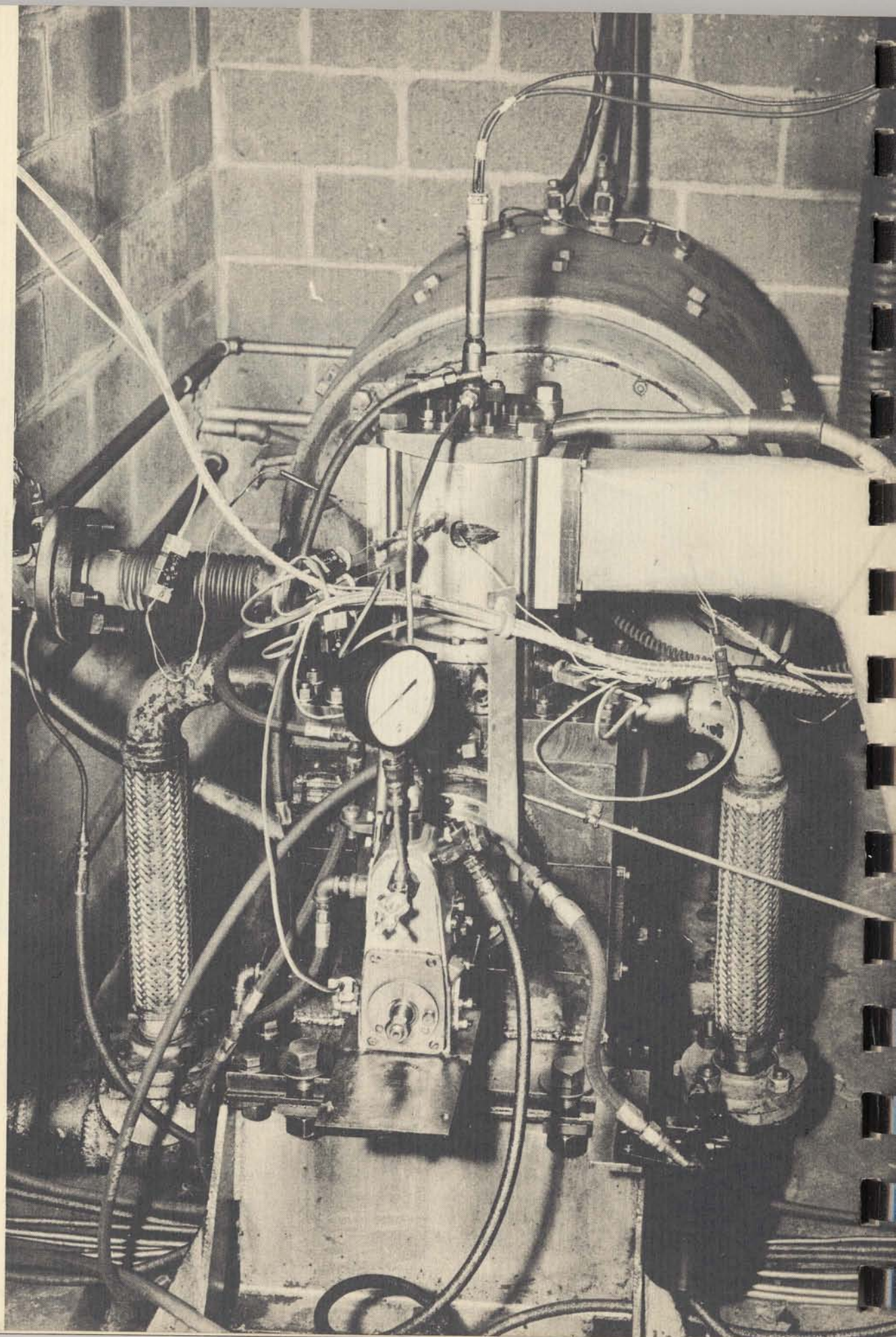
Engine Research

In the area of engine research, work continued on the development of a new high-performance compression-ignition engine. The limits in output attainable by this highly supercharged, air-cooled, loop-scavenged, two-cycle power plant are being investigated in a systematic experimental program on a special single-cylinder test bed installation. Results to date show a specific output far exceeding that of the conventional engine, plus reasonable wear characteristics and fuel consumption. Current plans call for early construction of a multi-cylinder pilot engine.

HIGHLY SUPERCHARGED SINGLE-CYLINDER TWO-STROKE
COMPRESSION-IGNITION ENGINE, INSTALLED IN
SPECIALLY EQUIPPED TEST CELL



DIRECTIONAL-STABILITY MODEL TEST
ON ROLLING ROAD FACILITY



Another special engine-test setup has been devised to study the performance of conventional spark-ignition engines operating at elevations corresponding to the high altitudes of projected highway tunnels. Measurements have shown that carbon-monoxide emissions increase severely at these elevations, in comparison with those at sea-level conditions. Work in this important field of air pollution is being continued.

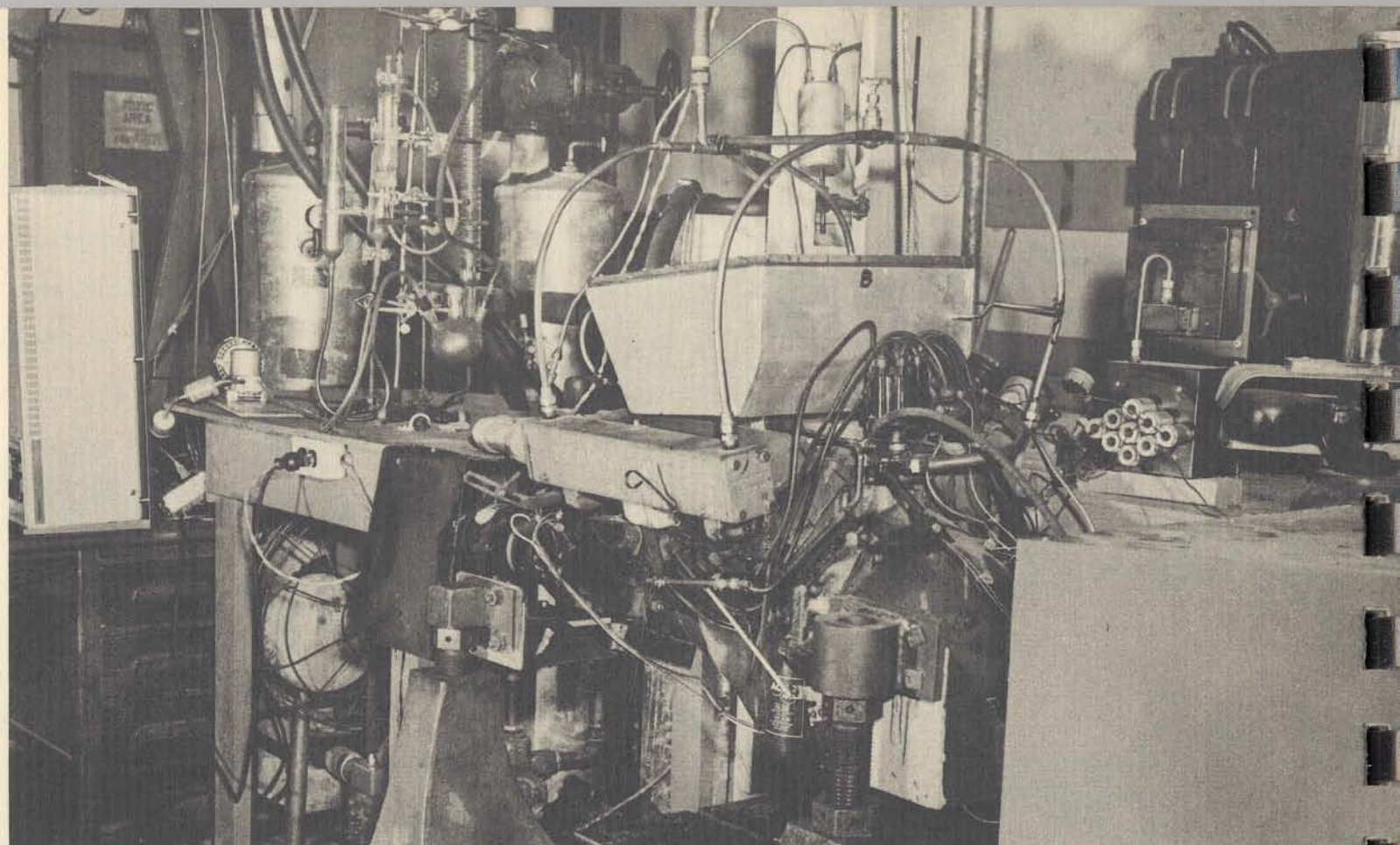
Coupled Mobility Device

The exploitation of the trackless-train concept to improve vehicle off-road mobility and efficiency is engaging more and more attention. A comprehensive investigation, recently undertaken conjointly with Wilson, Nuttall, Raimond Engineers, Inc., has advanced the development of a new concept in off-road vehicles — the coupled mobility device (CMD) — to the status of practicability. This concept, originally conceived by the Land Locomotion Laboratory, USATAC, consists of a multiplicity of low-ground-pressure, articulated wheeled vehicles, each of which is highly mobile when operated singly and all of which exhibit, in combination as a train configuration, even greater off-road performance capabilities. It is now recommended that a pilot vehicle of three 3-ton CMD units be constructed as soon as possible.

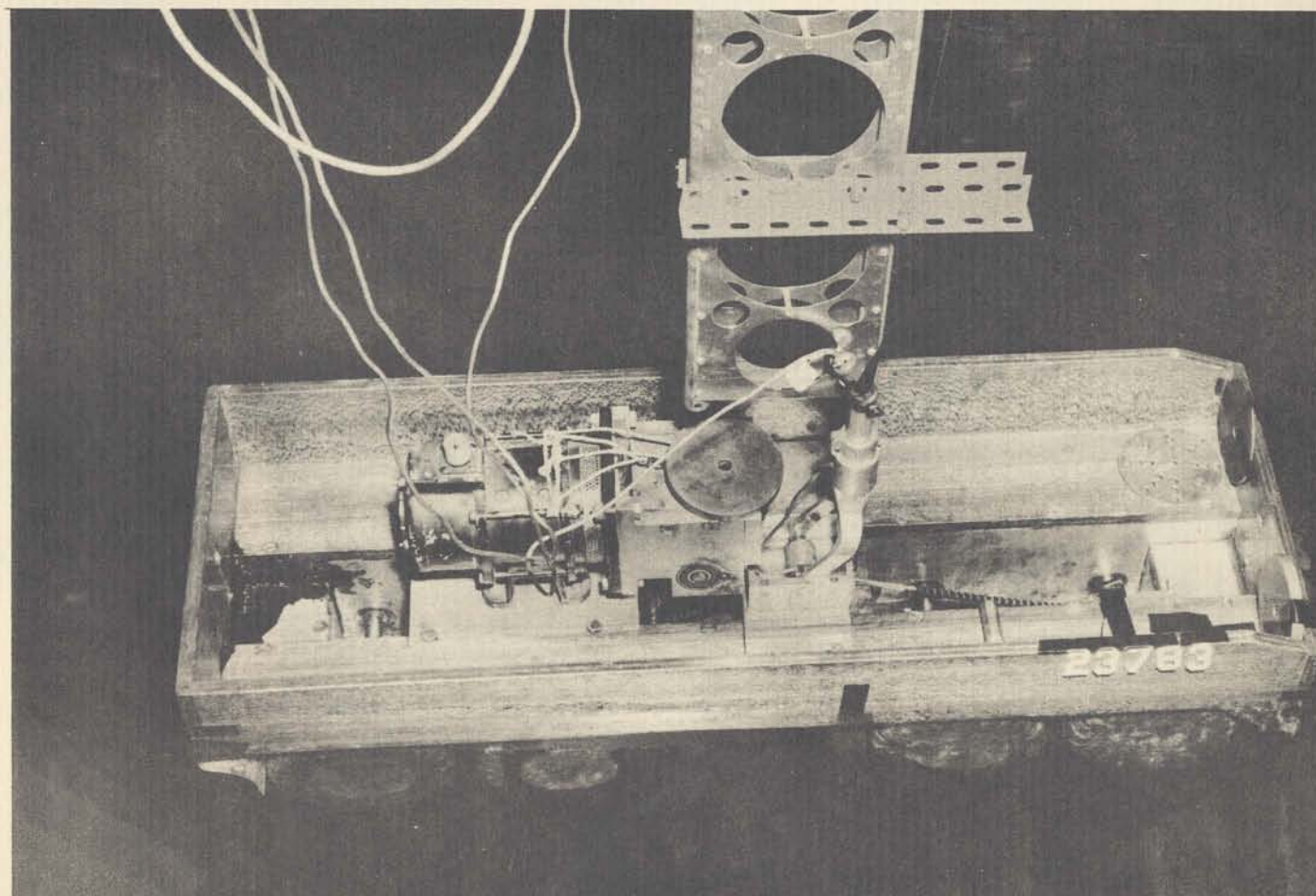
Trucks

The Jeep Train, an experimental trackless train comprising four slightly modified standard military $\frac{1}{4}$ -ton trucks, has demonstrated that dynamic lateral instability (as a problem in highway-train operation) can be overcome and that present engine and brake control systems are both

TEST OF COMMERCIAL PASSENGER-
CAR ENGINE UNDER SIMULATED
HIGH-ALTITUDE CONDITIONS, TO
DETERMINE THE VARIATIONS IN
EXHAUST EMISSIONS



SELF-PROPELLED 1/8-SCALE MODEL
OF AMPHIBIOUS VEHICLE,
UNDER TEST TO DETERMINE THE
PROPULSIVE EFFECTIVENESS
OF THE ROTATING TIRES



durable and reliable. At present, tests of this train are being conducted to measure mobility advantages and to make comparisons with conventional vehicles. Stability testing is also being continued as part of a program whose object is the development of general scale-model techniques for studying vehicle dynamics. In addition, theoretical work concerned with the dynamic stability of more conventional vehicles, viz., semi-trailer highway trucks, is being conducted. The current approach is more general than that taken in previous work; aerodynamic effects are considered.

Amphibians

The trackless-train concept is being further investigated for application to amphibious vehicles, and it is hoped that the reduction in hydrodynamic drag obtainable with effective increase in the critical vehicle length-width ratio will more than offset any degradation of propulsive efficiency which might be incurred. Other studies specifically related to the water-propulsion phase of the vehicle mobility problem are being pursued. The mechanism of thrust generation by the submerged wheels of a floating vehicle has been the subject of a theoretical analysis which is now being verified by an experimental program. A similar study related to the water performance of tracked vehicles is also under way, and attempts are being made to perfect a theory of scale-model testing for general use in evaluating and designing amphibious vehicles.

Ocean-Floor Vehicles

Certain other studies performed during the year fall under the general heading of vehicle mobility research. One model-test program, carried out as part of a design study for a remote-controlled tracked

vehicle intended to operate on the ocean floor, produced results suggesting that such a vehicle is feasible from a trafficability point of view. A part of this program involved the development of special techniques for the processing and description of submerged soils.

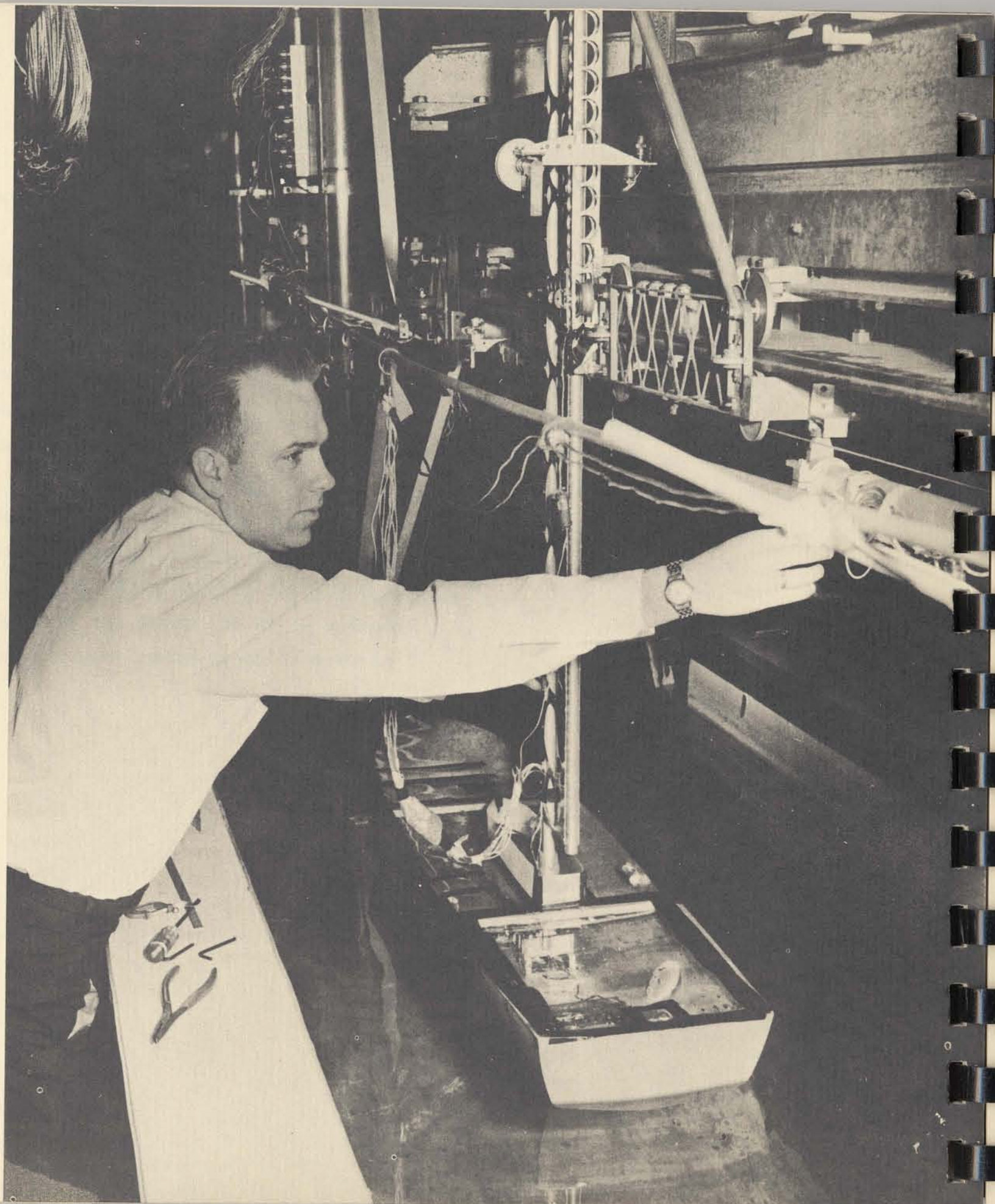
Soil-Vehicle Interaction

A more general attack on the soil-vehicle interaction problem is represented by an experimental study of the relationship between stress and strain for different soils under normally loaded flat plates of various sizes and shapes; an effort is being made to derive an empirical pressure-sinkage equation which accounts for both plate geometry and soil properties. Another empirical study in progress, concerned with the so-called "one-pass trafficability problem," is an attempt to develop a method by which very quick and simple in-situ soil measurements can be used to predict whether or not a particular vehicle can successfully traverse a given soil section.

Traffic Safety

A new research area, which the Division has recently entered in a natural extension of its vehicle stability studies, is the field of traffic safety. In 1964 a comprehensive program to investigate various problems associated with the installation of road-dividing center barriers was initiated. Accident records have been provided by the New Jersey Department of Motor Vehicles, for use in an objective statistical analysis to evaluate the total effect of center-barrier installation on traffic safety. In line with the general philosophy of the Division, model theory is now being applied to the vehicle-barrier interaction problem, so that scale models can be used to evaluate, and perhaps improve, barrier design. This same approach is being used in a study pertaining to hydroplaning of pneumatic tires — a problem of concern both on the highway and in airplane landings and take-offs. In this program, the Motor Vehicle Research Division is cooperating with the Fluid Dynamics Division, which has undertaken a theoretical study of the tire-water film-pavement interaction.

ROUGH-WATER LOADS-AND-MOTIONS
APPARATUS IN HIGH-SPEED FACILITY



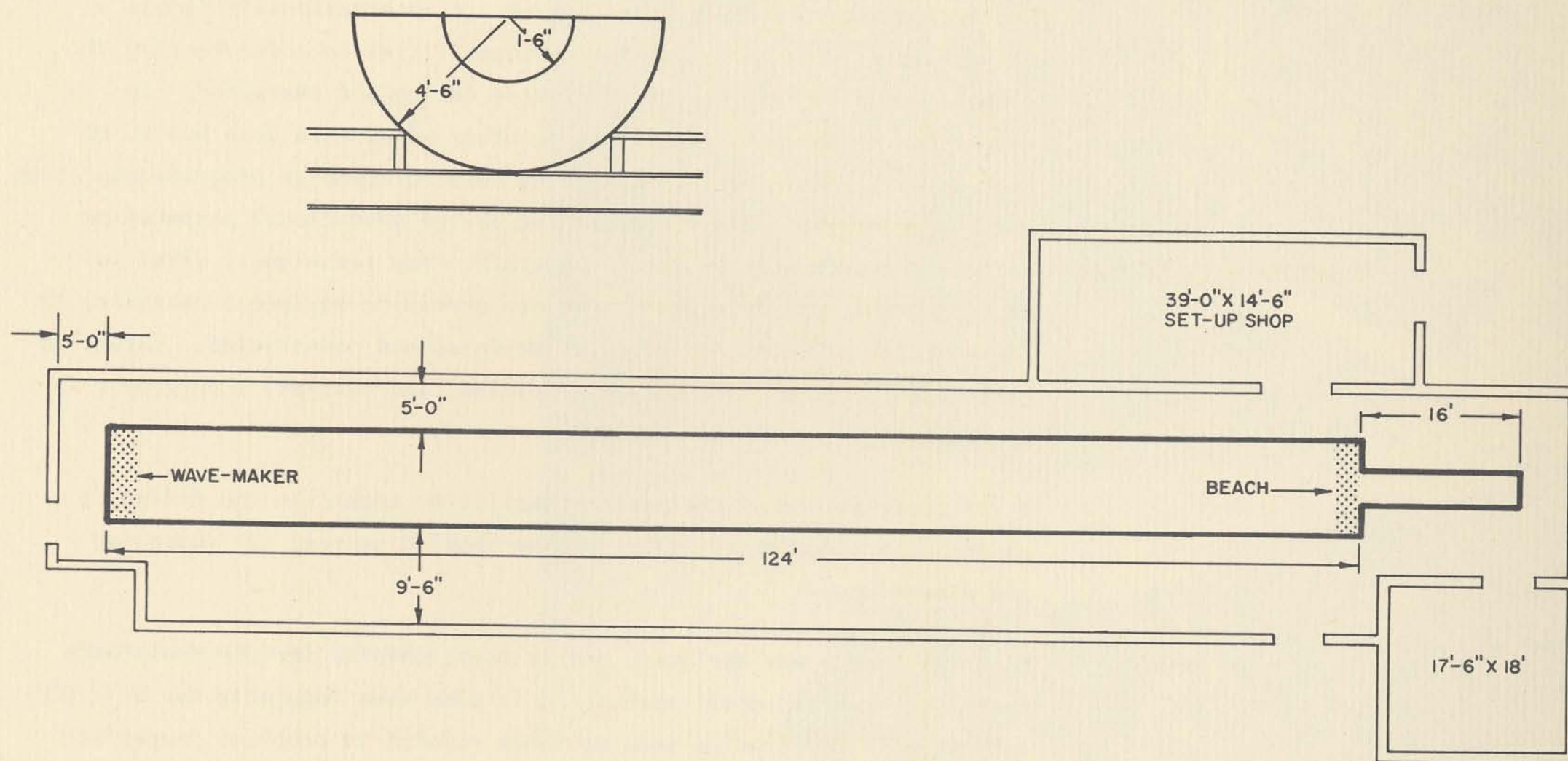
FACILITIES DIVISION

The Davidson Laboratory's water basins are internationally famous as facilities with almost unlimited capabilities in model testing of submerged and surface bodies of diverse design and character. In recent years, however, facilities of other kinds have been built, to provide additional means of obtaining data for complex programs embracing the important disciplines represented by the educational preparation and the research experience of the staff. New techniques, vital to such programs, are developed. And new precision equipment necessary to the exercise of such techniques is designed and constructed. Extensive tank reconstruction is sometimes entailed, and over-all improvement is programmatic.

Brief descriptions of the present facilities appear in the following pages, with a number of illustrations showing general configuration and dimensions.

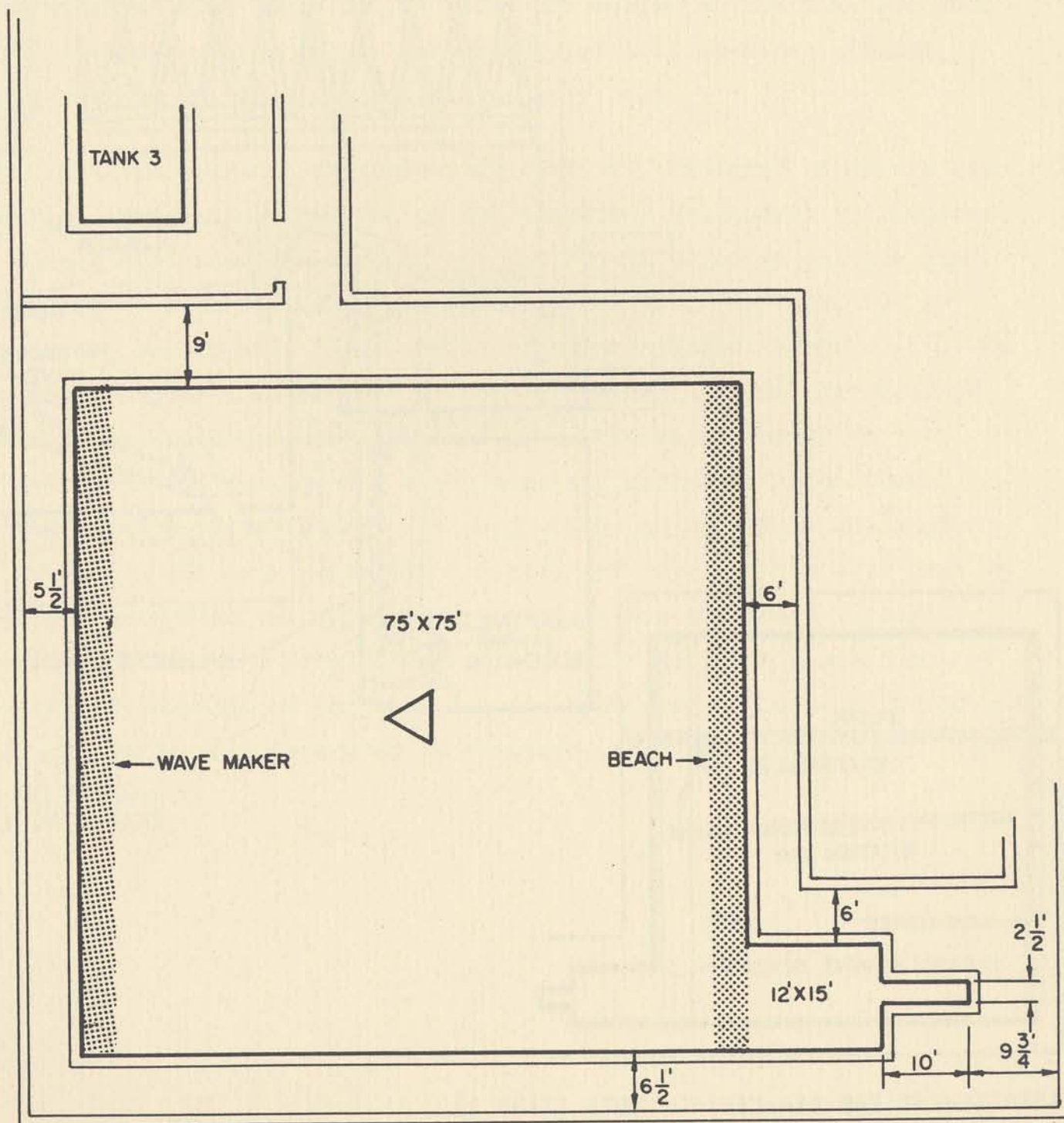
Tank 1

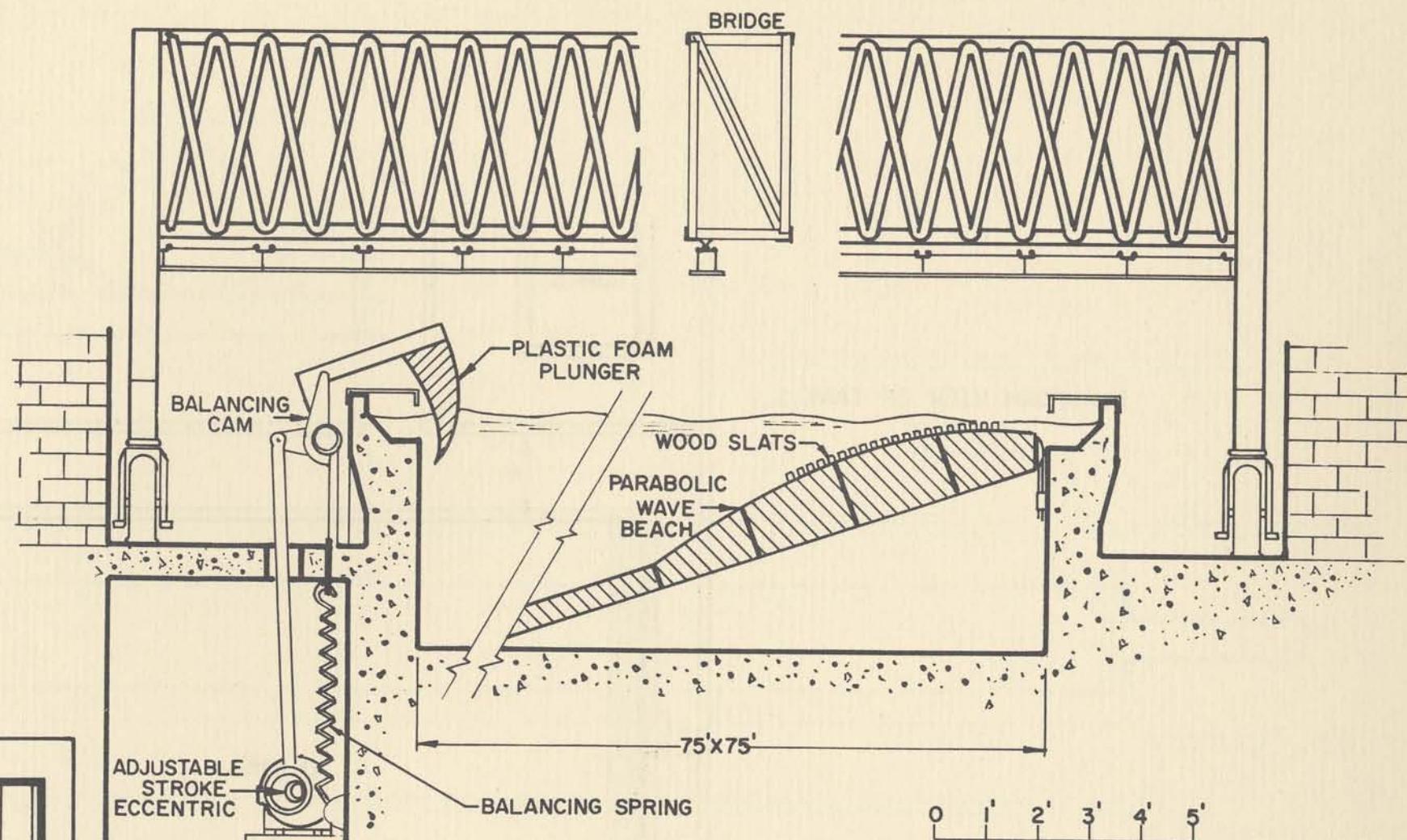
Although Tank 1 was designed, and is used, chiefly for the resistance testing of surface-craft models, it is also used regularly for a variety of other studies such as those related to problems presented by the lateral forces on sailboats, the trim of semi-planing boats, or barge-yawing. Ship and yacht models 3 to 6 ft long are tested at speeds of up to 20 fps. Electronically controlled acceleration is synchronized with the controlled generation of a spectrum of regular or irregular waves. These reproducible waves simulate ocean storm conditions, in tests to assess seakeeping characteristics in head and following



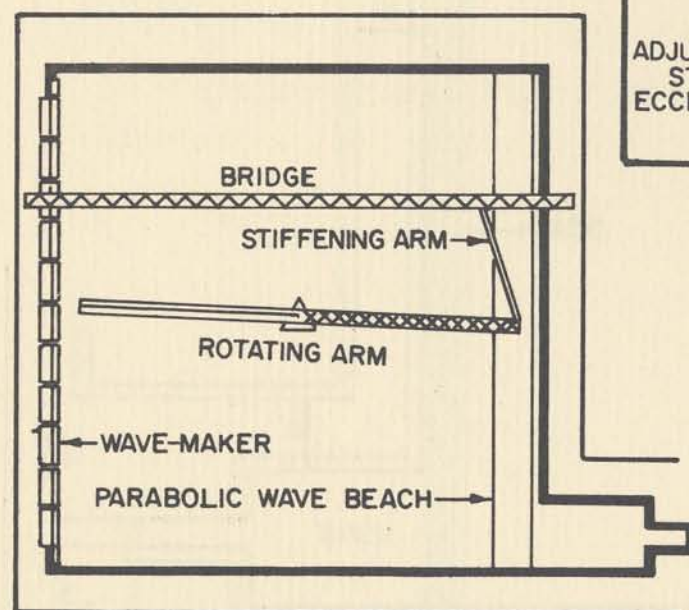
PLANFORM VIEW OF TANK 1

PLANFORM VIEW OF TANK 2





SEAKEEPING INSTALLATION (TANK 2)

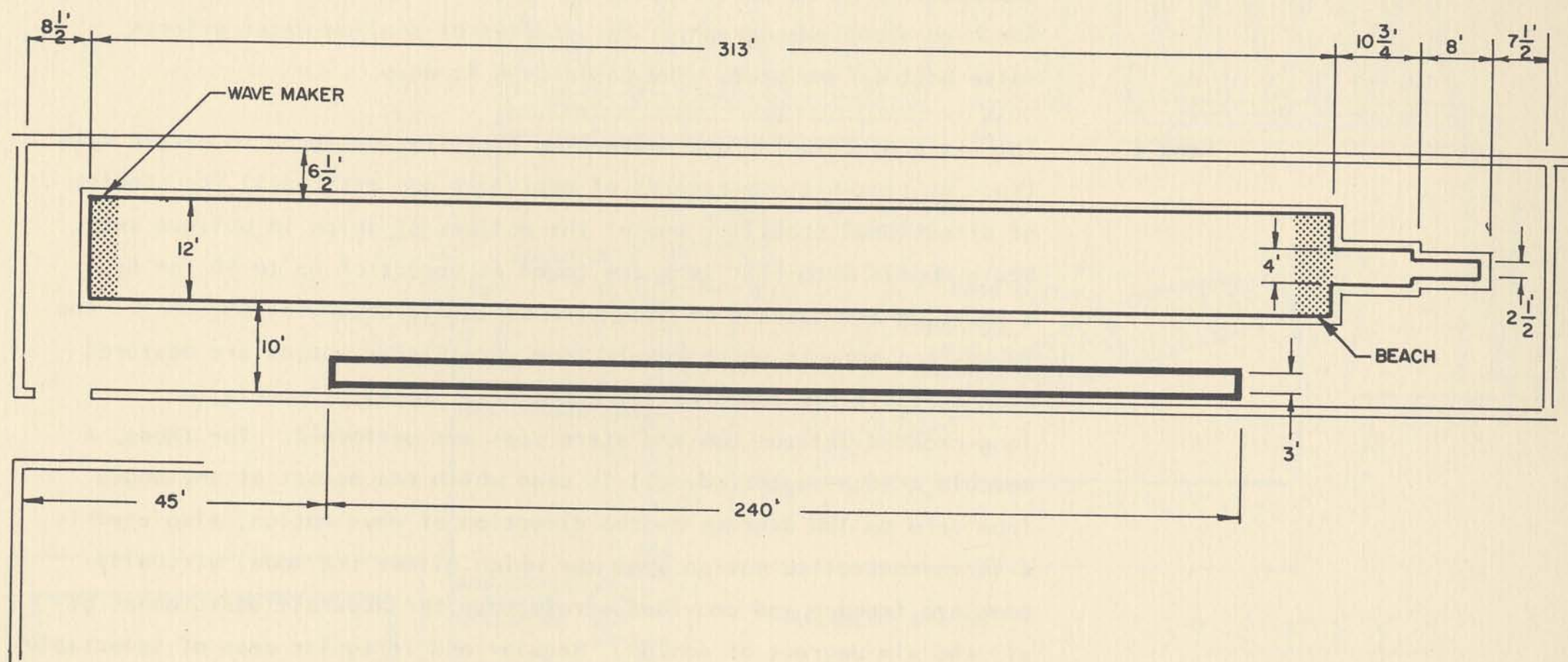


ARRANGEMENT FOR SEAKEEPING TESTS (TANK 2)

long-crested seas. Beaches at the end opposite the wave generator absorb wave energy and eliminate practically all wave reflection. Underwater viewing ports at the sides and bottom of the tank are used for high-speed photography. For studies of shallow-water effects, false bottoms are used. The basin is 4 ft deep.

Tank 2

This is a maneuvering and seakeeping facility, equipped to obtain data (such as time-history records of positions and attitudes) for studies of directional stability and of the motions of ships in oblique seas. Scale models 4 to 6 ft long are towed at speeds of up to 40 fps by a rotating arm capable of clockwise or counterclockwise movement. The forces and moments which result from curvilinear motion are measured with suitable six-component dynamometers. Tests of models in long-crested oblique bow and stern seas are performed. For these, a movable bridge-supported rail is used which can be set at any angle from zero to 180 degrees to the direction of wave motion; also used is a servo-controlled motion apparatus which allows the model virtually complete freedom and provides a reference for accurate measurement of all the six degrees of motion. Regular and irregular seas of selectable characteristics are generated to simulate actual sea conditions. Tank 2 is $4\frac{1}{2}$ ft deep.



PLANFORM VIEW OF TANK 3

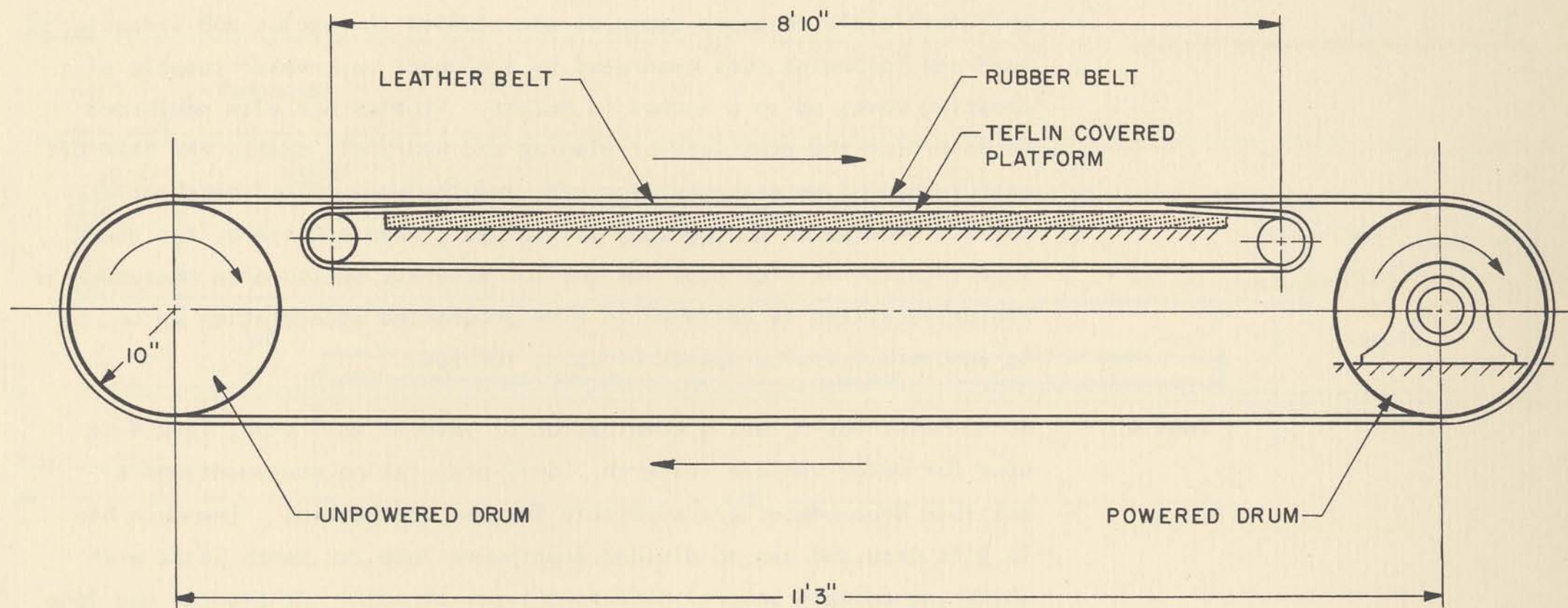
Tank 3

In this high-speed facility, 6 ft deep, the researcher can determine lift, drag, and moment of all types of high-speed craft, in calm and rough water. The dynamic responses of models varying in type from hydrofoil craft to space capsules are studied in regular and irregular head and following seas generated by a plunger wave-maker capable of creating waves up to 8 inches in height. Studies are also performed to determine the stability of planing and hydrofoil craft, the take-off performance of water-based aircraft, and the powering of merchant ships. Underwater photography is employed, when necessary, for the investigation of flow problems and for accurate wetted-area measurements. The drive system is designed to give programmed acceleration up to 3g and permit towing speeds of up to 100 fps.

Tank 4

Not a water basin, but a combination of several soil bins, Tank 4 is used for motor-vehicle research. Soil-preparation equipment and a soil-bin dynamometer are available for use in the bins. The main bin is 3 ft deep and can be divided lengthwise into two lanes $3\frac{1}{2}$ ft wide which can contain several different types of soil. At present one lane has a specially constructed bin, installed for submerged-soil studies relevant to ocean-floor vehicle research.

The soil-bin dynamometer measures performance of individual wheel or track suspension systems with vehicle loadings of up to one ton; this same range applies to loadings necessary in the processing of soils and for studies of soil characteristics and soil sinkage stress-strain relationships. The dynamometer control system has a unique



SCHEMATIC ILLUSTRATING OPERATION OF ROLLING ROAD

constant-slip-ratio feature by means of which the ratio of the vehicle's forward speed to its track or wheel speed can be kept fixed even though the individual values are varied during a test run.

Rolling-Road-Test Facility

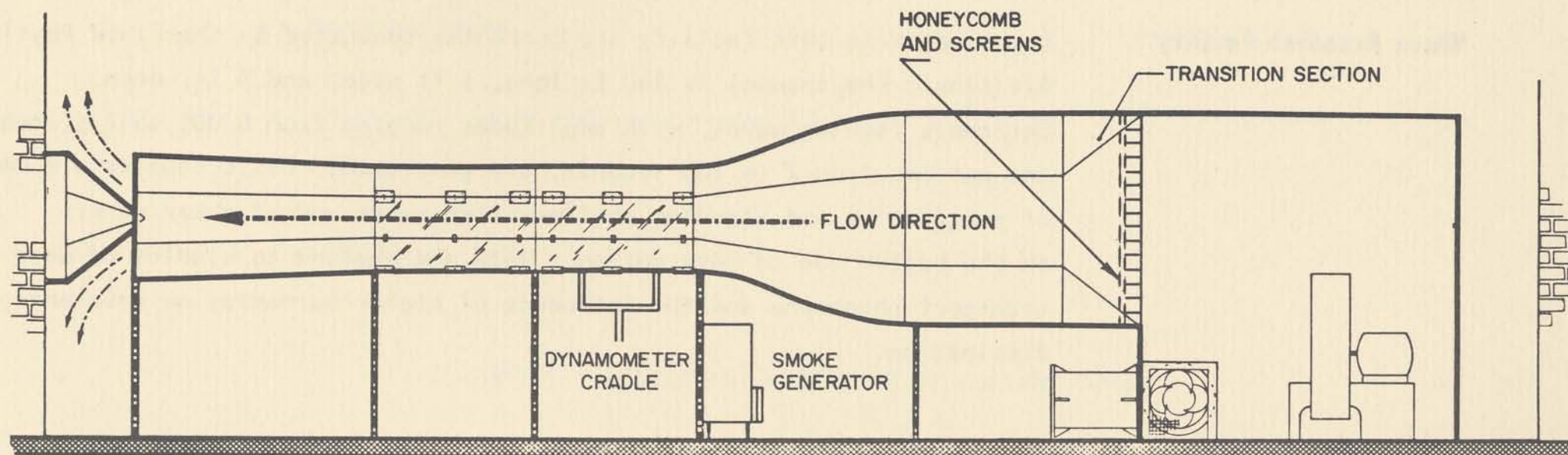
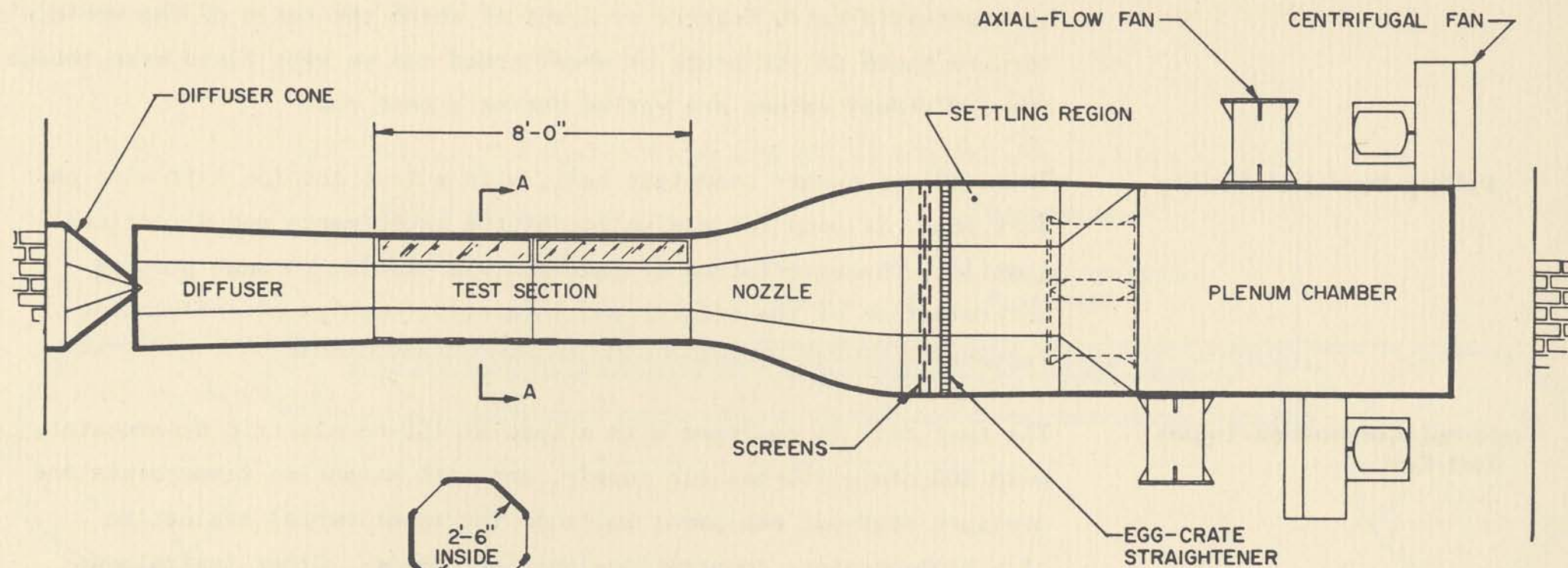
This endless rubber road-test belt, with a test section 4 ft wide and 8 ft long, is used for evaluation of the performance and directional-stability characteristics of land-vehicle models, through precise determination of the effects and interrelationships of influencing factors.

Internal-Combustion-Engine Test Cell

The test cell is equipped with a special 150-hp electric dynamometer, with 300-cfm - 120-psi air supply, and with extensive temperature and pressure read-out equipment suitable for experimental evaluation of a high-pressure compression-ignition engine. Other test stands are available for either code or special tests.

Wave Research Facility

Experiments in this facility are currently conducted by the Fluid Physics Division. The channel is 240 ft long, 3 ft wide, and 9 in. deep. Extremely regular waves, with amplitudes ranging from 0.005 to 1.5 inch and periods from 2 to 200 seconds, are generated. Basic studies are made of progressive and standing shallow-water waves and of shear stress on the bottom due to wave motion. Data are applied to studies of wave transport phenomena and the influence of higher harmonics on wave-energy dissipation.



LOW-SPEED WIND TUNNEL

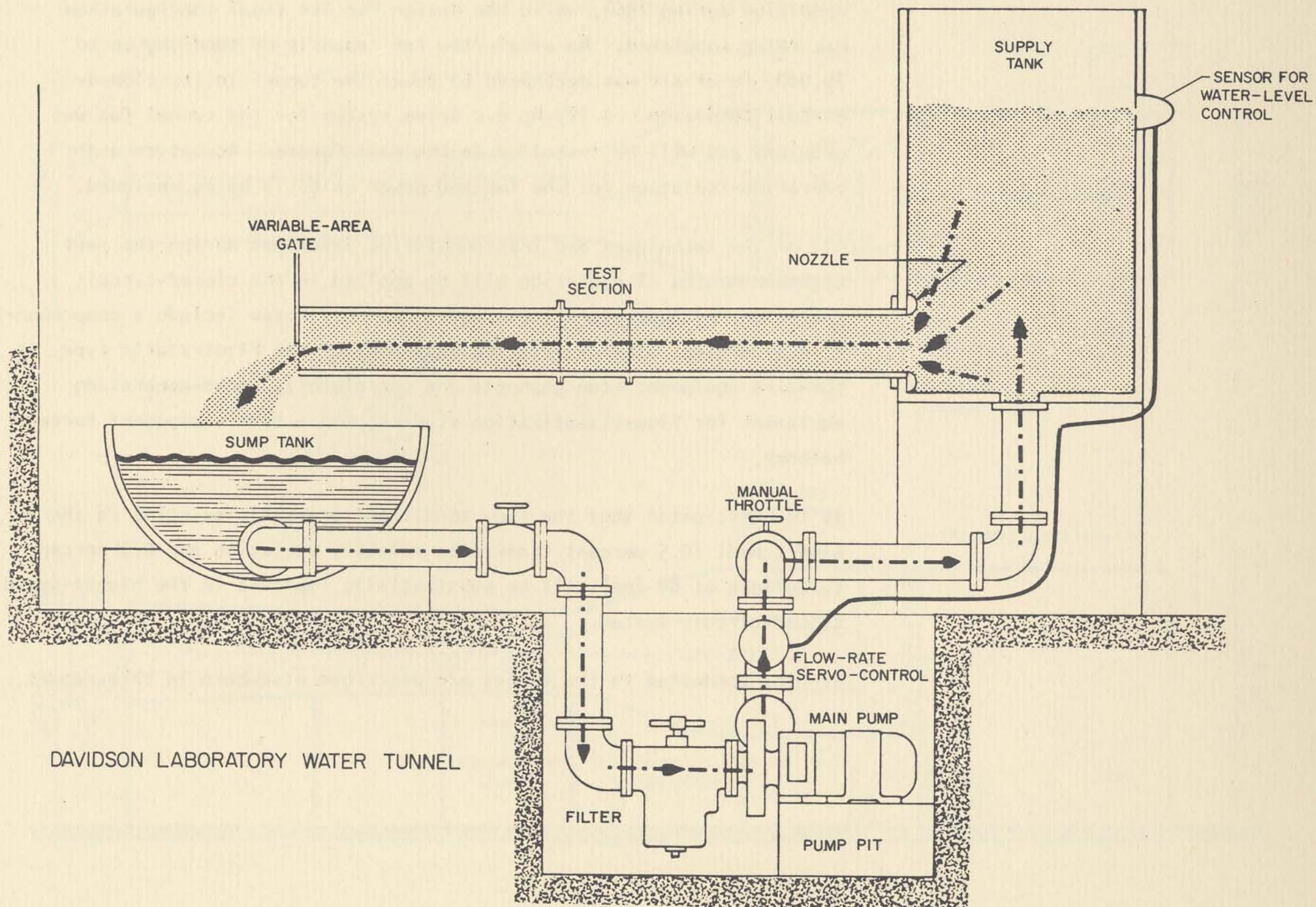
Wind Tunnel

The Laboratory's wind tunnel continued to operate in an open-circuit condition during 1964, while the design for its final configuration was being completed. An axial-flow fan capable of handling up to 75,000 cfm of air was purchased to power the tunnel in its closed-circuit condition. A 125-hp d-c drive system for the tunnel fan was acquired and will be installed in the near future. Acoustic- and vibration-isolation for the fan and power units is being designed.

All of the techniques and instrumentation developed during the past eighteen months of operation will be applied in the closed-circuit operation, without significant modification. These include a comprehensive assortment of flow-metering equipment of the Pitot-static type, hot-wire equipment (two channels and correlator), smoke-generating equipment for flow-visualization studies, and a three-component force balance.

It is anticipated that the flow conditions presently existing in the wind tunnel (0.5 percent transverse velocity variation and 0.3 percent turbulence at 80 fps) will be substantially improved in the higher-speed closed-circuit system.

Studies conducted in the tunnel are described elsewhere in this report.



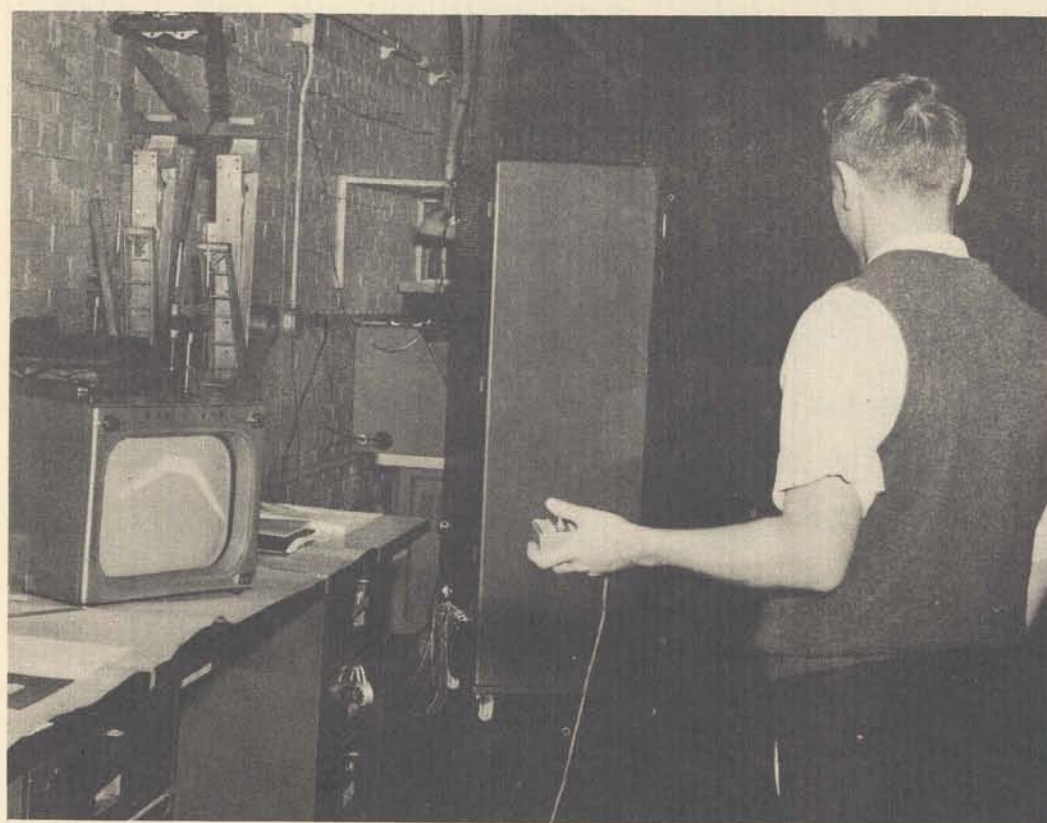
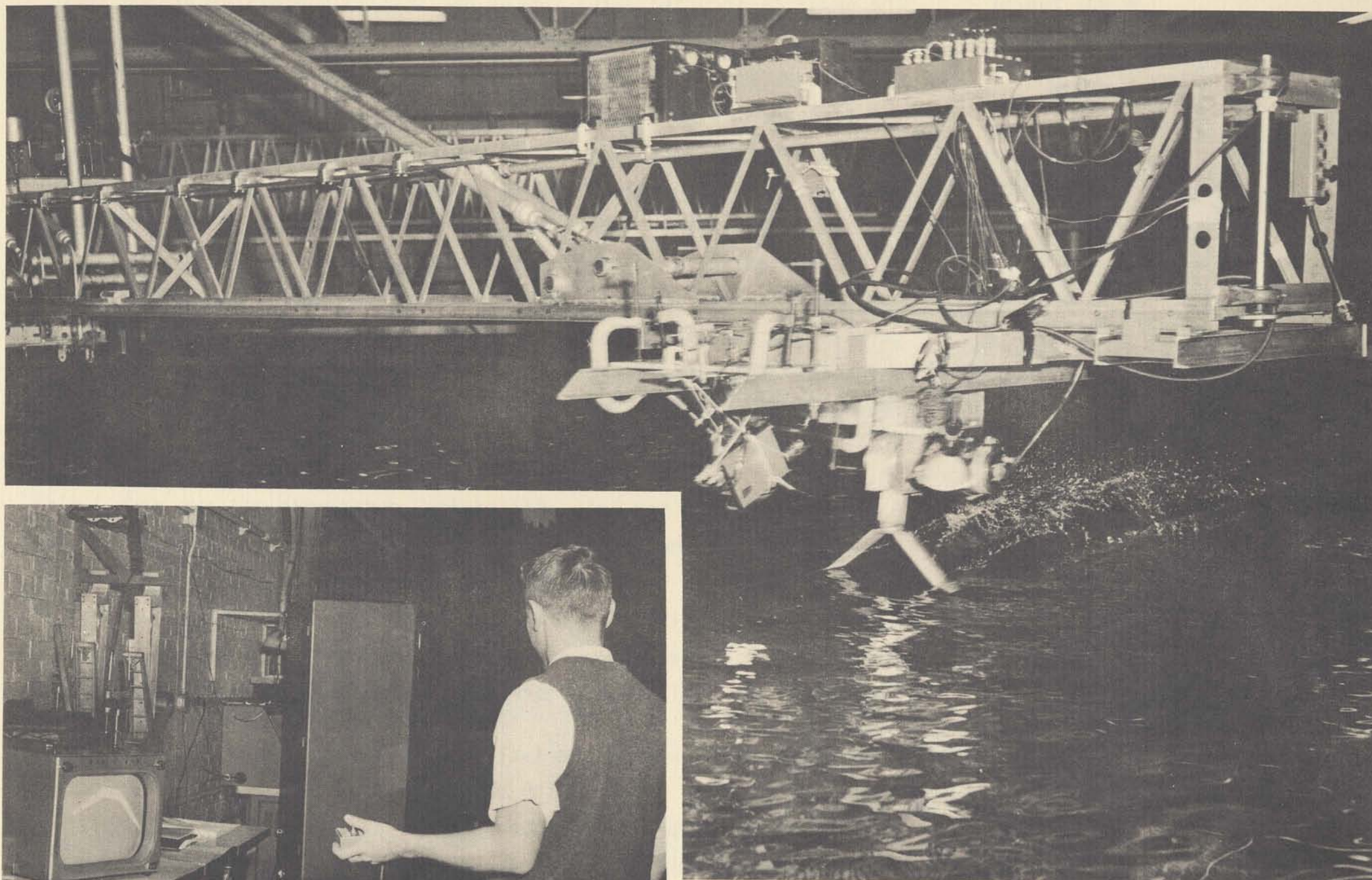
DAVIDSON LABORATORY WATER TUNNEL

Water Tunnel

The newly constructed water tunnel was initially operated during the latter part of 1964. A somewhat unusual feature of the tunnel is that it operates in a blow-down fashion from a constant-head reservoir through the test section to a sump tank. Water is recirculated from the sump tank to the reservoir by a 7.5-hp centrifugal pump, at rates up to 1500 gpm. Head control is accomplished by a special float valve which acts as a throttle on the recirculating-pump discharge. For flow rates up to 1200 gpm at a reservoir head of 60 inches of water, the head variation is less than plus-or-minus $\frac{1}{4}$ -inch of water. A throttling gate at the test-section duct discharge is used to control the test-section velocity. The actual test-section velocity depends upon the particular test-section geometry. One test section currently in use is a 1-ft-long lucite channel with a 3-by-10-in. rectangular cross section.

A separate circuit for water filtration, containing its own circulating pump, is part of the system and can be kept in constant operation. The main reservoir and the sump tank (each of approximately 750-gal capacity) are fabricated entirely of cyprus wood, for low maintenance. In the design of the tunnel, provision has been made for future temperature regulation and additional filtration circuits, as the need arises.

A variety of pressure- and velocity-measuring equipment has been designed, built, or acquired for use with this facility. This includes special static- and total-pressure probes as well as a newly developed hot-film probe compatible with the hot-wire equipment used in the wind tunnel. Force and moment balances are available for use in the water tunnel, and a dye-injection apparatus is being designed for flow-visualization studies.



USE OF THE TURNING-ARM TANK
AS A FLOW-VISUALIZATION FACILITY,
WITH CLOSED-CIRCUIT TELEVISION HOOKUP

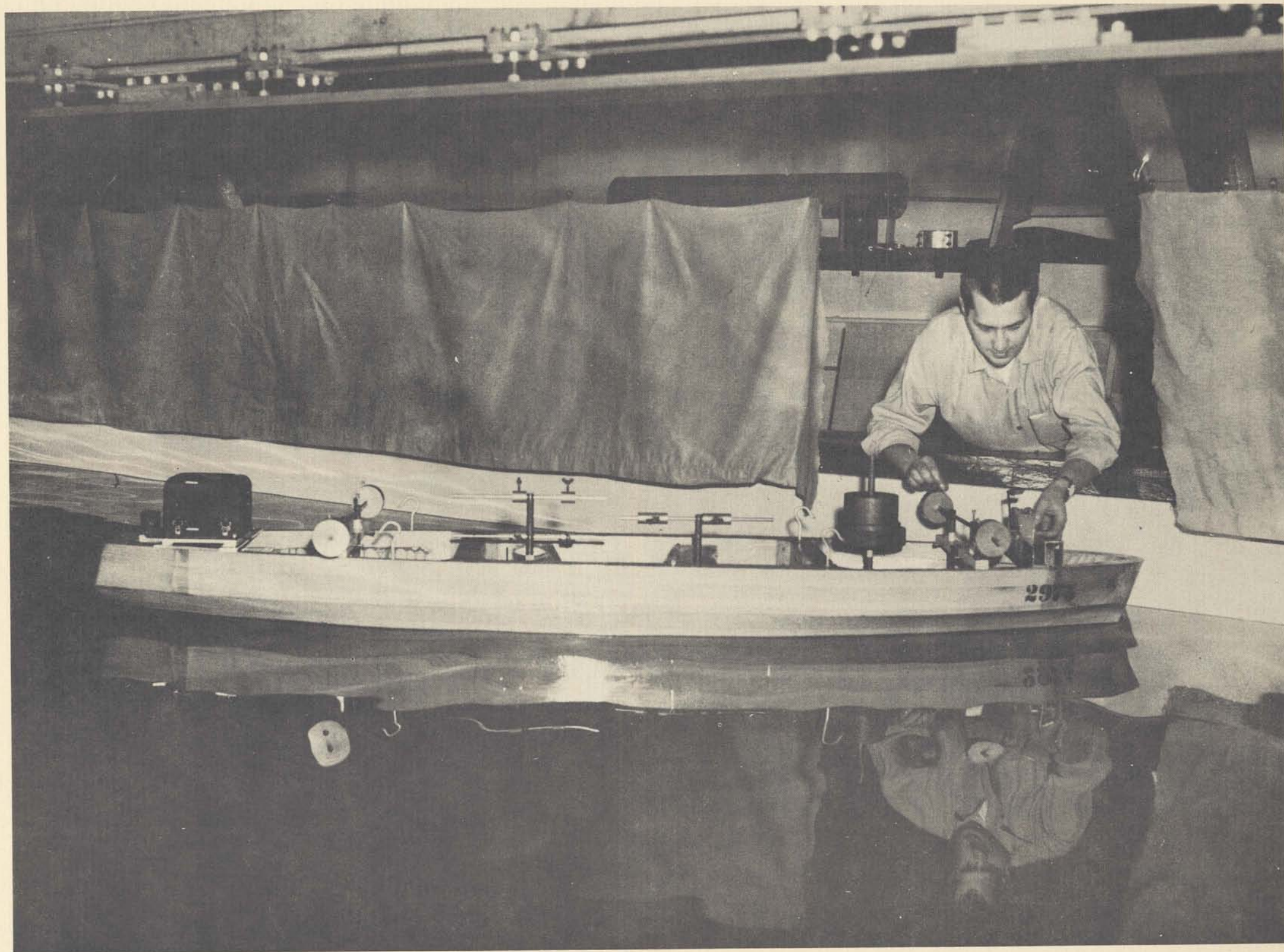
MARINE CRAFT DEVELOPMENT GROUP

The Marine Craft Development Group forms a link between fundamental research and the design office. Its function is to interpret the findings of the fundamental researcher and apply them to the development problems that confront the designer. Development tests, generally of a non-routine nature, are undertaken. Techniques which yield design information are evolved. Specific problems are solved, covering almost every aspect of marine operation from offshore drilling to sailboat design. While the research performed by other groups is highly useful, a certain amount of basic research is also carried on here — to fortify judgment and to broaden perspective. Existing facilities and techniques are adapted to current needs.

MARINE CRAFT DYNAMICS DIVISION

The members of this Division use Tanks 1, 2, and 3 to pursue both fundamental studies and testing programs concerned with the development and evaluation of designs for all types of craft operating on or near the water surface.

In 1964, development work of a proprietary nature included the following studies: tests of hydrofoil craft, power boats, and seaplanes; the determination, in Tank 2, of wind loads on the structure of a satellite-tracking antenna; wave-testing of column-type floating oil-drilling platforms and of several catamaran ships; evaluation of a large number of passive anti-rolling tank installations, both by



tank oscillation tests and by comparison of ship-model rolling motions in waves with and without the passive tank in operation; and testing of ship-hull appendages for wave-cancellation effects.

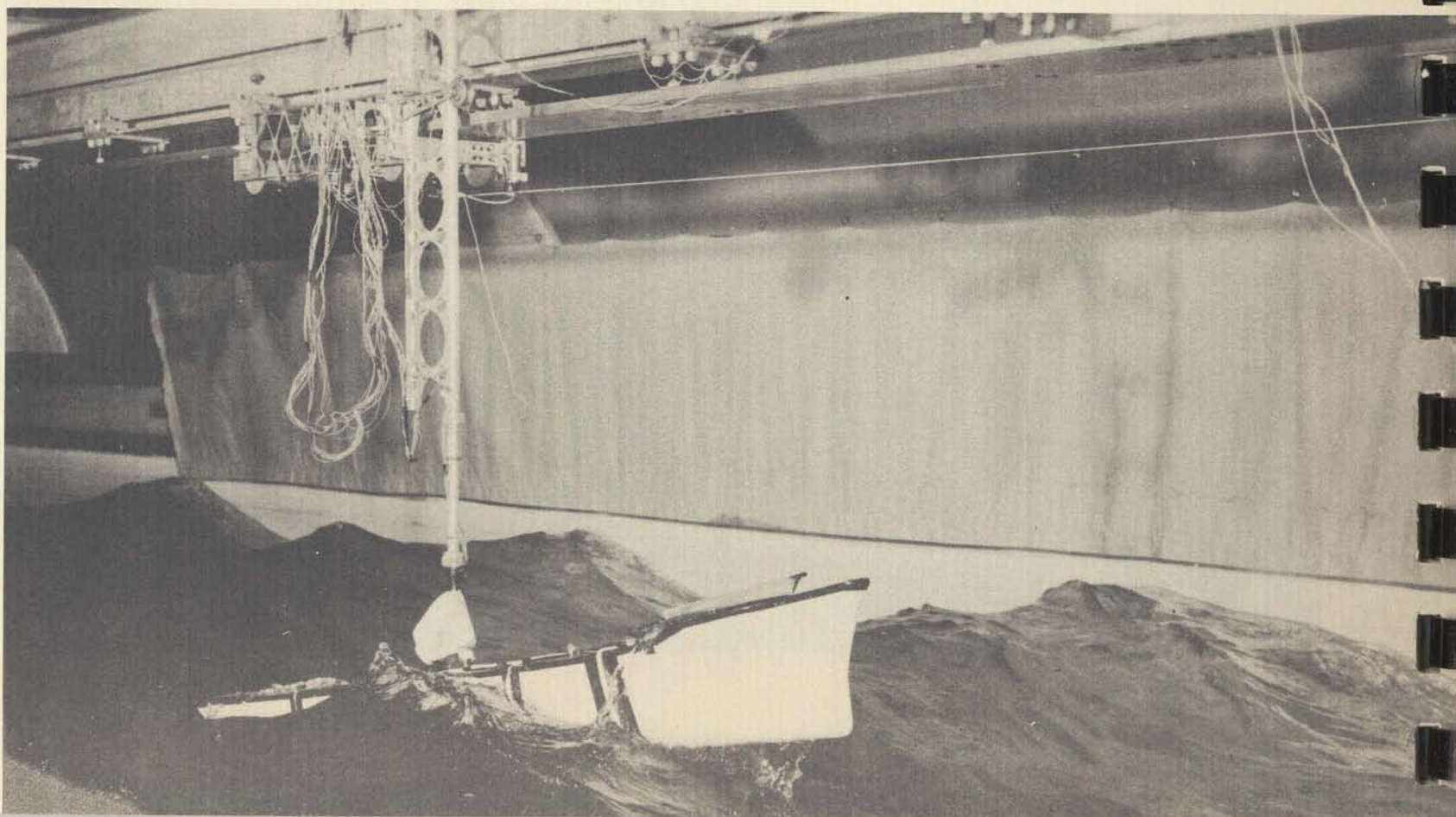
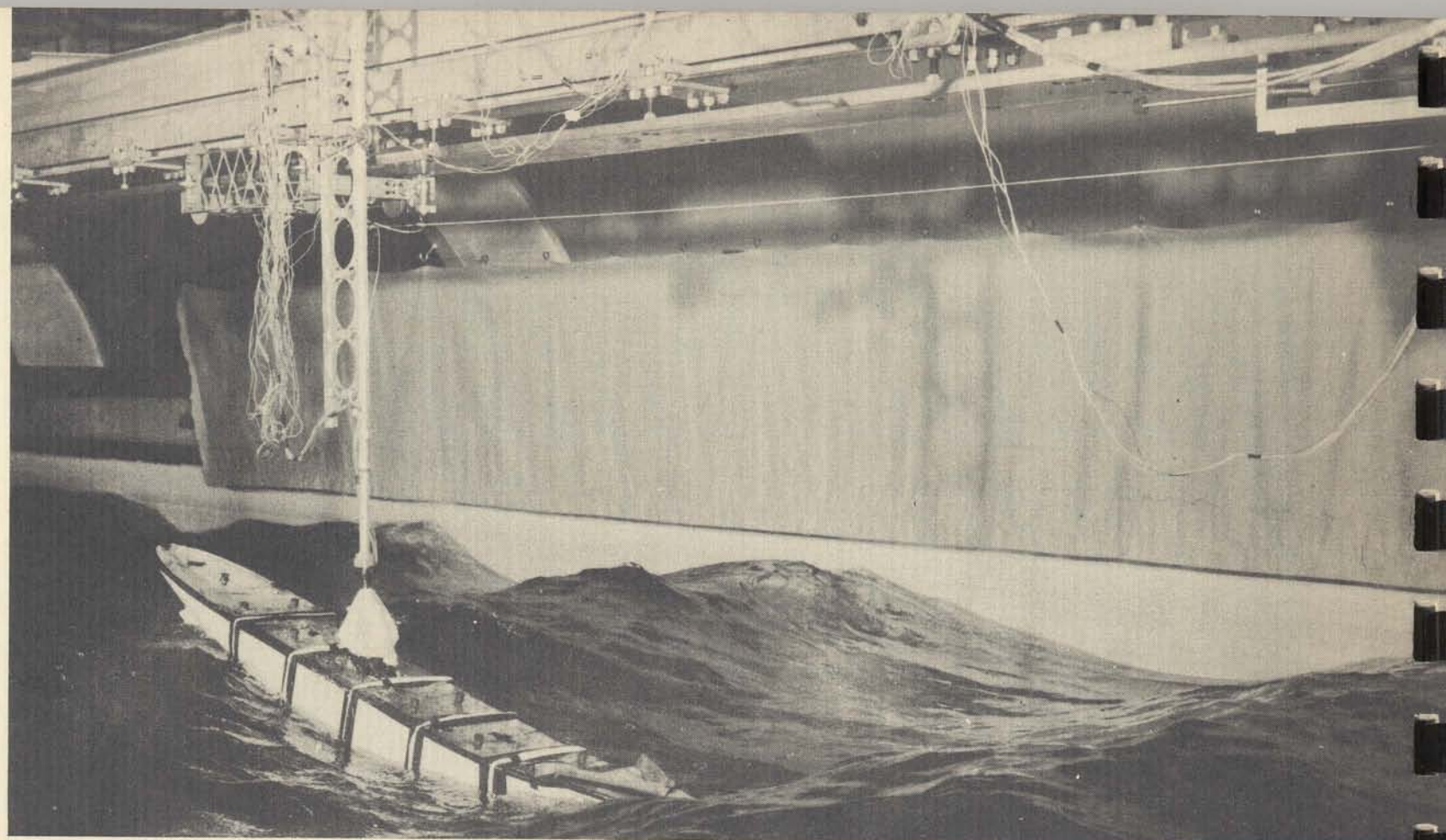
Ship Research

Some of the 1964 work was concerned with the testing of a restrained model of a fast cargo ship (Series 60, 0.60 block coefficient) advancing at constant speed at various headings to regular waves in Tank 2. The purpose of these tests was to determine, experimentally, the wave-excited forces and moments acting on the model under these conditions. Oscillatory components and mean components of sway force, yaw moment, heave force, and pitch moment were measured and found to vary only slightly with forward speed. Good agreement was obtained between the experimental results and the available theoretical results.

Other experimental study continues the investigation of ship hull-girder bending loads in waves of extreme steepness. In 1964 a determination was made of the bending moments at five locations within the midship half-length of a model of the *Mariner* cargo vessel with an extreme "cargo amidships" weight distribution.

PREPARING A 1/25-SCALE MODEL OF A MOTOR FERRY FOR ROLLING TESTS. THE MODEL IS EQUIPPED WITH A "FLUME STABILIZER" WHICH REDUCES ROLLING MOTION.

HULL GIRDER
BENDING LOADS
ON A
MARINER MODEL
IN WAVES OF
EXTREME STEEPNESS



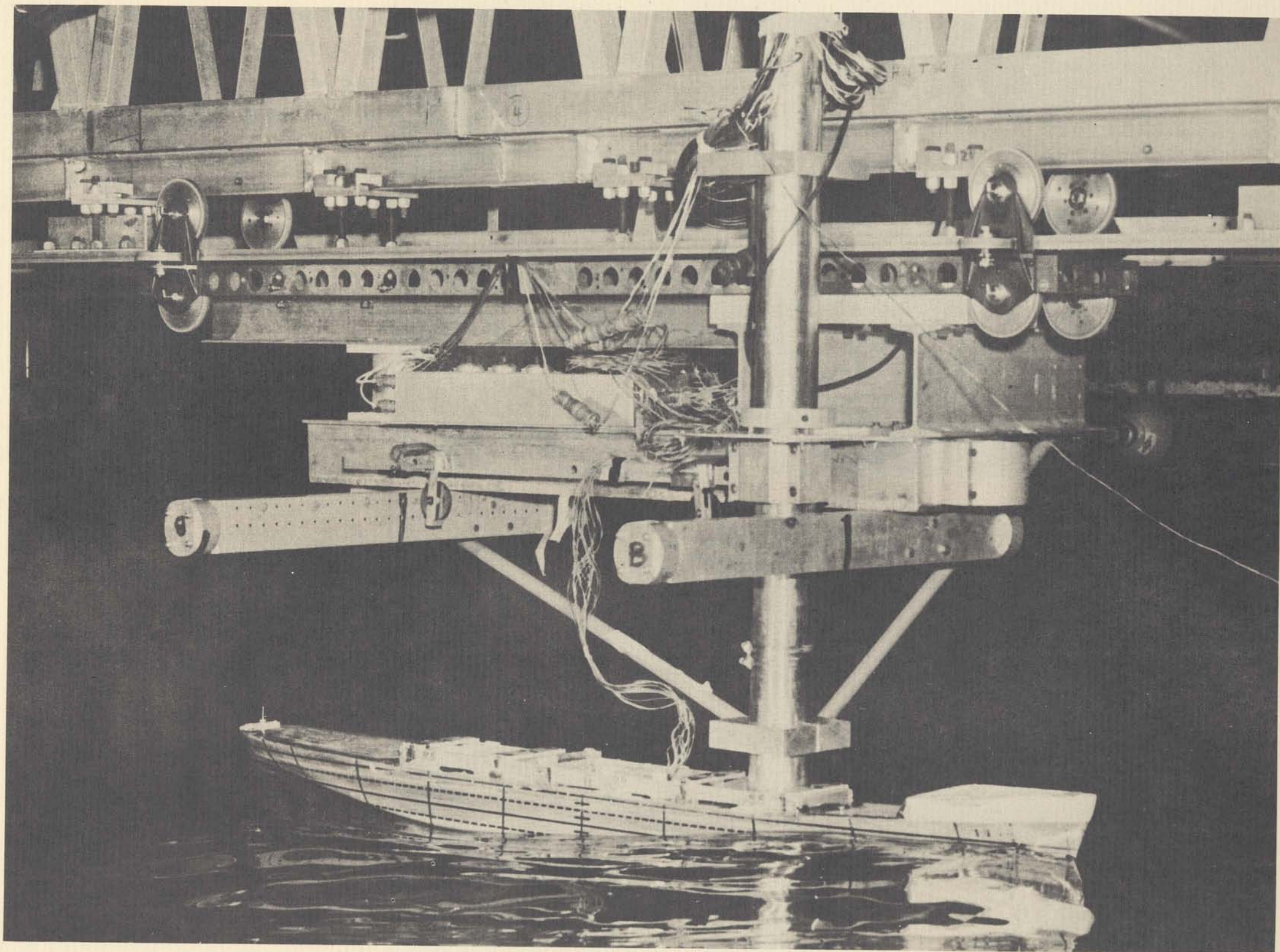
An additional investigation, begun during the past year, is associated with an extensive and systematic experimental study of the effect of above-water bow flare on the seakeeping qualities of high-speed ships in head seas. This study will include a comparison of ordinary flare with flare having a knuckle.

Hydrofoil Studies

In the area of hydrofoil research, the effort to provide basic information on hydrofoils has continued. Measurements have been made of the force and moment characteristics of a fully wetted surface-piercing dihedral hydrofoil with flap; and a theory has been developed for predicting these characteristics. A partially cavitated foil near a free surface was studied.

Seaplane Performance

Seaplane take-off performance has been investigated in a comprehensive study (completed in 1964) in which consideration of the effects of configuration, loading, power, and wave size was included. An experimental study of the effect of camber on a seaplane hydroski was also conducted. The existing data on planing surfaces was extended into the area of high aspect ratio, by use of re-entrant vee steps.



Damping Plates

In another study, on the effect of configuration on horizontal damping plates attached to bodies oscillating in water, it was shown that a perforated damping plate is considerably more effective than a solid plate.

MOHOLE Platform

The floating drilling platform for Project MOHOLE has continued to be the subject of development study. A wide variety of 1964 model tests has furnished data on wave forces and moments acting on the platform structure, data on rigid body motions, and data on drifting behavior in severe waves and wind of hurricane velocity. These data were needed for the design of the platform structure, to ensure survival during storms and to evaluate the effect of platform motions on drilling operations.



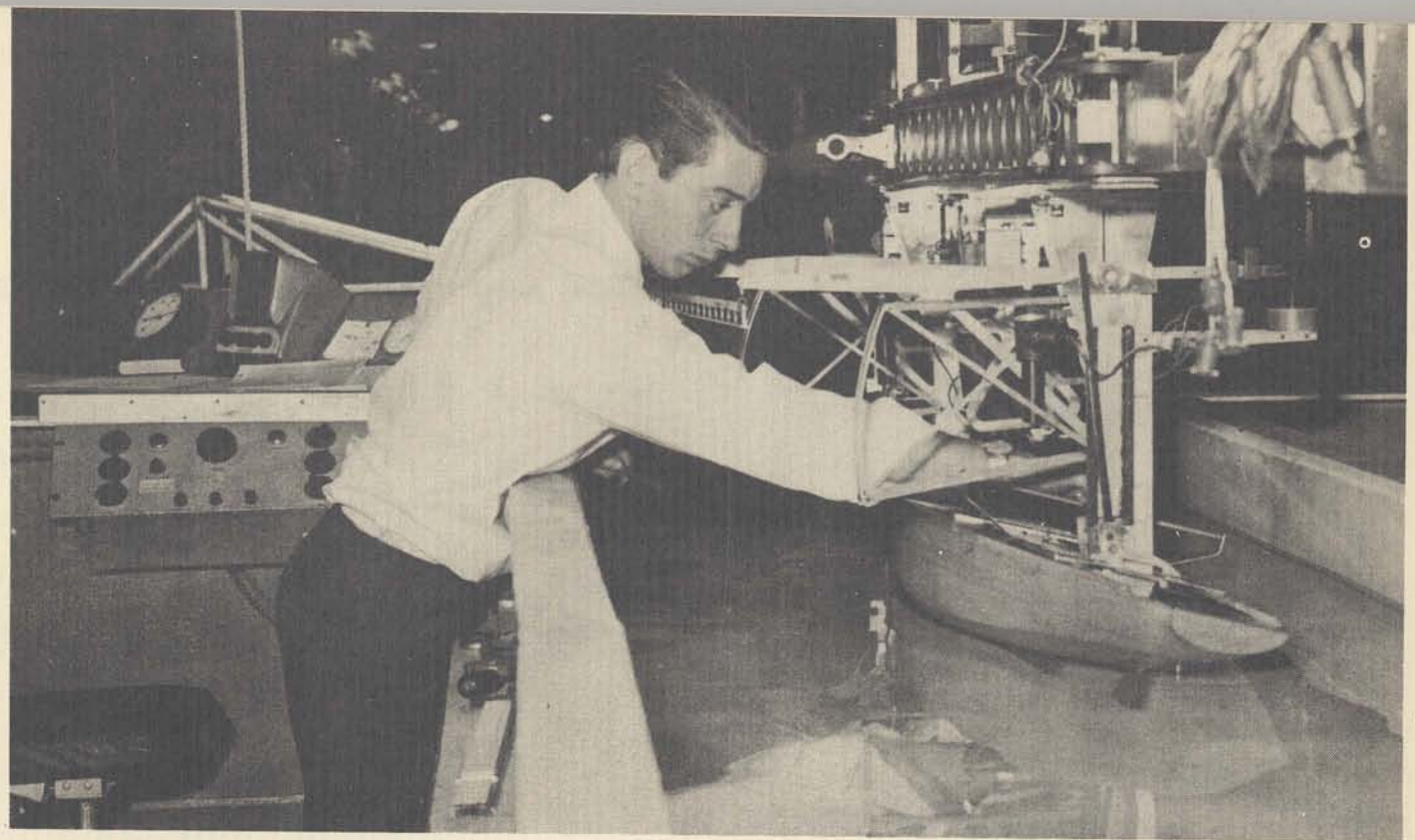
SHIP AND YACHT DEVELOPMENT DIVISION

Sailing-Yacht Studies

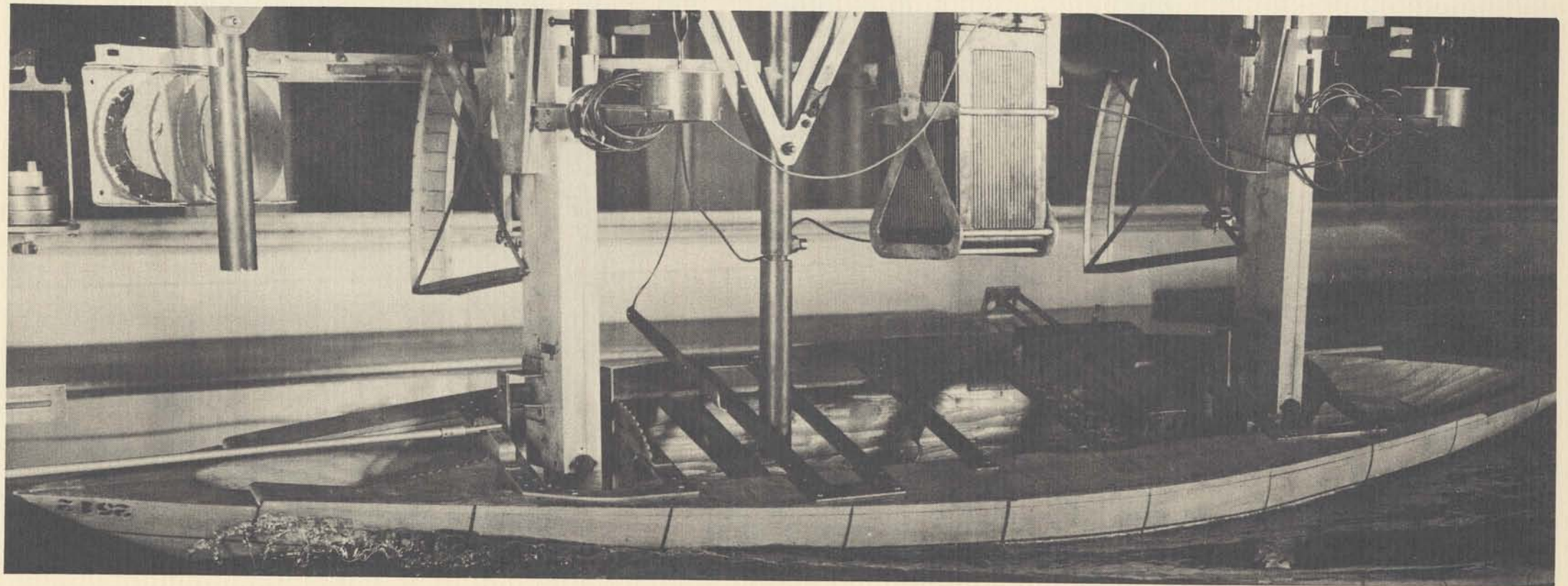
The studies of sailing-yacht models undertaken by this Division make it possible for designers to evaluate hull variations and compare the sailing-performance characteristics of newly designed hulls with those of previously tested hulls. Representative 1964 work of this nature included model tests of yachts competing for selection as the 1964 America's Cup Defender. Tests began in 1963 and continued through 1964, up to and during the time of the final trials; and the success of the Defender, *Constellation*, was the result of an intensified effort at Davidson Laboratory.

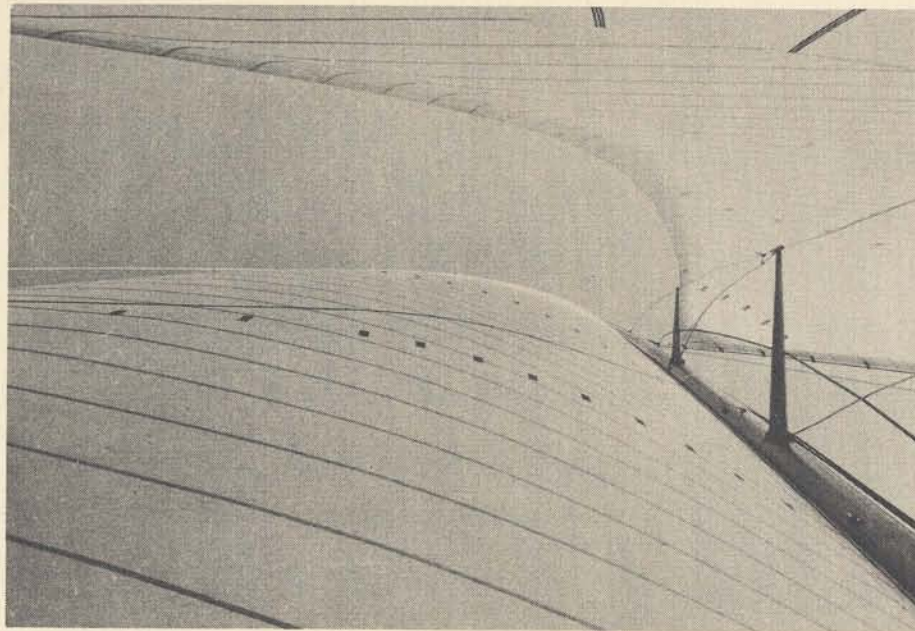
Later, a comprehensive full-scale performance trial of the 12-meter yacht *American Eagle* was conducted on Long Island Sound (model testing had been completed earlier). This trial was noteworthy because, with up-to-date equipment, a continuous record of wind speed, wind direction, boat speed, and heel angle could be obtained. Success with the technique led to a determination of the differences which a choice of two helmsmen would make on a windward course. Correlation such as this between the model and the full-size yacht is of great value in the design and tank testing of yachts, and will have highly important application in the yacht-sail research programs eventually to follow.

TECHNICIAN ADJUSTING
SAILBOAT APPARATUS

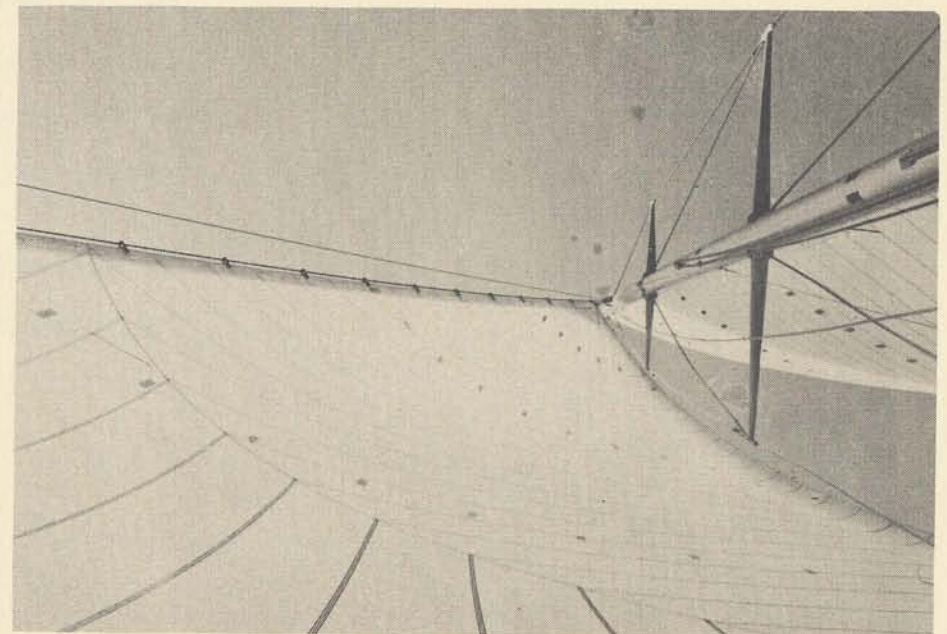
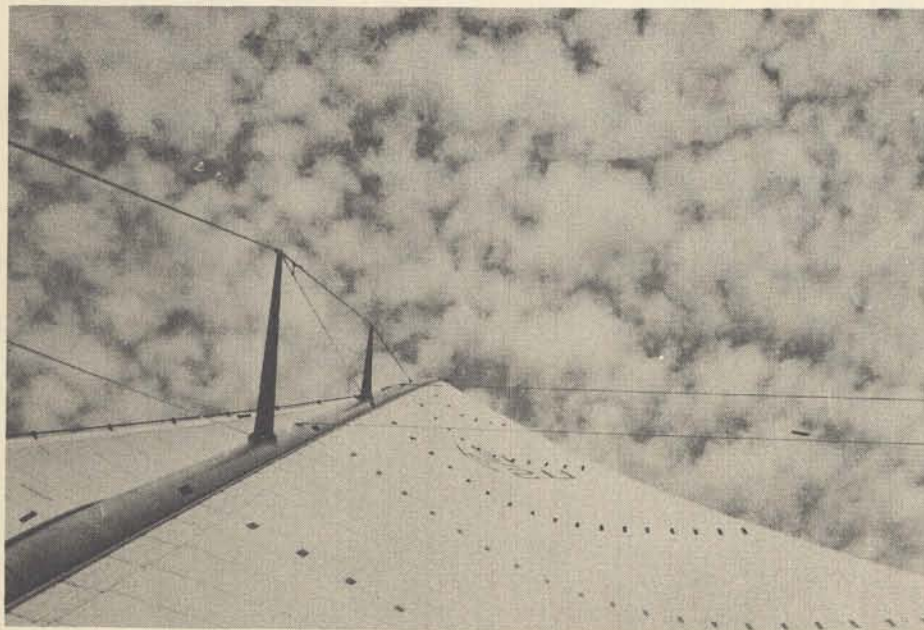


DETAIL OF THE HEEL-TEST APPARATUS,
WITH MODEL OF THE 5.5-METER-CLASS YACHT





12-METER-YACHT SAILS AS PHOTOGRAPHED FROM THE DECK DURING
PERFORMANCE TRIALS IN THE FIELD, TO DEFINE SAIL SHAPE



Further instance of the Division's contribution to modern yacht design was the outstanding performance, in the 1964 Summer Olympics, of both the winning Australian 5.5-meter yacht and the 5.5 meter selected to represent the United States. These yachts were developed in tank tests at the Laboratory.

Currently, tests are being initiated in the Tank 2 facility to evaluate a yacht's performance in waves, and it is hoped that evaluation will be possible not only in the windward condition but in the often dangerous following-sea condition as well. It will be the first time that an evaluation of the effect of seas on yachts has been attempted in a testing tank — in such a comprehensive manner.

Other Programs

Although long a pioneer in this area, the Division has also been successful in solving a wide range of problems arising in numerous branches of the marine field, quickly and at moderate cost. A substantial amount of 1964 work was devoted to problems encountered in efforts to increase the operating speeds of commercial and naval ships. Resistance tests of 5-foot models continued on a regular basis — with results permitting the accurate prediction of speed and power requirements so useful to naval architects in evaluation of hull lines.

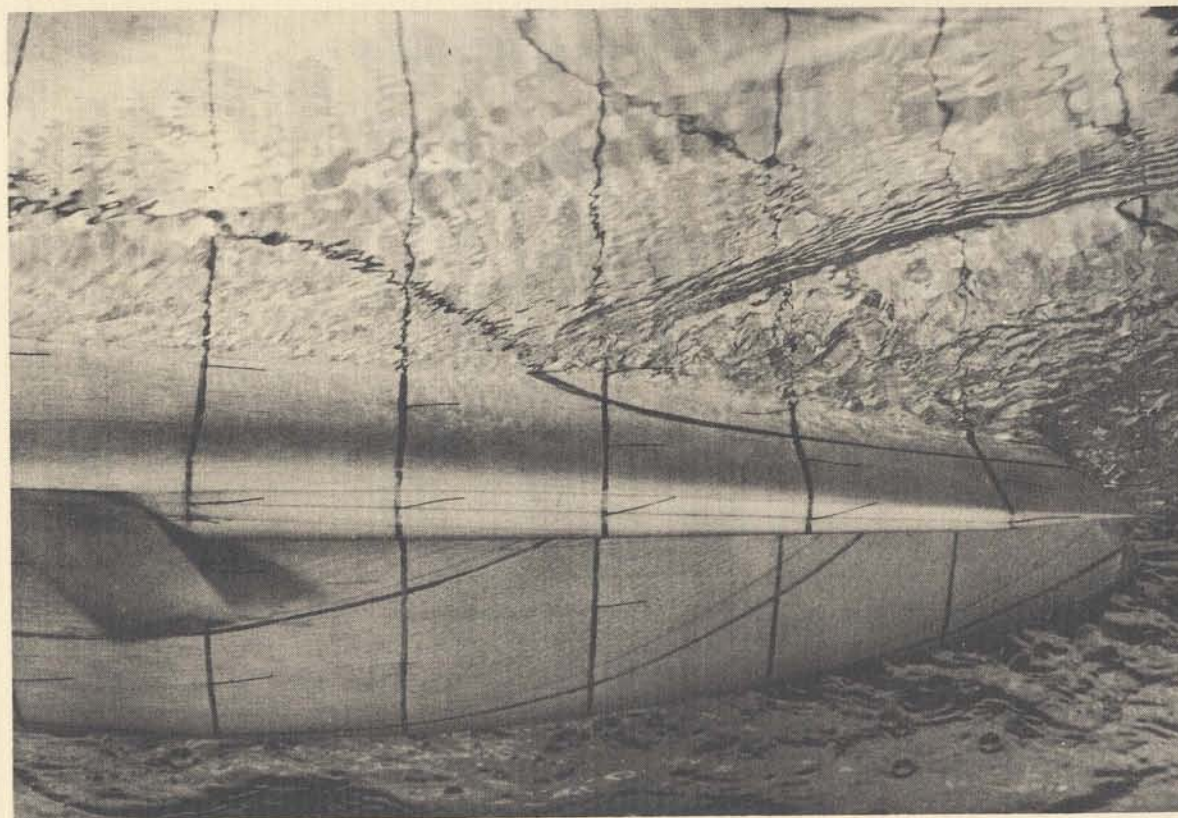
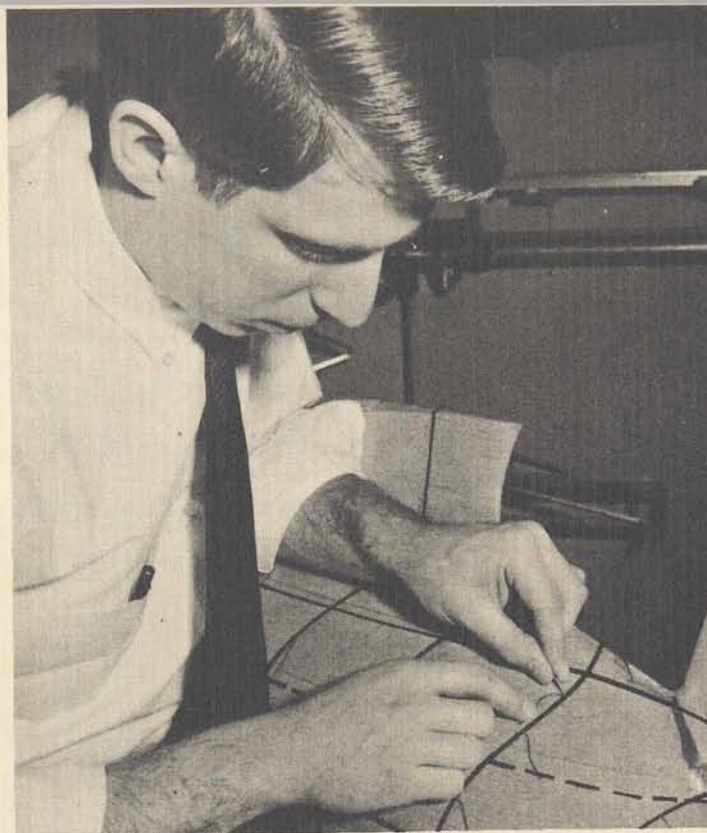
An appreciable effort was also devoted to the testing of high- and intermediate-speed power boats, for the prediction of full-size power

requirements and optimum running trim, and for evaluation of the effects of hull-form changes.

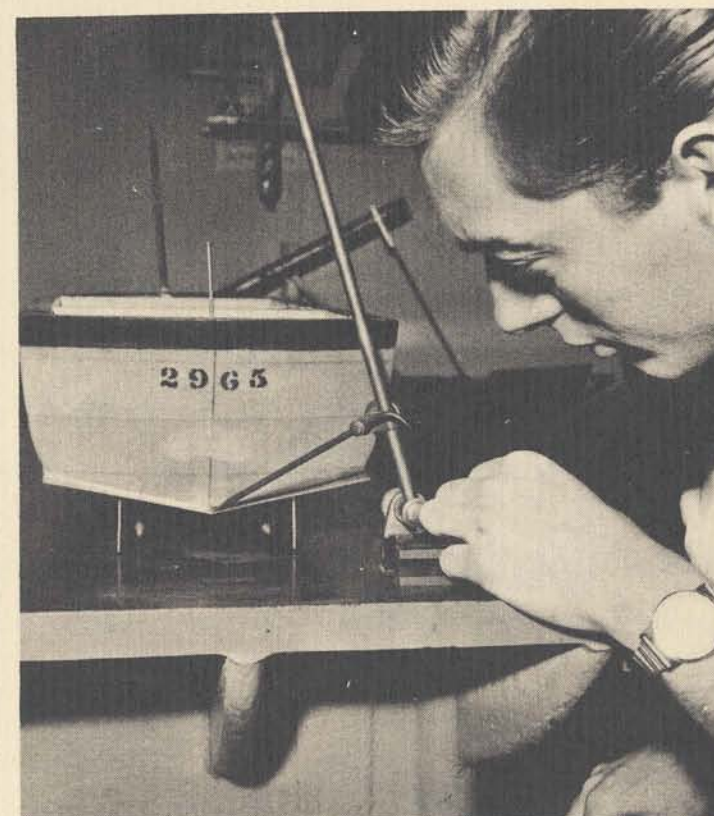
Other experimental work conducted by the members of the Division included tests to determine the characteristics of towed river-barges, underwater exploration vehicles, amphibians, and offshore drilling rigs. In terms of transportation economics, barge tests to determine resistance and directional stability are of special value.

To determine the proper placement (on a hull) of such appendages as bilge keels, studies of flow phenomena were undertaken. Underwater photographic techniques facilitated observation of lines of flow.

TUFTS OF THREAD BEING ATTACHED TO MODEL
IN PREPARATION FOR A FLOW-LINE STUDY
(THREADS STREAM IN THE FLOW, INDICATING DIRECTION)

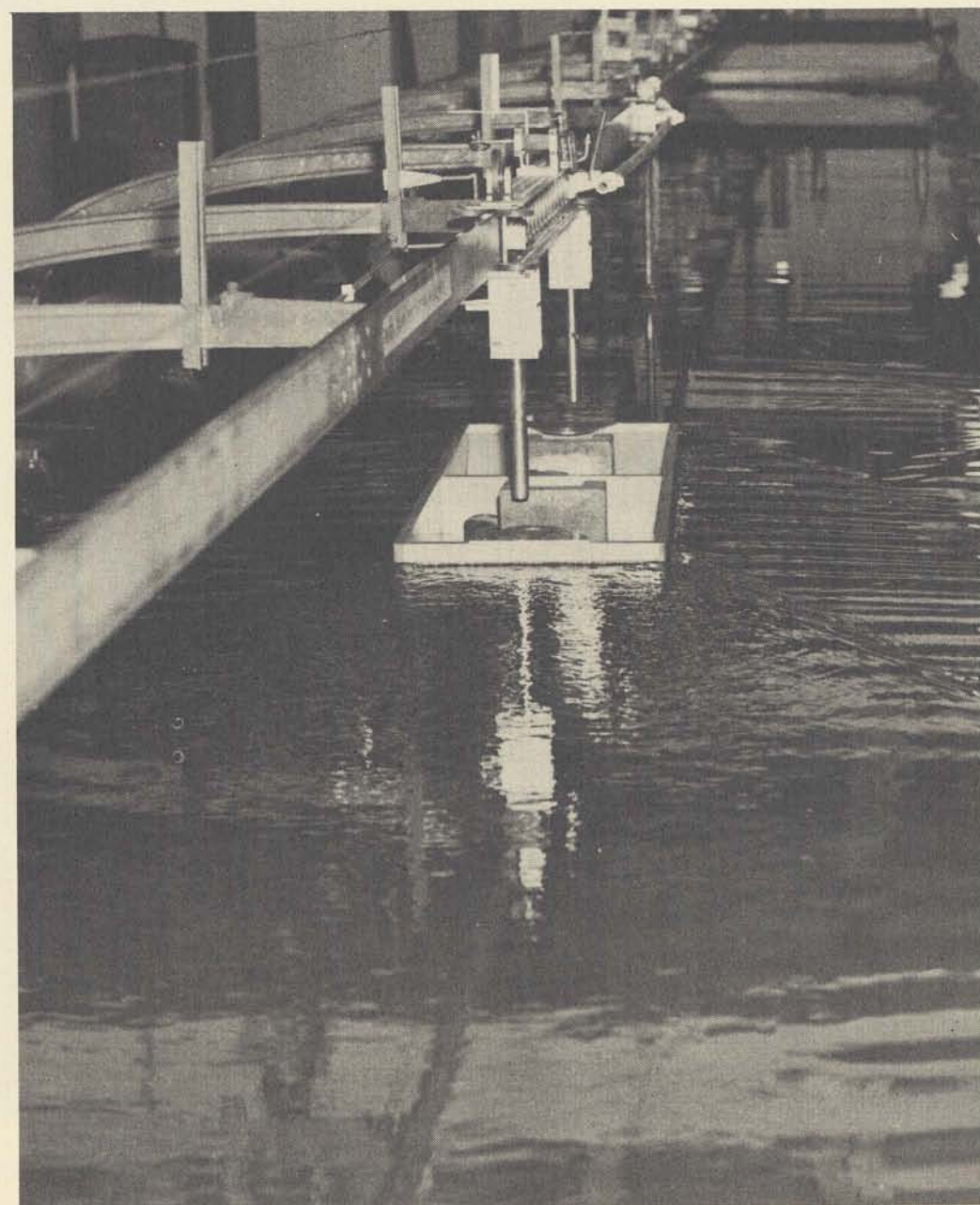
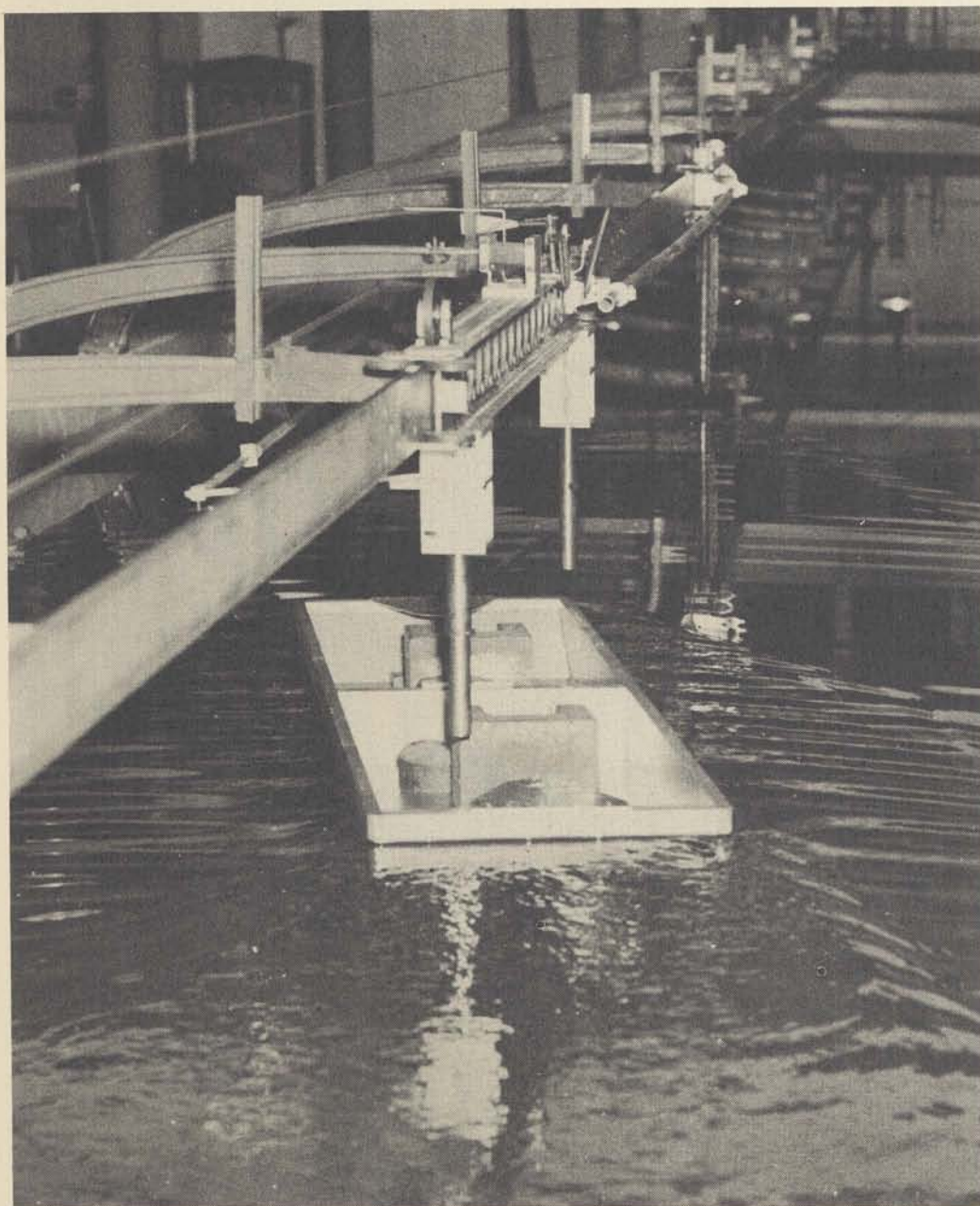


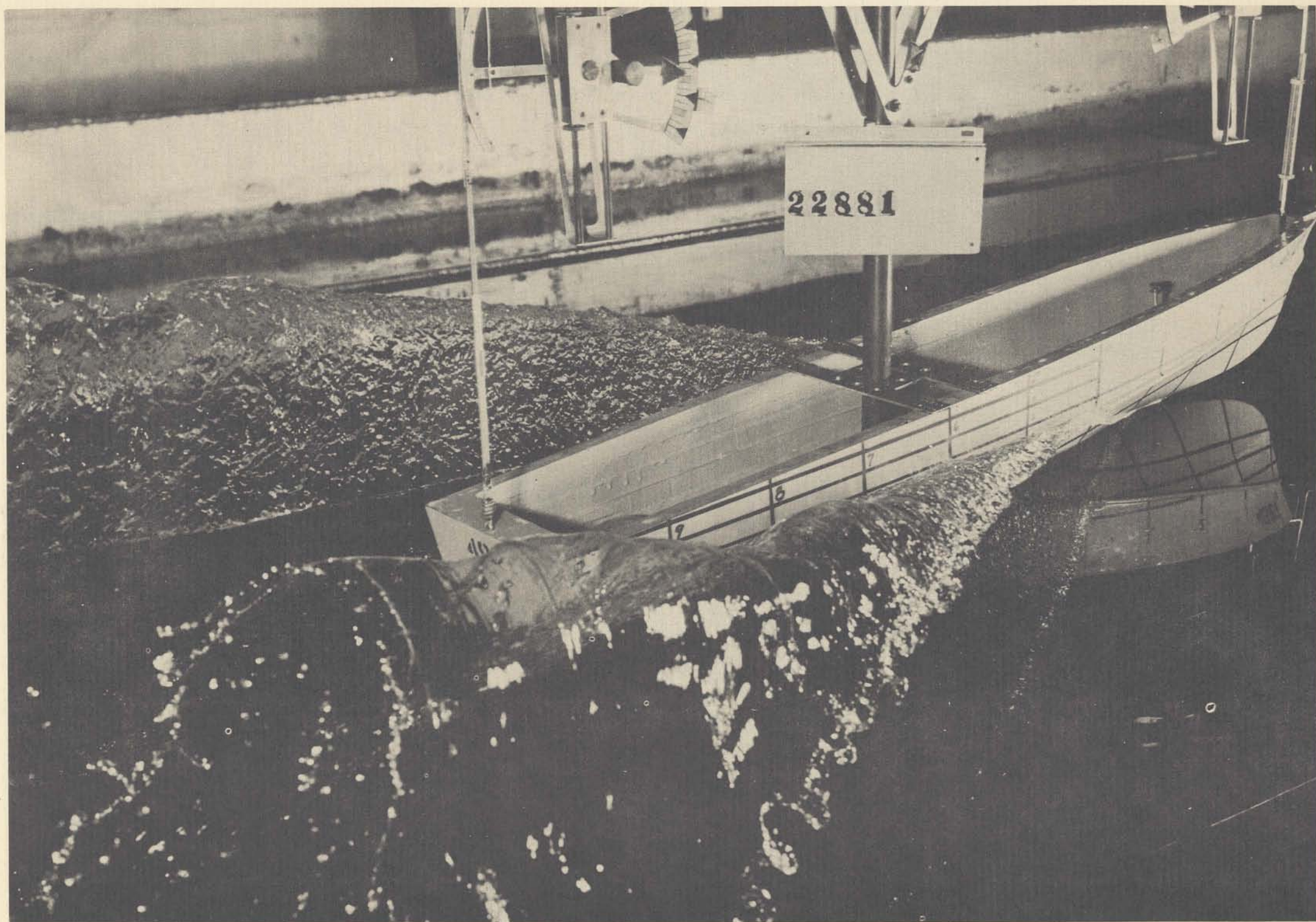
UNDERWATER VIEW OF CENTERBOARD SAILING YACHT,
SHOWING SEPARATED FLOW ON AFTER SECTIONS



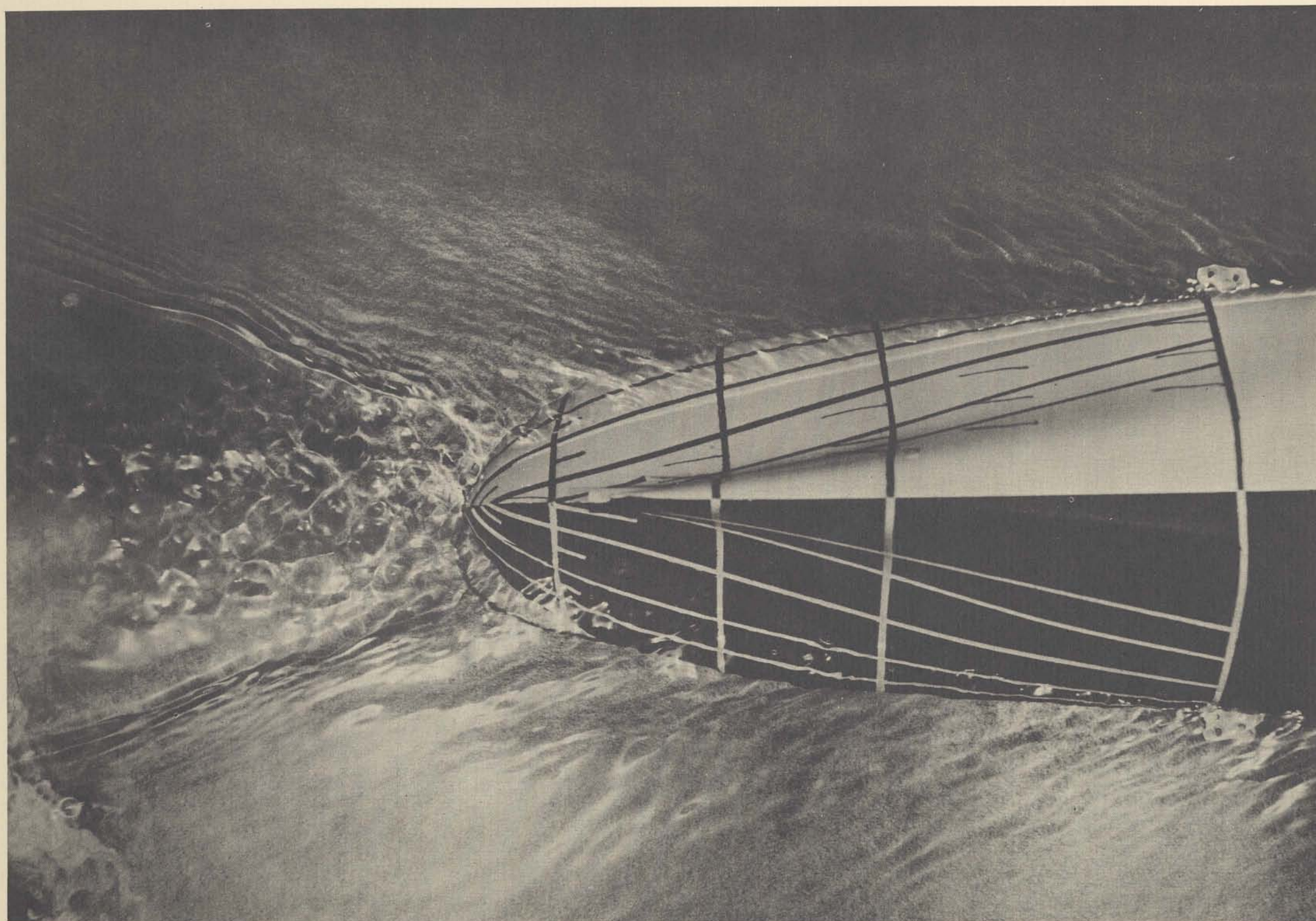
MEASURING HEIGHT OF AFTERBODY ON
SURFACE PLATE OF PLANING-BOAT MODEL

MODEL TESTS OF A TYPICAL BARGE, TO CORRECT TOWING INSTABILITY. IN THE PICTURE ON THE LEFT, THE UNCORRECTED BARGE IS YAWING OFF COURSE. ON THE RIGHT, THE CORRECTED BARGE IS ON COURSE. THE CORRECTION OF A BARGE'S INHERENT INSTABILITY CAN MEAN GREAT SAVINGS IN TOTAL TOWING TIME AND COSTS.

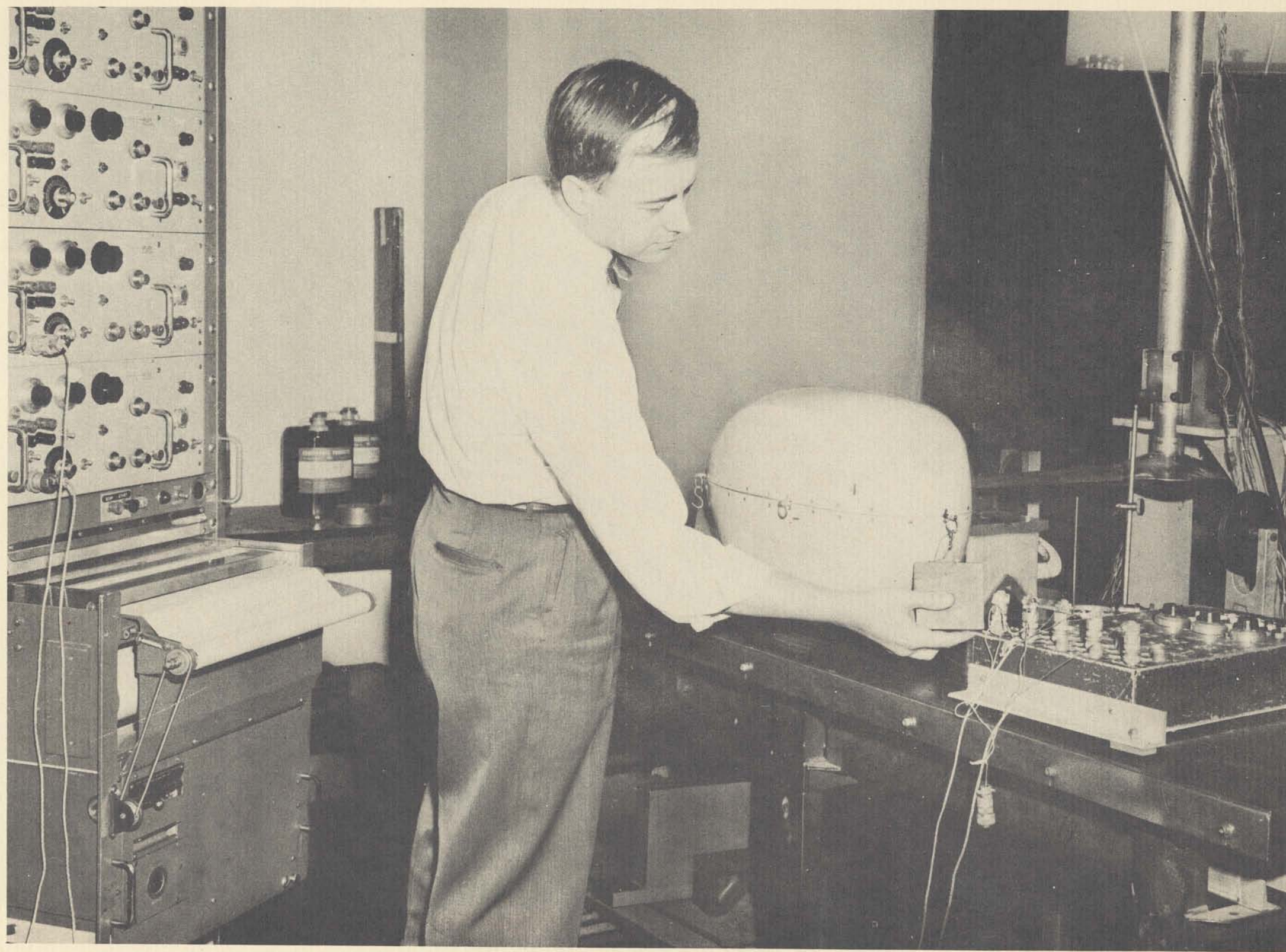




EXTREME SPRAY BLISTER PRODUCED BY PLANING BOAT



UNDERWATER VIEW OF SERIES 60 MODEL



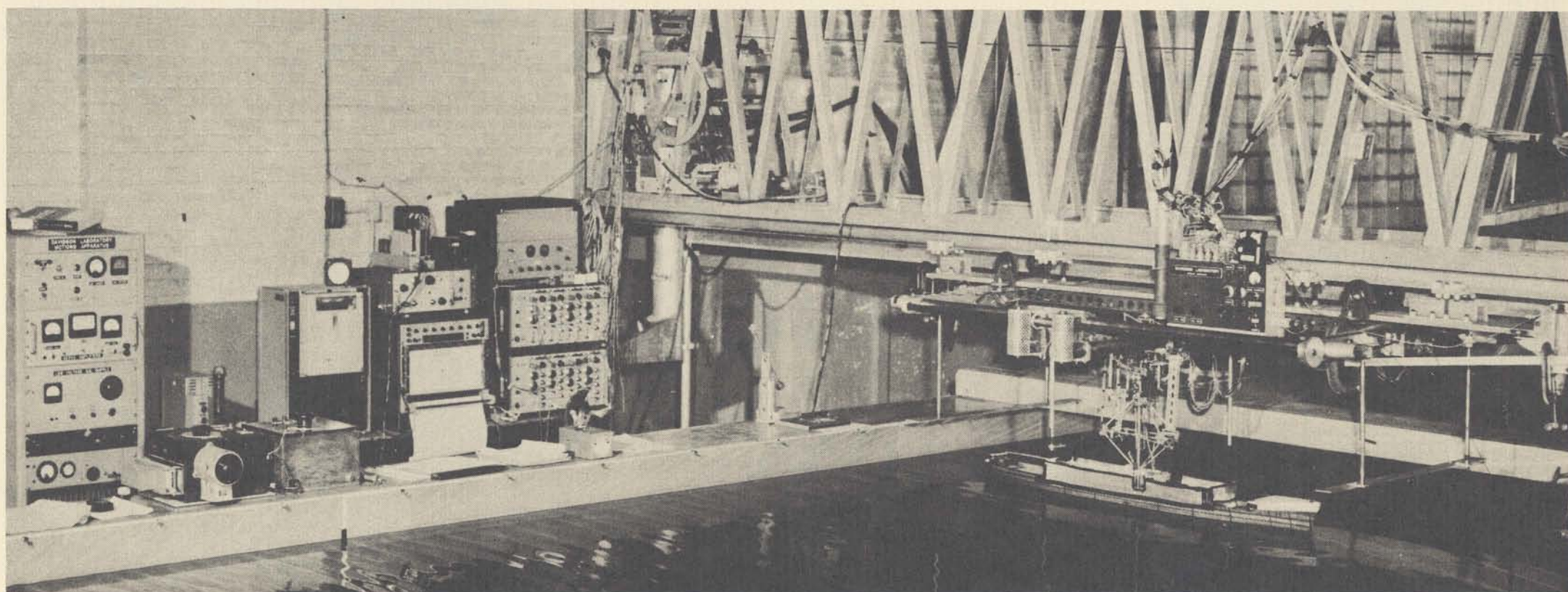
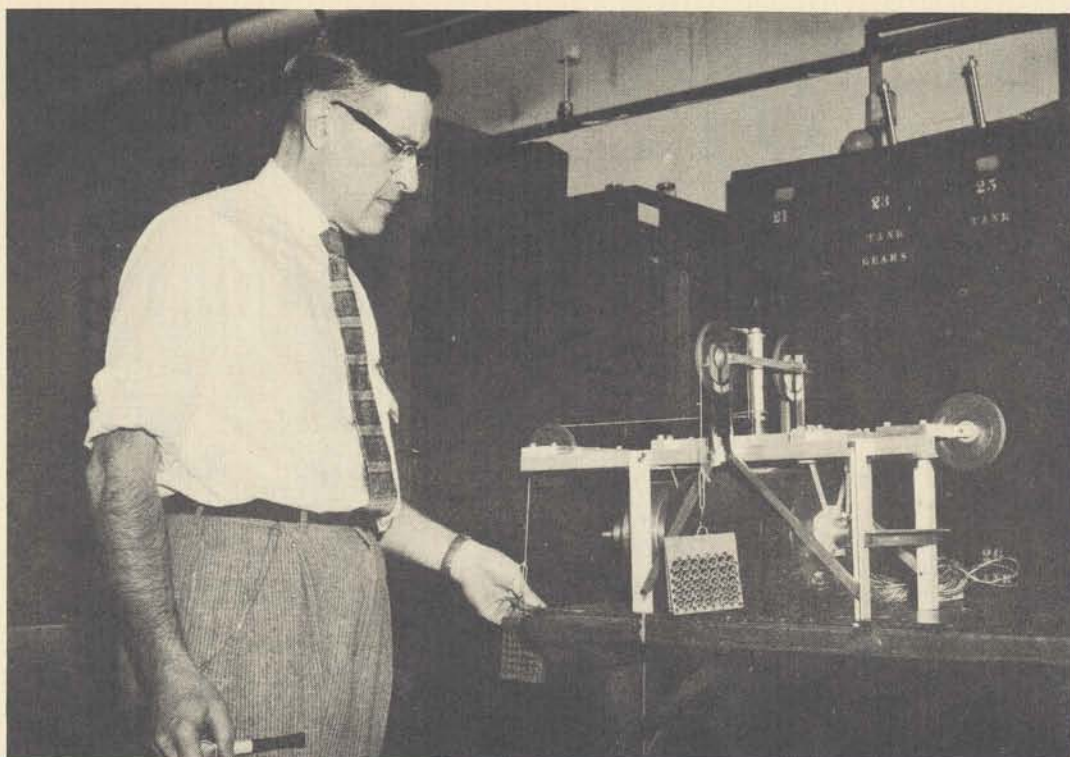
SERVICES GROUP

The members of the Services Group provide the skilled auxiliary services so essential to the execution of research projects. Variously engaged in such fields as instrument design and construction, computation, accounting, electronic development, maintenance of test equipment, drafting, reproduction, and secretarial work, they cooperate with research engineers — and with each other — to unite capabilities required for specific projects.

During the past year the Computing and Data Reduction Section was strengthened by the inclusion of a programmer who can coordinate the Laboratory's own computation activities with work done by Davidson Laboratory staff members at the Stevens Computer Center.

In the instrument shop, a new propeller torque-thrust balance has been designed and built. It can handle propellers up to 10 inches in diameter

PRELIMINARY CALIBRATION ON A BALANCE INSIDE AN
UNDERWATER TOWED BODY



and can be used in a ship model or in the open-water propeller boat; its maximum speed is 1575 rpm, its torque maximum is 4 ft-lb, and its thrust maximum is 40 pounds. The 4,900-sq-ft instrument shop is well equipped with the high-quality precision machinery required for such work. Problems referred to this area may be related to speed control, to transducer readout and feedback, to servo operation, to measurement of forces and moments, to model design, to model propellers, or to the design and building of new laboratory facilities.

Upper Left: NEW TORQUE-THRUST DYNAMOMETER FOR 10-INCH PROPELLERS,
SET UP FOR STATIC CALIBRATION OF TORQUE-THRUST SPRING
SUSPENSION

Upper Right: INSTRUMENT-MAKER ADJUSTS WHEEL-SPACING ON A TANK 1
TOWING CARRIAGE

Bottom: SHIP MODEL ON SIX-DEGREES-OF-MOTION APPARATUS IN TANK 2

CLIENTS / 1964

United States Government

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Ballistic Research Laboratories
Corps of Engineers
Picatinny Arsenal
Signal Corps
Tank-Automotive Center

DEPARTMENT OF COMMERCE

Maritime Administration

DEPARTMENT OF HEALTH, EDUCATION & WELFARE

Public Health Service

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NATIONAL SCIENCE FOUNDATION

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1964 PUBLICATIONS AND PAPERS

In the list which follows, an asterisk preceding the item indicates that application for copies may be made to the Defense Documentation Center, 5010 Duke Street, Alexandria, Virginia, or to the Office of Technical Services, Department of Commerce, Washington, D. C. Application for a classified report which is so listed should be accompanied by material demonstration of the "need to know."

Classified reports with classified titles and reports on work of a proprietary nature have been omitted from this list. Forty-eight letter reports and eighteen notes have also been omitted.

Technical memoranda and technical translations may be obtained from the Davidson Laboratory, but reprints of journal articles or transactions should be obtained directly from the publishers of such articles or transactions.

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*HU, P. N., and ENG, K. S., "Drifting Force and Moment on Thin Ships in Oblique Long Waves," DL Report 524, November 1964.

*JACOBS, W. R., "Estimation of Stability Derivatives and Indices of Various Ship Forms, and Comparison with Experimental Results," DL Report 1035, September 1964.

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