NASA LANGLEY RESEARCH CENTER,
SEAPLANE TOWING CHANNEL
Hampton (Independent City)
~~Hampton County~~
Virginia

HAER No. VA-118-C

HAER
VA,
28-HAMP,
4C-

PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

REDUCED COPIES OF MEASURED DRAWINGS

Historic American Engineering Record
National Park Service
U.S. Department of the Interior
1849 C St., NW Room NC300
Washington, DC 20240

HISTORIC AMERICAN ENGINEERING RECORD

HAER
VA
28-HAMP,
4C-

NASA LANGLEY RESEARCH CENTER,
SEAPLANE TOWING CHANNEL

HAER NO. VA-118-C

Location: Building 720, NASA Langley Research Center, Hampton, VA

UTM Coordinates: USGS Hampton Quadrangle Universal Transverse Mercator Coordinates:

	Northing	Easting
A	4104906.02	381096.22
B	4104836.24	380799.77
C	4104867.60	380737.01
D	4104987.82	380790.97

Dates of Construction: 1931, 1937, refurbished in 1983

Engineer: Starr Truscott

Present Owners: Naval Underwater Systems Center
Langley Research Center
Hampton, Virginia 23665-5225

Present Use: Development of laminar flow technology for drag reduction of small underwater vehicles.

Significance: This facility performed an essential function in solving design problems that are unique to seaplanes. Several major principles of seaplane hull configuration were developed at this facility. The tow tank's staff was instrumental in developing the design principles that were essential to successful seaplane performance. Models of most American seaplanes used in early development of commercial aviation were tested and refined at this facility. The facility performed a vital function in the testing of World War II military flying boats. It continues in use as a test facility for underwater weaponry.

Project Information: This documentation was initiated July 17, 1995 in accordance with a Memorandum of Agreement with the National Aeronautics and Space Agency and the National Park Service.

This recording project is part of the Historic American Engineering Record (HAER), a long-range program to document historically significant engineering and industrial works in the United States. The HAER program is administered by the Historic American Buildings Survey / Historic American Engineering Record Division (HABS/HAER) of the National Park Service, U. S. Department of the Interior. The National Aeronautics and Space Administration (NASA) - Langley Research Center Recording Project was cosponsored during the summer of 1995 by HABS/HAER under the general direction of John Burns, Deputy Chief, and by the Langley Research Center, Paul F. Holloway, Director.

The field work, measured drawings, historical reports, and photographs were prepared under the direction of Eric N. DeLony, Chief, HAER, and project leader Dean A. Herrin, PhD. The recording team consisted of Charissa Y. Wang and Donald M. Durst, Principals/Partners - Hardlines: Design & Delineation. Robert C. Stewart, Industrial Archaeologist, West Suffield, CT produced the historical report. Jet Lowe, HAER, was responsible for large-format photography.

Others who have contributed their time, advice, documents and help were: Brad Ball (GIS Team Leader); Cyler W. Brooks Jr. (ADYD Transonic Aerodynamics Branch); Charlie Debro (FST Building Coordinator); Dana Dunham (FST); Charles D. Harris (ADYD Transonic Aerodynamics Branch); Ron Harvey (Langley Research Center Public Affairs Office); Rick Hoff (LaRC Photo Lab); Richard Layman (Historical Program Coordinator); John Mouring (Facilities Systems Engineer); Gene Nutall (Towing Tank Supervisor); Bill Salyer (LaRC Photo Lab). Jay Waravdekar, GIS Analyst, provided the UTM coordinates for the facility.

Historian: Robert C. Stewart June 1996

For additional NASA Langley Research Center information see:

HAER No. VA-118-A - NASA Langley Research Center, Full-Scale Wind Tunnel

HAER No. VA-118-B - NASA Langley Research Center, 8-Foot High Speed Wind Tunnel

HAER No. VA-118-D - NASA Langley Research Center, 8-Foot Transonic Pressure Tunnel

CONTENTS

Introduction - The Tow Tank as a Research Tool

Aeronautical research requires analysis of both aircraft and the medium in which they operate. Seaplanes or flying boats are a compromise design which must operate in the air and on water. The complexity and unique problems associated with these specialized aircraft required distinctive facilities for their development and testing. One of these test facilities was vital in producing practical seaplane designs during the developmental period of commercial and military aviation.

In the early days of commercial aviation, seaplanes had advantages over landplanes. Except for a few major cities, airports suitable for commercial aviation were non-existent. Nevertheless, most principal cities were located near large bodies of water. With their ability to land on and take off from almost any sizeable body of water, seaplanes trailblazed commercial routes all over the world. In the 1930s flying boats established the first commercial air links to Hawaii, the Philippines, China, South America, and Europe.[1] In addition, seaplanes were considered safer than landplanes. Since three-quarters of the globe's surface is covered by water, a forced landing was not usually as hazardous for the seaplane as it was for a landplane.

At one time a seaplane held the record for the heaviest load that had ever been lifted by any aircraft. A Mars flying boat attached to the Naval Air Transport Service flew from Maryland to Natal, Brazil in November of 1943. Its gross weight was 148,500 pounds. The aircraft flew 4,250 miles non-stop to its destination in twenty-eight hours and twenty-five minutes. During World War II the American Navy used seaplanes for combat, transport, search and rescue missions, and antisubmarine patrol.[2]

Hydrodynamic Research at Langley Research Center

In general, shapes which are efficient for maneuvering on water are not very practical for flight. In addition to problems in hull configuration, engines and propellers must be mounted well clear of the water. Consequently a seaplane hull had to be designed larger than a corresponding land plane fuselage to provide flotation and power plant clearance. These factors compromised airborne performance. The need for a hull with sufficient displacement to keep the plane afloat added significant drag to designs and sacrificed speed.[a]

The present National Aeronautics and Space Administration (NASA) was

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[a]A good example is the comparison of two World War II military aircraft, the Coronado and the Liberator. Both used four engines of equal power, identical propellers, and the matching wings. The Liberator, a streamlined landplane, exceeded the maximum speed of the Coronado, by thirty miles per hour. The Coronado's seaplane hull was almost twice the size of the land-based Liberator (Gray 1948:63).

established by congress in 1958 as an expansion of an earlier agency, the National Advisory Committee on Aeronautics (NACA). NACA's mission was oriented to the practical solution of engineering problems facing the aircraft industry and the military. NACA broke ground for its first laboratory building on July 17, 1917 in Hampton, Virginia. The new installation was named after Professor Samuel P. Langley of the Smithsonian, one of aviation's pioneering researchers.

The initial research agenda at Langley was not directed at aircraft hydrodynamics and seaplane design. Nevertheless investigations into wing shape, efficient propellers, engine cowlings and aerodynamically clean shapes benefited seaplane design. As aircraft design improved, the Langley engineers observed that an aircraft on the water had unique problems. In 1929 the National Advisory for Aeronautics (NACA) decided to devote additional effort to research in hull hydrodynamics. A naval architect from the Bureau of Aeronautics, Starr Truscott, was named as head of the new division. His first task was to design a towing tank for hydrodynamic analysis.[3]

A towing tank is a research tool which is analogous to the wind tunnels used to develop aircraft designs except that it uses water as the testing medium instead of air. Its focus is primarily the portions of a seaplane's configuration that provide floatation; its hull and pontoons. A wind tunnel illustrates the principles of airflow while the towing tank is used to analyze the laws of waterflow and their effect on a seaplane hull. The towing tank allowed engineers to quantitatively measure hydrodynamic influences on seaplane hull.

Tow tanks had been used by naval architects in the design and development of ships for many years. In the 1920s existing tanks at the Navy Yard in Washington and at the University of Michigan in Ann Arbor were used to test models of seaplane hulls and floats. Unfortunately these tanks were designed to evaluate ship hulls and could not achieve the high speeds and test durations required to acquire useful data on a seaplane design.

Truscott's tank had to be long enough and have a carriage with enough speed to simulate the actual take-off conditions of a seaplane. These capabilities imposed specifications that set length at about 2,000 feet and a minimum towing speed of 60 m.p.h. Width was established at 24 feet and depth of water at 12 feet. The tank was so long that the curvature of the earth had to be considered in its construction.[4]

Truscott's team designed and built the tank in 1931 on the western shore of the Langley facility's Back River. The original tow tank was 1980 feet long, with a maximum carriage speed of 50 knots. The original towing carriage was propelled by four electric motors driving four pneumatic tires.

Construction technique was borrowed in part from methods that had been successfully used in drydock fabrication. The unstable, water saturated soil complicated construction. Horizontal extensions or "wings" at the bottom of the vertical walls were incorporated to prevent the tank from floating when it was empty.

The tank served as a test facility for most of the flying boats and other seaplanes designed and built in the United States. However, it wasn't long before aircraft performance progressed beyond the test envelope prescribed by tow tank specifications. New requirements mandated an upgrade to allow testing of faster and larger air boats. In 1937 the tank was extended to length of 2,880 feet. This allowed the collection of additional data points during a run and increased operational efficiency. The towing carriage was repowered with eight motors driving eight wheels to increase it's speed to 80 m.p.h. (60 knots). A wave-making machine was added to create rough-water conditions so that heavy-weather seaplane performance could be studied.[5]

The principal problem challenging designers as well as pilots of seaplanes was water resistance. Resistance of water to a seaplane hull attempting take-off rises to a high peak, or "hump," right after the seaplane begins to move. However, at the beginning of take-off, air drag is relatively low and increases only gradually with escalating speed. Thrust, created by the aircraft's power plant, is at its maximum when an airplane is stationary. Thrust decreases as the plane accelerates. The following graph illustrates how the forces of thrust, drag and resistance are related during a seaplane's take-off.

There are two significant problems of seaplane design. The engines must provide sufficient power so that the curve of resistance always is below the curve of thrust, otherwise the plane would never be able to take-off. The second problem faced by the designer is to maintain the widest possible distance between the drag and thrust curves. The span between these curves defines an aircraft's performance efficiency.

In general, a hull shaped for the most efficient movement on water creates excessive turbulence when airborne and requires inordinate amounts of power to overcome its drag. Cargo capacity, speed, fuel consumption and range are adversely affected to the point of making a hull designed for optimum hydrodynamic performance nearly worthless for flight.

However, a shape designed for ideal aerodynamic performance would have a tendency to submerge when forced through the water. Consequently, a seaplane hull is a compromise design that must perform within fairly narrow limits. The tow-tank at Langley was vital in evolving seaplane hulls which effectively combined low water resistance with low air drag. Langley engineers were able to develop fundamental practical design criteria using scale models in the tow tank.

Some of the seaplane designs investigated at the tow tank included the 314 Clipper flying boat, the amphibian Goose, Catalina, Coronado, Hercules, Mariner, Mars and Sea Ranger.

An early project was to establish how hull water resistance varied with increasing speed. Truscott's group determined that the extent of water resistance was affected by trim. That is, if a plane yawed or slewed off a dead center take off path, resistance to its passage increased dramatically. They found that trim is controlled in large part by the horizontal tail. Studies of trim and tail forces enabled designers to predict how much longitudinal control was required from the tail to keep an accelerating plane on a straight course.

Further research indicated that there was a critical ratio between gross aircraft weight and engine horsepower. If the total load was held below about fifteen pounds per horsepower, water resistance effects became less critical in hull design.

With a series of trials using scale models, Truscott's group also established the optimum ratio of hull length to beam (width). They found that long narrow hulls were more efficient and had less resistance than shorter, broader hulls. Increasing the length-beam ratio also resulted in reducing drag when the hull became airborne. The new design parameters characteristically showed drag reduction of up to 20% over hull designs then in common use. In practical terms the data indicated that with the new hull designs, a flying boat would use less fuel to fly an assigned distance, leaving more capacity for cargo. Alternatively, a seaplane could carry an equivalent load further.[6]

The low-drag hull type was designated the NACA Model 84 Series. It became the basis for the hull design of the Hughes-Kaiser eight-engine cargo transport Hercules, later known as the "Spruce-Goose" This aircraft had the lowest drag for its size of any hull design.

Aircraft design continued to improve stimulated by commercial and military aviation requirements. By the mid-1930s this produced designs for larger seaplanes able to lift heavier loads. These advanced designs took-off and landed at higher speeds than the earlier generation of seaplanes. New problems cropped up as the heavier and faster hulls attempted to become airborne; they were inherently unstable.

Instead of expected slow changes in trim, correctable by the pilot, the hulls went into a pitching or seesawing movement similar to that of a plunging porpoise. The effect became known as "porpoising." In some instances the motion was exceedingly violent and caused breakup of the aircraft.

Similar dynamic instability occurred when a landing seaplane would bound along the surface of the water like a thrown stone. This bouncing motion was termed "skipping." By 1937 turbulent take-offs and landings were serious and frequent. NACA authorized the hydrodynamic researchers to investigate the problem. Data indicated that propeller thrust and air flow over the wings played a role in hindering stability, consequently the new models required for testing were equipped with wings and powered propellers. They also had to be accurate in scale and weight distribution. High powered miniature electric motors were developed and carefully installed to maintain the center of gravity on the models. By 1939 most of the available towing tank time was being devoted to porpoising and skipping problems.

Research was expanded to include spray deflection problems. The tow tank operations were expanded to cover three eight hour shifts. An additional 1,800 foot long tank, specifically designed for take-off and landing problems, was built east of and adjacent to Tank No. 1. Tank No. 2 was used in studies evaluating the effects of aircraft ditching (forced landing of a landplane at sea). Concurrently, an impact basin was built at the south end of the new tank. It was used to explore the effects of sudden stresses inflicted on hulls and floats by landing.[7] Another critical project tackled by the hydrodynamics group was the development of step configurations on the bottom of seaplane hulls. In a seaplane the continuous underbody of a hull ends abruptly amidship then rises to a higher level, forming a step (Figure 3).

The step helps control trim during take-off and enables air to come between the hull and the water. An improperly designed step allows a mixture of air and water to enter the area and create a vacuum which can prevent take-off.

Porpoising occurred if the step was too close, either fore or aft, to the center of gravity. The studies also indicated that the center of gravity had to be maintained within a narrow range amidships. Skipping was related to the depth of the step. It occurred when the step was overly shallow. A shallow step would entrap small quantities of air which allowed a landing hull to glance off the water's surface. Towing tank experiments developed criteria for positioning and determining the depth of the step.[8]

An interesting by-product of research at the tow tank laboratory was a device called the events recorder. Originally it was used to correlate data obtained from model testing with actual aircraft performance in the air or water. The instrument automatically measured and recorded air and water speed, trim, position of the elevators and rudder, engine speed, propeller torque and revolutions per minute. The events recorder found application outside the laboratory. It was the genesis of the flight recorder or "black box" used on present day commercial aircraft.[9]

NACA operated the tow tank until 1959, at which time the flying boat was deemed obsolete. In 1960, the facility was turned over to and operated as a detachment of the David Taylor Model Basin (DTMB), now the David Taylor Naval Ship Research and Development Center (DTNSRDC). DTMB operated the facility for 17 years as a tenant of NASA (the successor to NACA), testing both surface and underwater craft. In 1977, DTMB closed and mothballed the facility.[10]

In 1983, NUSC's Improved Performance Undersea Vehicle program, supported by the Langley Research Center, began a major restoration of the tank. The facility was reactivated in 1984 and the first laminar flow test was conducted in the fall of that year. At present, the The Langley Tow Tank is maintained and operated by Naval Underwater Systems Center with support from the Langley Research Center.

Facility Description

Tank Building

The building housing the tow tank consists of columns on 20-foot centers supporting ceiling trusses. Each column is marked with a frame number. No. 1 is at the extreme southern end of the building and No. 148 at the northern end. The frame numbers constitute a marking system for pinpointing location in the tank. The frame numbers also provide specific positions for starting points and stopping trips.

This frame structure supports the walls and roof, which are made of 5/16-inch corrugated cement asbestos sheets (Carrystone). Office spaces, a machine shop, storage areas, and model-working space are located at the southern end of the building. Except for the drydock area, offices and shop, the building is not heated, air-conditioned or insulated. It serves primarily to protect the tank from wind and rain.

Tow Tank

The tank is made of reinforced concrete. Above the waterline the tank walls curve inward and form ledges on either side of the tank. Wave supressors made of flat steel plates are installed transversely at intervals formed by the coves under the ledges. Steel "I" beams resting on transverse support "chairs" which are also made of "I" beams, run the length of the tank. The beam structure rests on top of the ledges. The "I" beams support and guide the towing carriage (Figure 4).

Any subsurface tank installed in water saturated, unstable soil must be designed so that it does not have a tendency to rise out of the ground when empty. The ground water level on the banks of the Back River at Langley is only a few feet below the surface. Truscott adapted a feature used in drydock construction to stabilize the tank. The design included reinforced concrete horizontal "wings" which were molded at the base of the tank walls to help prevent the tank from floating. In addition Truscott designed an undertile drain beneath the basin which leads to a sump in the main pump room. When the tank is empty the undertile drain is continuously pumped to lower the ground water level in the vicinity.

The concrete was poured in 60 foot sections with rubber gaskets between segments to allow for thermal expansion and contraction of the concrete (Figure 5).

TOW TANK WATER

Sea water is brought into the tank through a 14-inch pipe that extends 400 feet into the river. This pipe is located at the southern end of the facility. The water from the Back River is brackish, containing approximately 15-25 parts/thousand of salt. If trials in fresh water are required, it is pumped in from Hampton's municipal system.

Fresh or salt water is filtered through a dual filter 500-gallon/minute system. A 25-micron depth filter that uses anthracite and silica, and a cartridge-type polishing filter (typically 5-10 microns). The system also continuously filters water in the tank. The locations for the intake and outlet cause the water to move from north to south during filtering.

Because of the high ground water level, the tank is thermally coupled to the Back River and the water temperature varies with seasonal temperature changes. Algal growth is controlled with chlorine additions and by minimizing the amount of light which reaches the tank.

WAVE MAKER

The wave generator has been unused since 1977 but remains in place. It is located at the northern end of the tow tank. The dynamic component is a heavily reinforced steel plate attached to a horizontal hinge at the bottom of the tank. A variable speed, 75-horsepower, dc motor oscillated the plate through a transmission and crank mechanism to produce waves. The generator could simulate rough seas in the tow tank to determine the effect of stormy weather on seaplane performance.

CARRIAGE RAILS

The carriage rides on unmachined, wide-flanged, 12-inch by 9-inch steel I-beams having a 3/8" web. Each individual beam is 60 feet long. Joints on opposite sides of the tank are staggered. Simple butt joints with a small space allowed for thermal expansion are used.

The east rail supports the carriage and also guides it laterally. Since it is the primary directional control it is aligned both vertically and laterally. The west rail is aligned vertically. The carriage's horizontal stability and guidance is established by eight solid rubber guide wheels, four placed forward and four aft on the east side of the towing carriage. These bear on opposite sides of the web on the "I" beam. There are no guide wheels on the west side of the carriage.

Vertically, the beams follow the curvature of the earth. Over a distance of 2000 feet a difference in elevation of approximately 0.5 inch occurs between the line of sight and the earth's curvature.

Truscott managed to stay within his Depression-era budget by using pneumatic tires. Unmachined "I" beams and pneumatic tires are not typically used in tow facilities. Tow tank facilities normally utilize carriages with machined steel wheels riding on machined rails. However, sufficient funds were not available to machine the rails. In addition to cost, pneumatic tires were favored because they had better starting and stopping traction than steel wheels. This in turn permitted higher test speeds and more time at constant test speed. Pneumatic tires also counteracted vertical roughness in the unmachined "I" beams, and dampened carriage vibrations. Flat spots forming on the tires are prevented by a hydraulic jacking system that removes the weight of the carriage from the tires when the carriage is at rest. If the tires fail and the carriage drops more than 0.5 inch, steel rollers bear the weight. The wheels are driven through a 5.75:1 gearbox.

TOWING CARRIAGE

The 18-ton towing carriage is formed of five longitudinal truss bridges constructed of welded thin-walled tubular steel. The test models are carried on the center truss. Loads are transferred to the wheel assemblies through two transverse truss networks. The wheel assemblies are coupled by two longitudinal side trusses. The wheel truck assembly has two motors and two wheels. The truck assembly is attached to the carriage with a pivot pin. The pivot pin permits the wheel truck to accommodate unevenness in the rails and dampen shocks. When the David Taylor Model Basin operated the facility starting in 1960, the designers added an air conditioned room to house instrumentation.

CARRIAGE PROPULSION

In 1937 the original four-motor carriage drive was replaced with eight 75-horsepower, dc shunt motors. The four motor sets are wired with armatures are connected in series and shunt fields in parallel. Armature currents and voltages are varied depending on the required acceleration and speed while motor field currents are kept essentially constant at 3.3 amperes per motor. The overhead trolley system supplies power to the motors from an 850-kW motor-generator set through an overhead trolley system. The overhead trolley system consists of 14 solid copper buss rods hanging from the building's ceiling trusses. A frame at the rear of the carriage supports carbon brushes. These brushes glide over the buss rods and transfer power to an on board load distribution center which supplies power to the carriage motors, instrumentation, carriage speed control and the test model. The trolley arms are stable only the forward direction at high speed. This, as well as poor operator visibility when running backwards, limits reverse speed to 10 feet/second. If high speed runs in both directions were required an additional set of trolley arms and a control station would be installed. Reverse runs in conjunction with a wave-making apparatus, enabled engineers to test the effect of head-on or following seas on a model (Figure 6).

The addition of the instrumentation room dropped maximum attainable speed from 60 knots to 45 knots. This speed is sufficient to test underwater shapes evaluated as directed by the present mission requirements of the facility. Currently, the maximum acceleration is 3.5 feet/second^2 and the maximum deceleration is 6.5 feet/second^2.

CARRIAGE SPEED CONTROL

Carriage speed is varied by controlling the field and thus the power output from the 850-kW generator. A phase-lockloop, solid-state speed controller built by Robicon Corporation of Pittsburgh, Pennsylvania which was installed in 1976 performs this function. The present carriage speed controller was originally installed in 1976.

The carriage may be operated manually or automatically. In the manual mode, the driver controls speed and acceleration rates with a potentiometer. Acceleration and deceleration is directly related to the speed that the potentiometer is advanced or retarded to the desired speed setting. Maximum acceleration rates are achieved by presetting the potentiometer to the desired speed setting. Maximum speed setting is 99.9 feet per second. The details on speed control are contained in Appendix B.

Typically data collection runs start at frame 10 and stop at frame 90. Acceleration and deceleration rates govern the available time at test speed. For example at a speed of 35 knots, with 6,000 pounds of weight and 2,000 pounds of hydrodynamic drag acting on the carriage, 14 seconds of data at constant speed is available using maximum acceleration rates.

Carriage Safety

Runs are limited to 2,100 feet from dead start to full stop. There are several braking systems which engage sequentially to stop the carriage. They are broken into two categories: track-trip-controlled and operator-controlled.

Track-Trip-Controlled Stops.

The high-speed slowdown trip is located at frame 104. Normal regenerative braking starts when the carriage passes over this trip and the drive motors act as generators, feeding power into a resistive load. The carriage then decelerates at the rate preset on a control device which is set with a thumbwheel. The carriage will not reach the emergency stop trip located at frame 120 if it has not been running above 35 knots. The emergency trip activates maximum regenerative braking. The carriage motors act as generators and output maximum current (1800 amperes) to the load.

An emergency airbrake trip is located at frame 123. This automatically activates a completely isolated, wholly mechanical airbrake system. Four separate wheel tanks charged to 120 psi and a main tank make up the system. The brakes on each corner of the carriage are served by an individual tank. Should the brakes fail on any one corner braking is still available on six of eight wheels. The air brakes also have a fail-safe feature. If pressure in any tank falls below 65 psi, the regenerative braking system will be activated at the maximum current limit. Further pressure drop below 40 psi activates the airbrakes.

If both braking systems fail, friction or grab plates attached to the sides of the carriage seize up on inverted T-rails which are bolted to the walkways between frames 139 and 145. Stop trips and T-rails are also located at the southern end of the tank. When the carriage is south of frame 15 or north of frame 120 the operator must activate a bypass switch to move the carriage (Figure 7).

Operator-controlled Stops

If the automatic braking systems fail to activate during a normal carriage stop, the operator can depress an emergency stop button which activates the regenerative braking system. In addition, maximum regenerative braking is energized by releasing a foot-operated deadman switch located on the floor of the control station applies. The control station also has a floor pedal which energizes and controls the airbrake system. Other safety systems on the towing carriage prevent carriage runaway, motor overload, generator overload, motor imbalance, and field imbalance.

Available Power

Three-phase 208-volt ac power is supplied to the carriage for lights, model power, and instrumentation. The capacity of the circuit is 70 kVA. This circuit also powers the speed controller. 110-volt ac single-phase power is obtained from the existing three-phase circuit.

Drydock

The southern end of the tank forms an 80 foot long drydock used for servicing test models. The drydock is sealed off from the main tank by a door which is hinged at its bottom. The door folds down, away from the model to open the drydock area to the main tank. Steel cables connected to an air winch raise and lower the door.

Conclusion

NACA Tank No. 1 performed a vital role in developing efficient seaplanes during the evolutionary period of commercial aviation. Design problems which defied solution using theoretical mathematical methods available at the time were resolved using empirical data collected from extensive model testing in the tow tank. Pragmatic engineers worked out solutions that resulted in seaplanes that flew well, opened up commercial air transport routes and enabled the United States Navy to achieve air superiority in the Pacific theater during World War II.

References Cited

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3 James R. Hansen, Engineer In Charge, (Washington, D.C.: National Aeronautics and Space Administration, 1987), 450.

4 Gray, 65.

5 D. A. Brown, Langley Sea Water Tow Tank Facility: Description and Operation, (Newport, Rhode Island; Naval Underwater Systems Center, 1985, 1.

6 Gray, 68.

7 Ibid, 71.

8 Ibid, 80.

9 Ibid, 75.

10 Brown, 1.

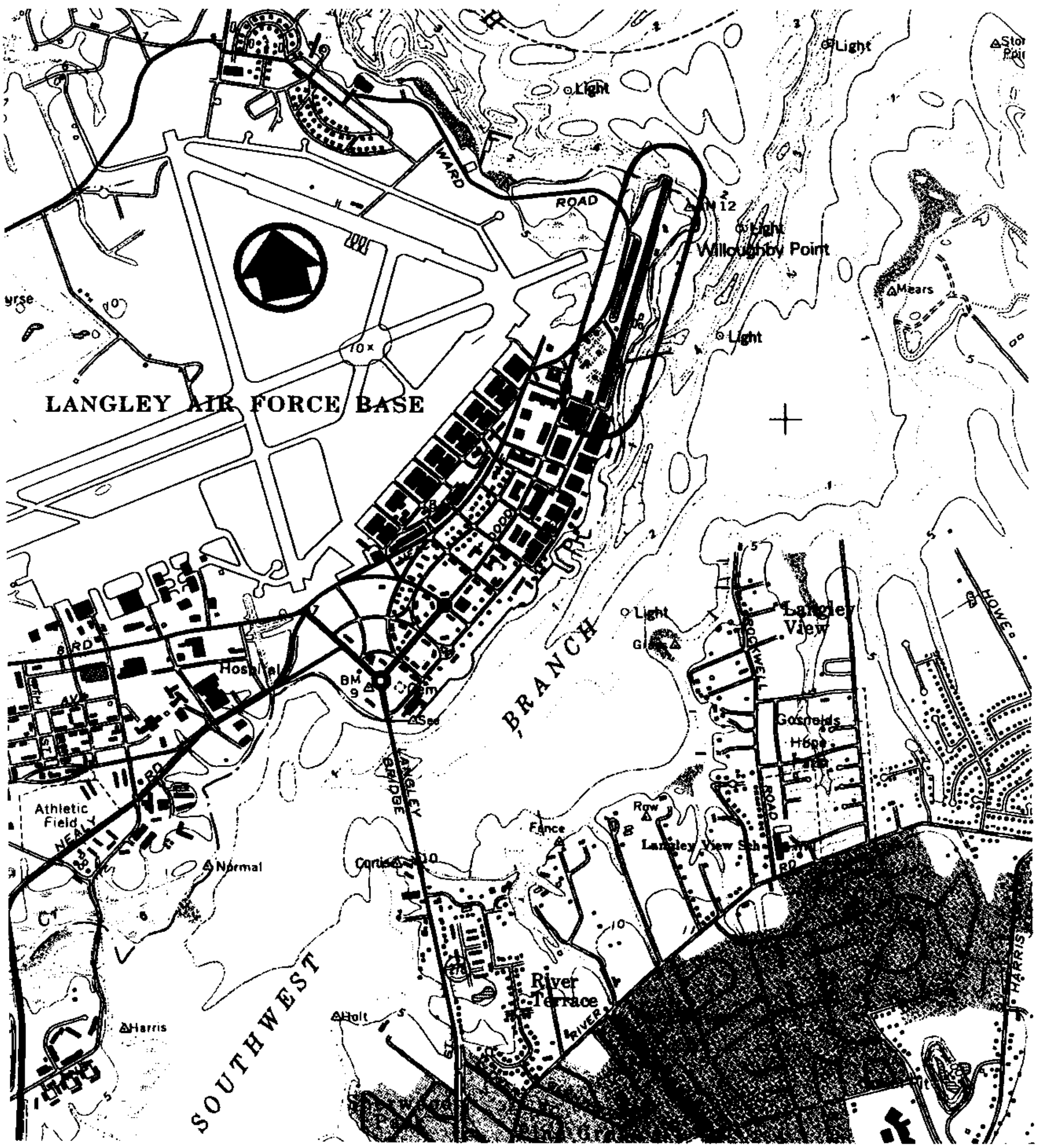

Figure 1 - Location Map
Langley Research Center - Seaplane Towing Channel
Quadrangle: Hampton, Virginia - 1:24000

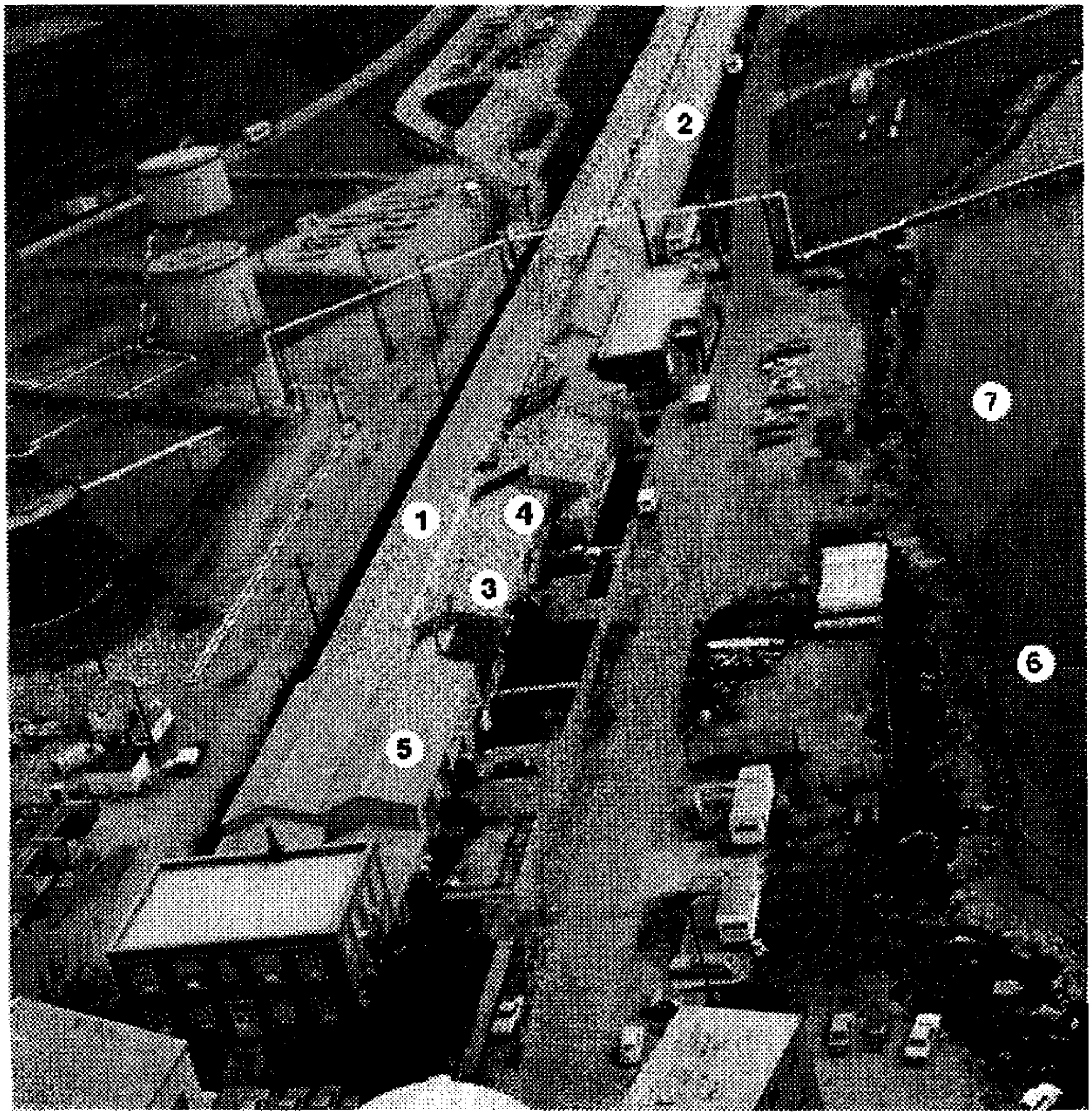

Figure 2 - Aerial View North - 1980s
Langley Research Center - Seaplane Towing Channel

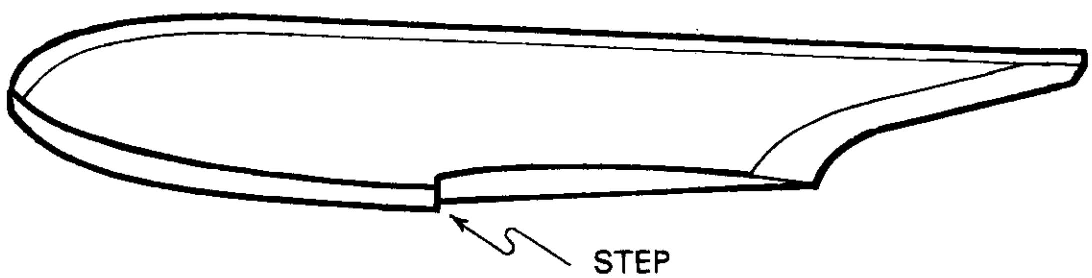

Figure 3 - Seaplane Hull Step Location

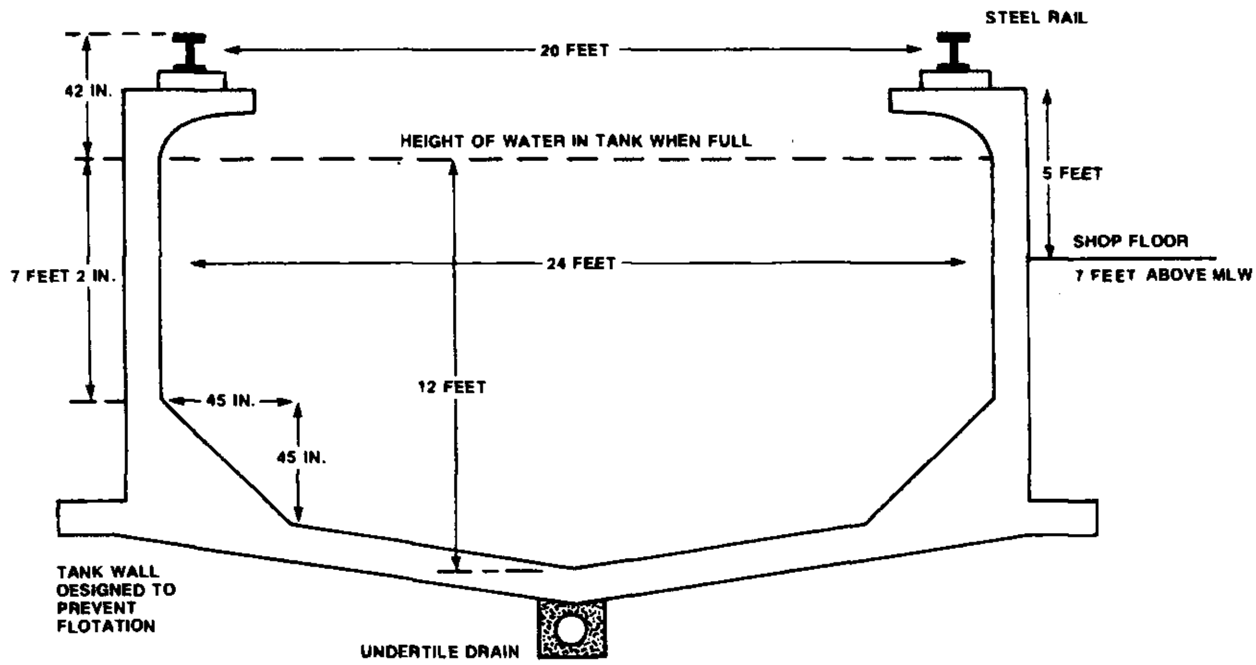

Figure 4 - Cross-Section of Tow Tank (Brown, 3.)

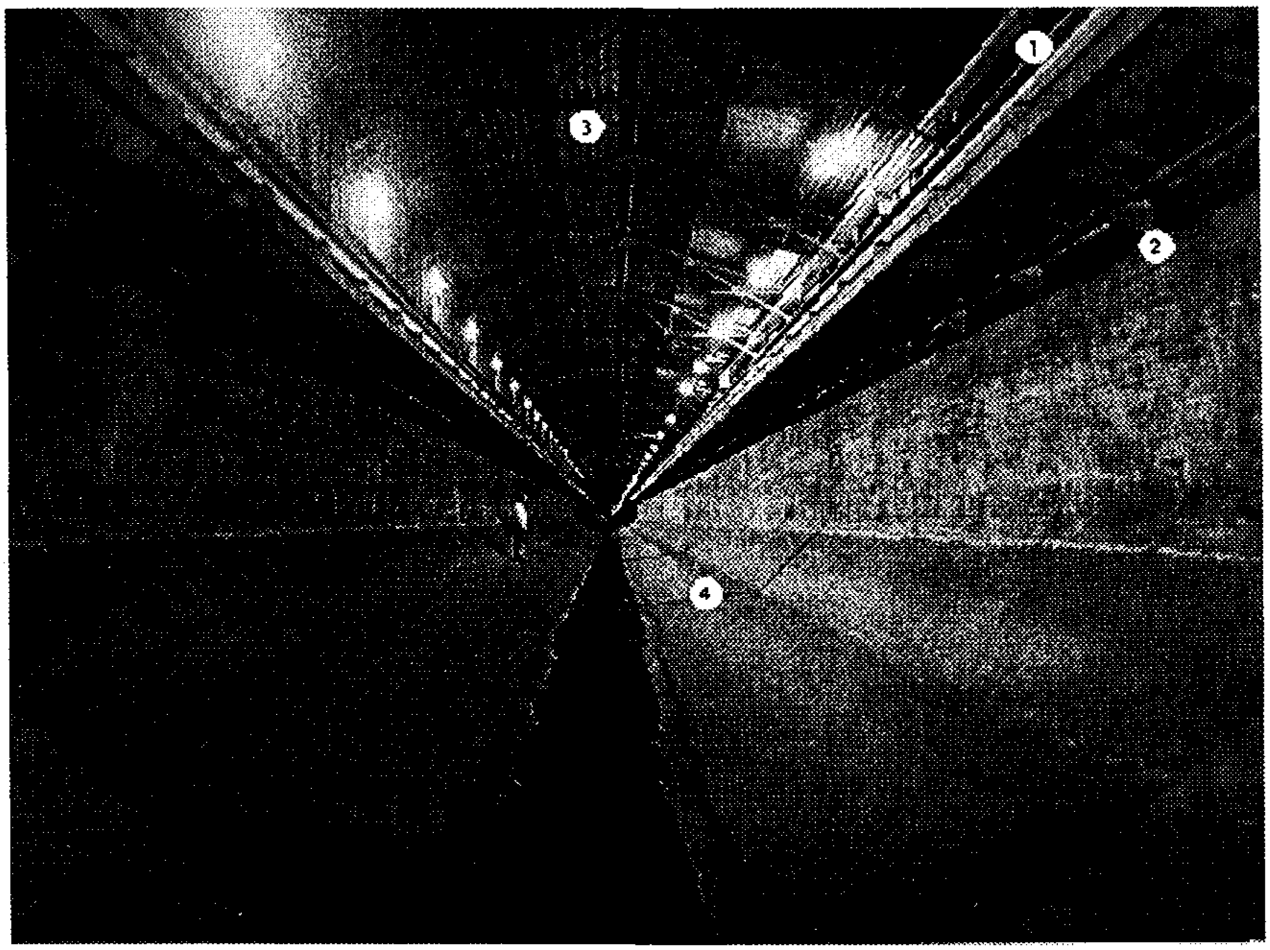

Figure 5 - View North - Drained Tow Tank
1. Steel Carriage Rail; 2. Wave Supressor; 3. Trolley Power Buss; 4. Tank Seam

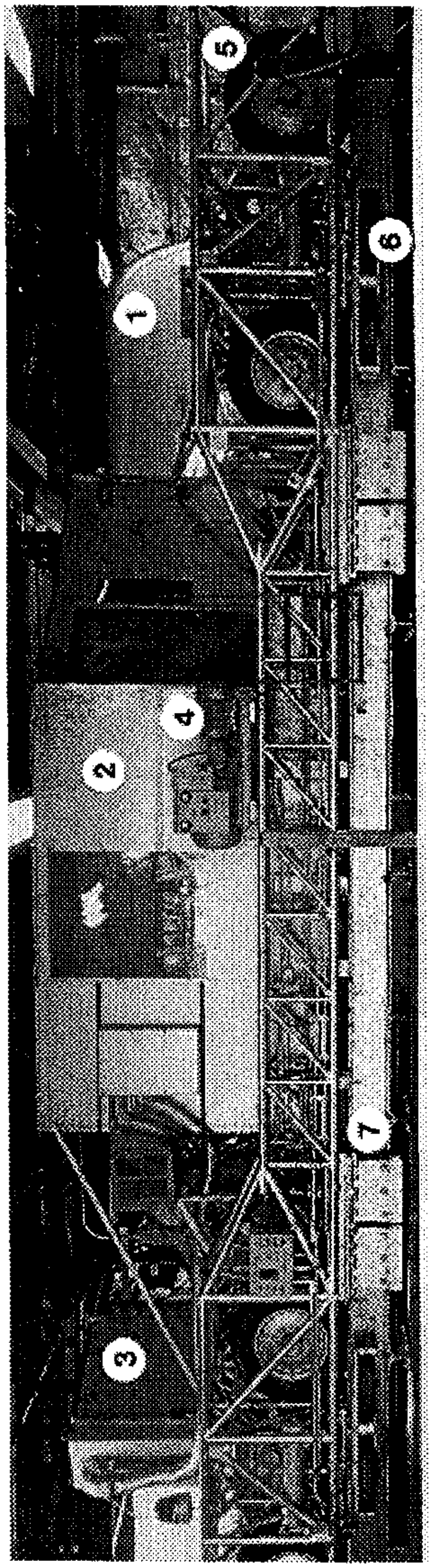

Figure 6 - Side View of Tow Carriage
1. Operator's Control Housing; 2. Instrument Room; 3. Robicon Speed Controller; 4. 6.25 kVA 120 Vac Generator; 5. Tires; 6. Guide Wheel Assembly; 7. Grab Plates

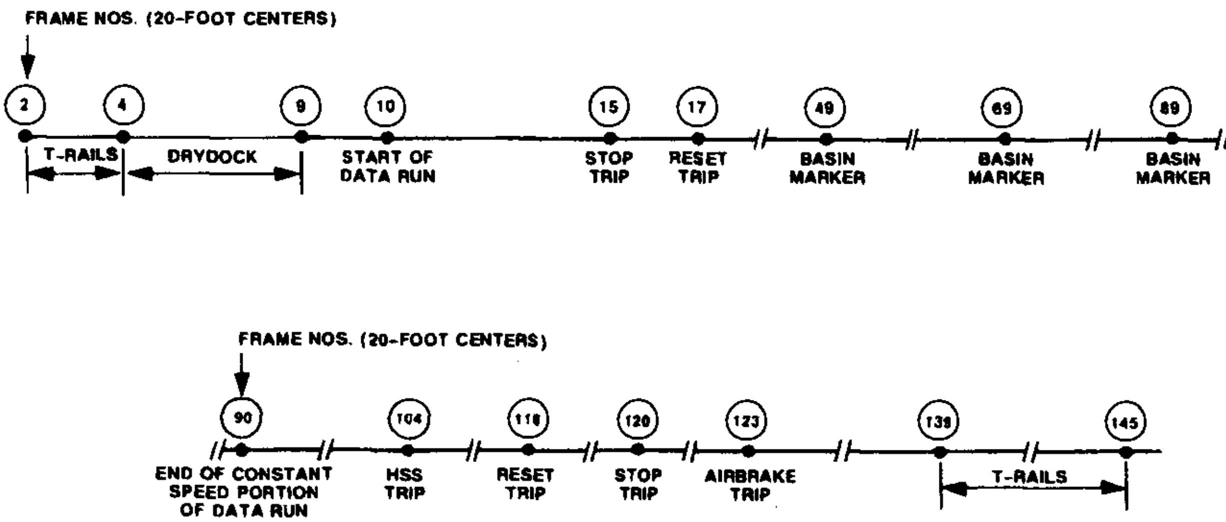

Figure 7 - Frame Location of Trips, T-Rails and Basin Markers

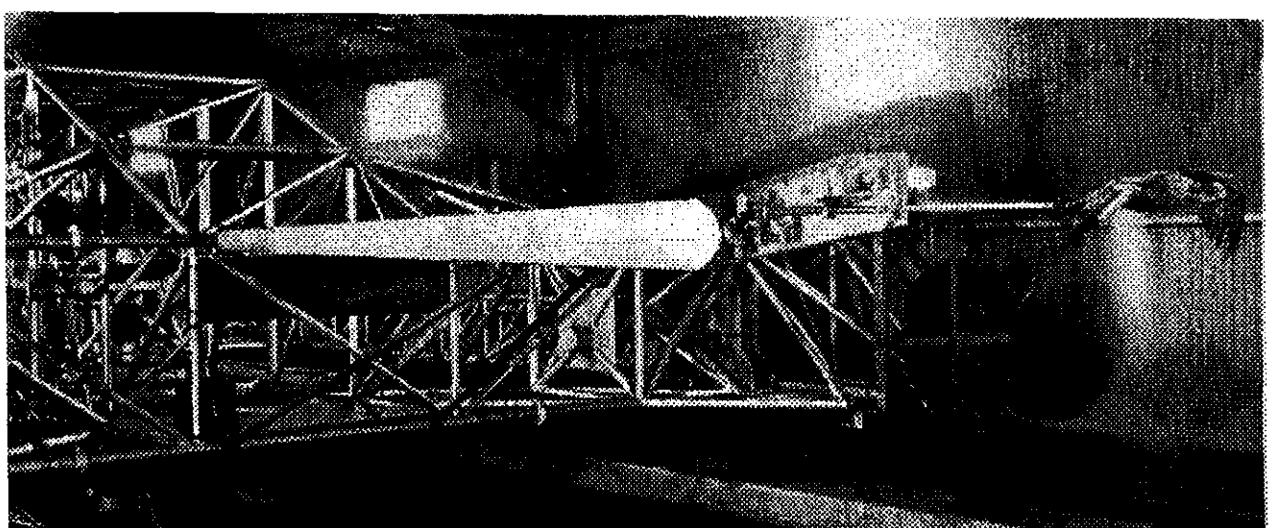

Figure 8 - Early View of Towing Carriage, Bird Experiment

Appendix A

"Bootlegging" in the Tow Tank

In Engineer in Charge, James Hansen shows an early photograph of the tow carriage before the operator station housing was installed. Hansen also reports on some questionable scientific experiments:

> Langley old-timers refer to unauthorized testing as "bootlegging." Some of their stories about bootlegged tests are apocryphal, however, according to one of these tall tales, a group of employees wondered out loud during a lunchroom conversations in 1932 about the aerodynamic characteristics of some of the birds that flew over Langley. One of the men who took the subject most seriously, Tom Collier, shot a buzzard, and froze it with its wings outstretched for unauthorized testing in the NACA towing tank. The test results indicated that the frozen bird could not fly because it was inherently unstable (birds are, in fact, unstable, but this has never stopped them from flying)! The teller of the tale never mentions, however, that tests of soaring birds in the NACA tank had been proposed by Victor Lougheed of the U.S. Navy Bureau of Aeronautics. Moreover, in May 1932, the Virginia Commission of Game and Inland Fisheries had issued a permit for Lougheed "to Possess and transport for use in connection with flight investigations, ten sea gulls." (The photograph shows) one of these gulls being tested on the carriage of the towing tank.[1]

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[1]Hansen, 38.

Appendix B

Details on Carriage Speed Control

The manual mode employs voltage feedback for speed control. Pulses obtained from an encoder physically attached to a tachometer wheel are converted to a voltage and compared to a reference voltage obtained from the speed controller (5 volts corresponds to 100 feet/second). The manual mode of operation usually is not used for data collection runs. It is simply used to position the carriage at slow speeds (e.g., moving the carriage in or out of the drydock).

The automatic mode of operation, which is used for data collection runs, relies on phase-lock feedback circuitry. very simply, the pulse train from the tachometer is compared to the pulse train from the speed controller. In this mode, carriage speed is controlled with a high degree of accuracy. An indication of how well the controller performs was obtained in the first NUSC test where carriage speed was held to within +0.02 knot of the desired speed. A check on carriage speed is obtained using tank markers that photoelectrically trigger an electronic timer. The amount of time to traverse a given distance between the markers is measured.

In the automatic mode, speed in either the forward (north) or reverse direction, as well as acceleration and deceleration, are controlled. These parameters can be changed at any time or held constant during a run. For a data collection run, the acceleration/deceleration rate and forward speed are preset using thumbwheel switches calibrated in hundredths of a foot/second^2 and hundredths of a foot/second, respectively.

When the run button (on the carriage control panel) is depressed, the carriage accelerates at the preset acceleration rate until it reaches the speed set on the forward speed thumbwheel. To stop the carriage, the stop button is depressed. The deceleration rate is constant and corresponds to the deceleration thumbwheel setting. In stopping the carriage, the eight carriage motors act as generators, restoring power to the 850-kW motor-generator set. All normal carriage braking is done electrically and is known as "regenerative braking." Just prior to the carriage stopping, the deceleration rate is decreased automatically by the controller to avoid a whiplash effect. At any time during a run, any of the thumbwheel settings may be changed. Thus, data points may be collected at several speeds during a single run.

The main carriage motor generator set is an 850 kw, 125-horsepower, 2,300-volt synchronous motor driving a 850-volt, 1,000-ampere generator. Maximum voltage and amperage output from the set is 150 volts and 2,050 amperes.

A SMALL motor-generator set mounted on the carriage is also available for instrumentation power. Its output is single-phase 110-volt ac with a total capacity of 6.25 kVA. This supply is used for delicate instrumentation sensitive to voltage changes and line noise. Also available is 600-volt, 150-kW, variable dc power from an auxiliary motor-generator set. The maximum output of this set is normally 250 amperes. It may, however, be operated at 125 percent of maximum load for short periods. (Reprinted from NASA Technical Document 6392)[2]

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[2]Brown, 18.

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