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FULL-SCALE DEMONSTRATION OF VERTICAL FLOAT SEA-STABILIZATION CONCEPT

PHASE I REPORT

OCTOBER 1963

GENERAL DYNAMICS | CONVAIR
Post Office Box 1950, San Diego 12, California

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FULL-SCALE DEMONSTRATION OF VERTICAL FLOAT SEA-STABILIZATION CONCEPT, Phase I Report,

Phase I Report
Contract [redacted]. NOw 63-0793-f

August 1963,

Prepared by
by D. B. Dewey,

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General Dynamics/Convair
San Diego, California

ACKNOWLEDGEMENT

Full credit for the origination of the vertical float sea-stabilization concept is due Mr. E. H. Handler of the Bureau of Naval Weapons, Washington, D. C. We wish to express our sincere appreciation to Mr. Handler for his continuous support and assistance during the recently completed program. We also thank Captain B. K. Beaver of BuWeps FLTREADREPPAC for his assistance in scheduling Naval ships and personnel for the open sea operations. Without the vigorous cooperation of these two men, the test program could not have been completed in the short time span allotted.

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SUMMARY AND CONCLUSIONS

This report presents the results of an experimental program covering the design, construction, installation, and testing of a vertical float stabilization system on the PBM-5 seaplane.

Dynamic model investigations had demonstrated previously the effectiveness of the vertical float system in reducing wave-induced motions, and it was appropriate to extend the program to full-scale testing. The purpose of the present study was to compare the wave-induced motions of a vertical float-equipped PBM-5 seaplane with the motions of a standard hullborne PBM-5. Both seaplanes were manned and instrumented for the tests.

The PBM open sea tests have dramatically demonstrated in full scale the capability of the vertical float system to provide a steady platform in waves. Sea State II conditions produced only minor motions in the PBM equipped with vertical floats. Air crewmen on board this seaplane reported no seasickness or discomfort, in direct contrast to general discomfort and seasickness experienced by the crew on board the standard hullborne PBM.

The 1963 full-scale PBM vertical float tests have resulted in the following noteworthy conclusions:

1. Installation of vertical floats on a seaplane will eliminate much of the pitching, rolling, and heaving motions in Sea States I and II and the lower spectrum of Sea State III. For example, during Test D, the maximum roll amplitude was 4 degrees on the vertical float seaplane, while roll amplitudes greater than 14 degrees were experienced on the hullborne PBM.

2. The addition of vertical floats to the PBM seaplane eliminated motion sickness and discomfort of the crew while resting on the water for extended periods in Sea States I and II.

3. Because of additional underwater drag, the drift rate of the vertical float-equipped seaplane was approximately 1/3 the drift rate of the conventional seaplane in 10 to 20-knot winds.

4. The addition of vertical floats does not present special towing prolems on PBM seaplanes. No unusual pitching, rolling, or heaving was noted due to towing at speeds up to 4 knots in any direction with respect to the waves.

Engineering design studies show that incorporation of vertical floats on an ASW seaplane is a practical goal for the immediate future. It appears that an operational installation can be designed to be both retractable and stowable without imposing an excessive weight penalty. This contractor is currently conducting preliminary design studies in this area, including work with major rubber companies on the possible application of inflatable materials to float design.

Because of the pressing need for more effective anti-submarine weapons, it is strongly recommended that tests of the vertical float system be continued at an accelerated pace into higher sea states, greater gross weights, and variable aircraft operating heights to determine the practical operating limits of such a system. Design studies should be initiated now to utilize the knowledge gained from this program in the development of future open-ocean, anti-submarine weapon systems.

INTRODUCTION

The future ASW weapon system will probably require the use of a true open-ocean seaplane, both as a fast sensor-bearing vehicle and as a weapon carrier-launcher. To date, the seaplane has been ill-suited to the rough water conditions normally encountered in ASW operations — not only because of hull structural limitations, but also because of rapid deterioration of crew performance while the seaplane is tossing on the surface of the rough ocean. Because of these limitations, the open-ocean mission of the seaplane has been largely assigned to the aircraft carrier and its smaller short-range aircraft.

To take full advantage of its speed, superior load-carrying ability and long range, the seaplane must be able to more fully utilize its operating environment, the ocean's surface. Not only must the seaplane be able to land and takeoff in the open sea, but it must also survive for long periods at rest on the surface, while providing the crew with a stable platform from which they may carry out their assigned ASW mission.

One very promising method of achieving rough water stability is the vertical float system originated by Mr. E. H. Handler of the Bureau of Naval Weapons. In rough water the vertical floats support the entire weight of the vehicle and, at the same time, minimize pitching, rolling and heaving motions caused by waves.

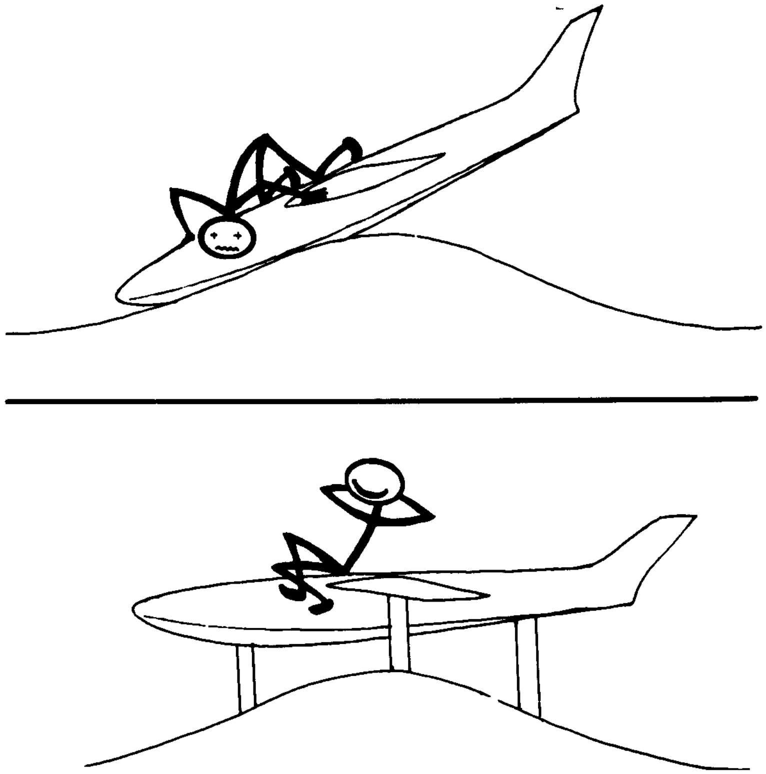
During the summer of 1962, under Contract NOw 63-0399-t, General Dynamics/Convair conducted initial experiments with vertical floats on dynamic models operated in the Hydrodynamics Laboratory Towing Basin. The results of the model tests were so satisfactory that further full-scale testing was desirable to extend knowledge of the system to actual open sea conditions and to evaluate crew reactions under these conditions.

In anticipation of a contract for the full-scale tests, the Navy provided two PBM-5 seaplanes. One of the seaplanes would be modified to receive the vertical floats while the other would remain in the standard PBM-5 configuration to serve as a test control. Both seaplanes would be similarly instrumented to permit correlation of data.

Since the actual modification program did not start until January 1963, time was of the essence to complete the test vehicles by April 1963 and to take advantage of the final winter storms expected for the season. Under Contract NOw 63-0793-f, General Dynamics/Convair designed and constructed a vertical float system for one of the airplanes. Fabrication of the floats, modification of seaplane hulls, and installation of instrumentation and other equipment was completed by 11 April 1963, as scheduled. The seaplanes, together with all associated equipment, were then shipped to San Clemente Island for assembly and testing during the latter part of April. Actual testing did not begin, however, until mid-May 1963 because of storm damage to both seaplane hulls while on barges en-route to the assembly area at San Clemente. Completion of the hull repairs delayed the test program for four additional weeks.

The San Clemente Sea Island Range of the U.S. Naval Ordnance Test Station, which lies 60 miles off the southern California coast, was selected as the initial test site for several reasons. First, the Wilson Cove area of the island provides a relatively sheltered mooring adjacent to an open expanse of generally rough ocean. This was an important consideration since the towing and handling characteristics of the full-size vertical float seaplane were yet unknown. Second, this NOTS facility maintains a public works section with large cranes and barges capable of handling the seaplane for vertical float assembly. Third, the ocean around San Clemente Island offers a relatively uncongested operating area in which the seaplanes and towing vessels could drift for extended periods without interference from ocean traffic.

The actual testing took place during the latter half of May 1963 and was concluded by the first of June — at which time the two seaplanes were shipped back to San Diego for repairs and preservation.



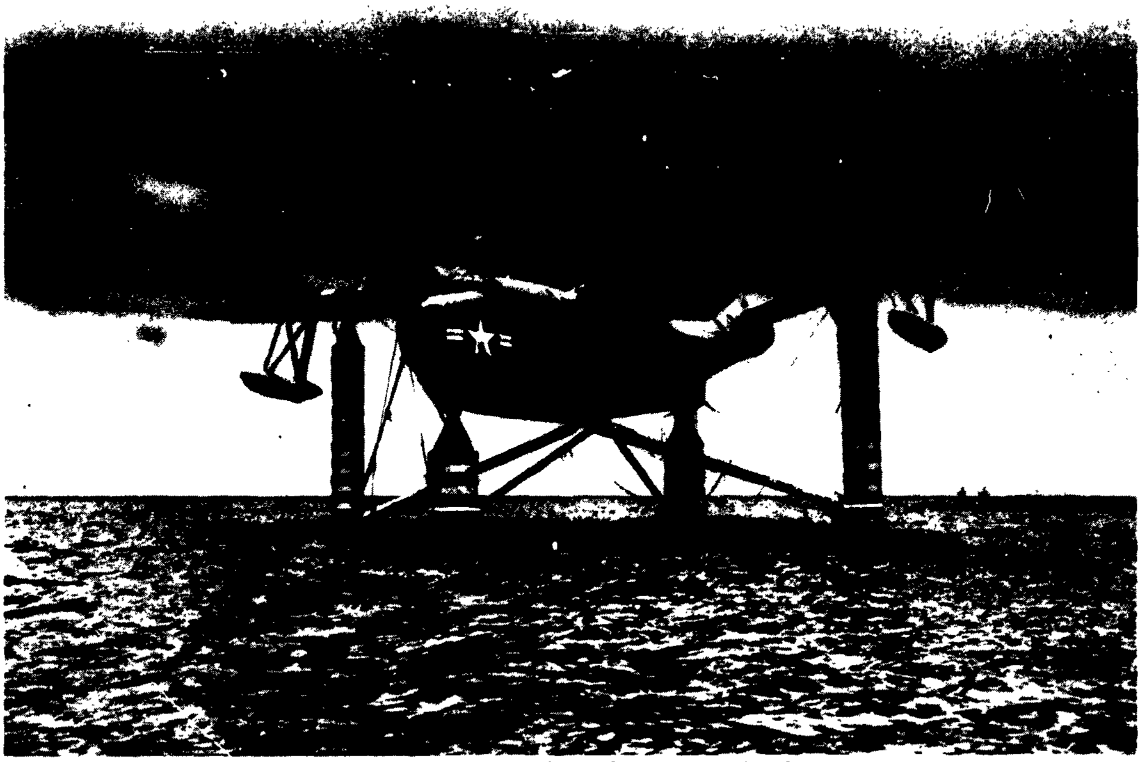


Figure 1. PBM-5 Equipped With Vertical Float System — Airplane is Resting at 10-Ft. Keel Height Above Water

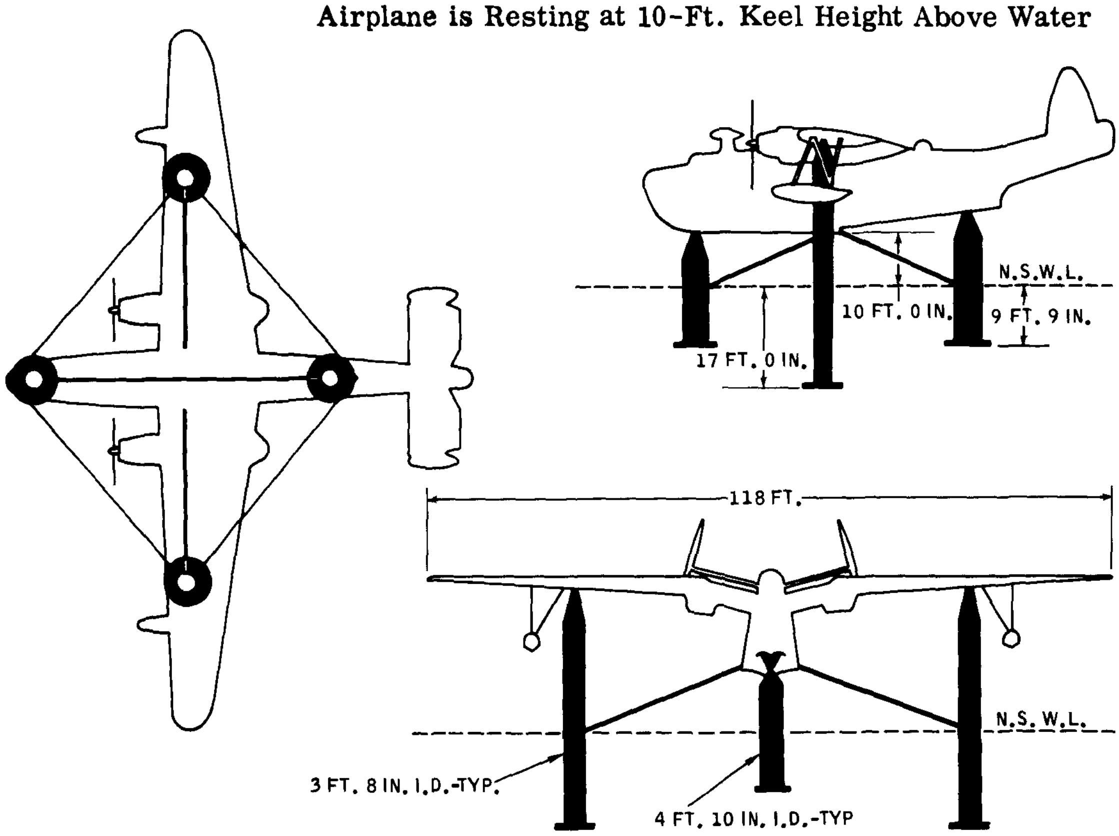


Figure 2. Principal Dimensions of Vertical Float Installation

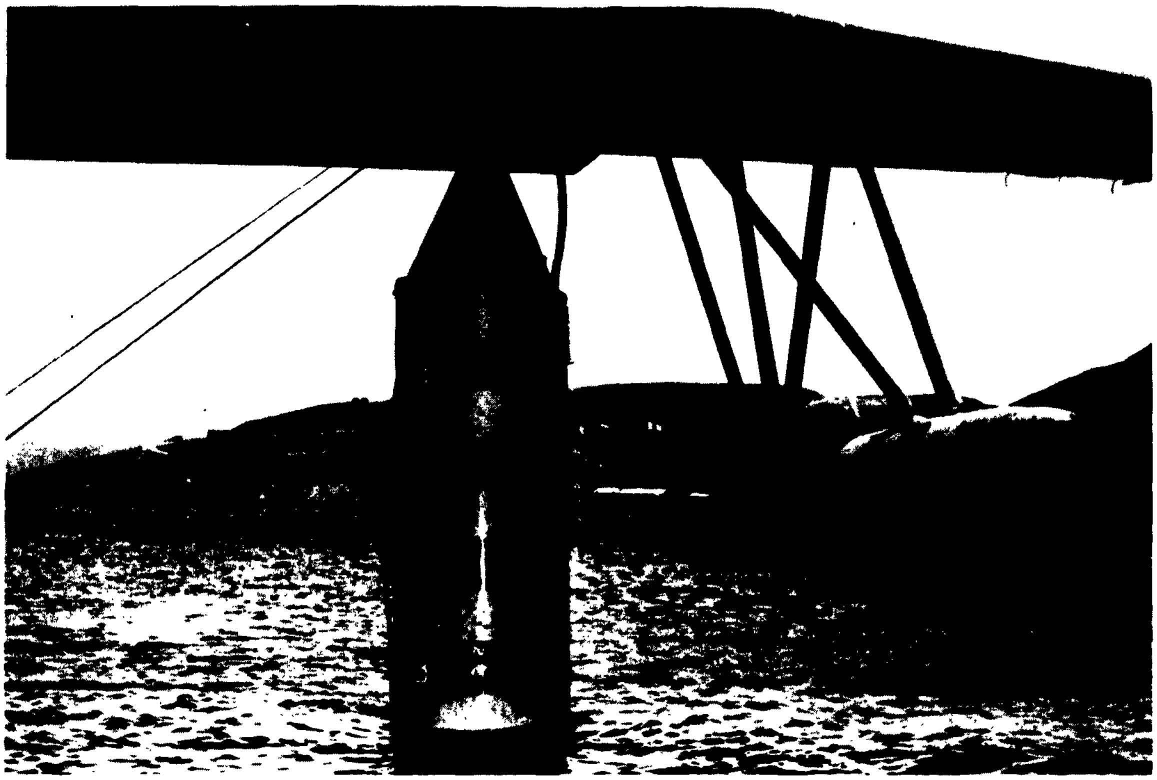
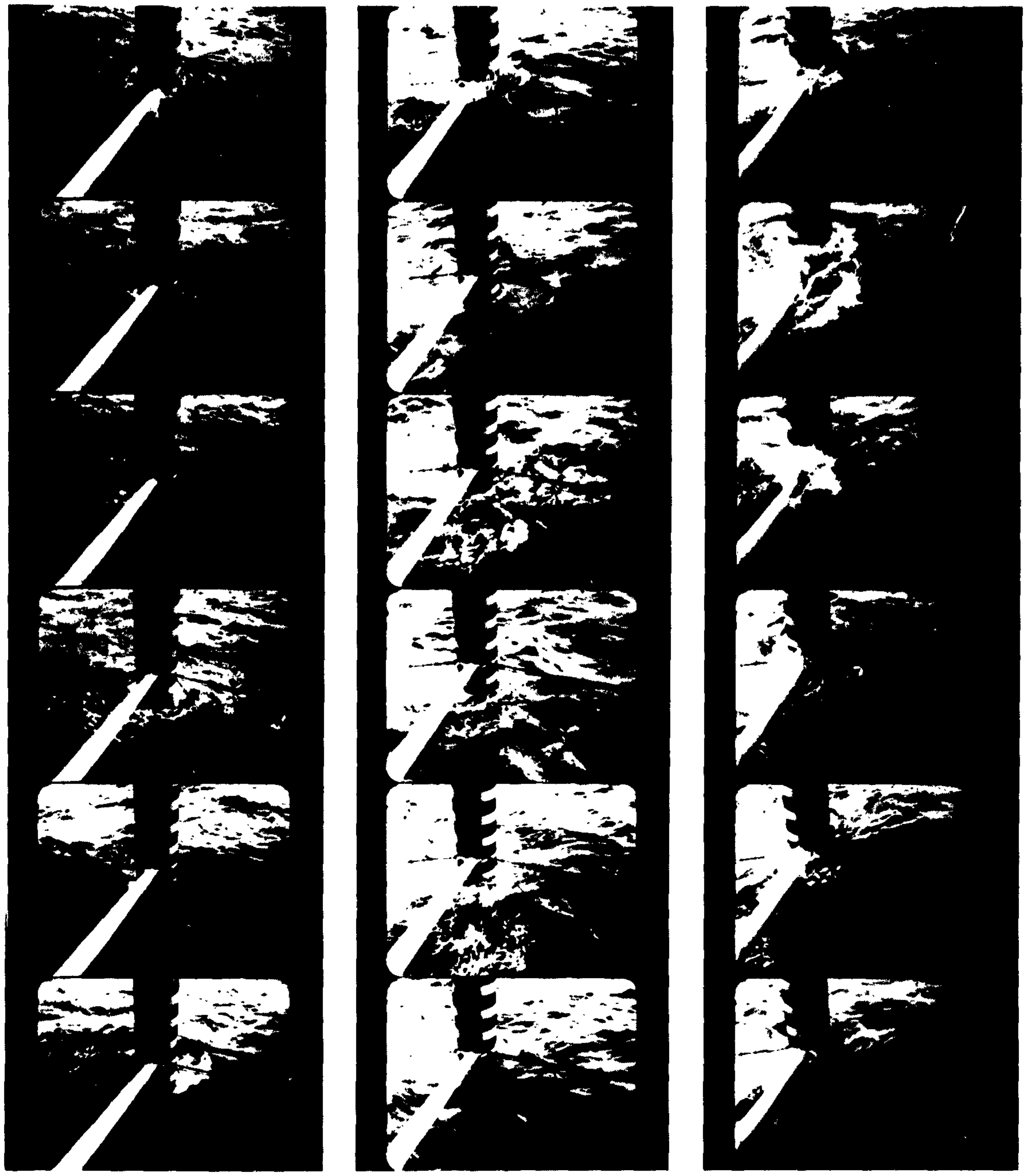


Figure 3. Wing Float Attachment — Aircraft is in Hullborne Condition With Vertical Floats Flooded

Figure 4. Wilson Cove Mooring Area at San Clemente Island (view looking East)



DRIFTING IN 4-FT.
- HIGH WAVES
(1 FRAME / SEC)

TOWING AT 4 KNOTS
WAVE HEIGHT 3 TO 4 FT.

TOWING AT 3 KNOTS
WAVE HEIGHT 3 FT.
(1 FRAME / SEC)

Figure 5. Wing Floats in Waves

DESCRIPTION OF TESTS

HARDWARE

Testing for the full-scale vertical float system was accomplished using two Navy-furnished PBM-5 seaplanes. The seaplane engines were preserved and not used during this program. Both aircraft has been cannibalized to the extent that they were no longer air worthy. Electrical power for instrumentation and lights was supplied by the regular ten-horsepower auxiliary power unit. In addition to the aircraft system, the vertical float seaplane carried a 2.5-KVA, 60-cycle auxiliary power unit to supply 115-volt AC current for the float pumps.

The vertical floats and compression struts were constructed of MIL-A-19070 5086 H aluminum alloy. This material was chosen for its high corrosion resistance when exposed to sea water, in addition to its weldability. These parts were fabricated from 1/4-in.-thick material. At stress concentrations such as float pivot fittings, 75T6 alloy was used. Cables, shackles and turnbuckles were hot-dipped galvanized steel which, after installation, were coated with Paralketone compound to further improve corrosion resistance.

All vertical floats were pin connected to the aircraft by use of a limited universal joint. Cable ends and compression struts were attached with single bolt or pin fittings to facilitate assembly. None of the hardware developed any abnormal corrosion problems during the test program.

RECORDING THE DATA

Each aircraft was equipped with a Convair-fabricated photo panel containing the instrumentation required to record changes in pitch, roll, acceleration, aircraft heading, wind direction and velocity versus time and film counter number. Inasmuch as time at sea was usually seven or eight hours, actual filming of the photopanel was done for selected short intervals. Photopanel filming was done concurrently in both seaplanes to give a valid time comparison. Motion picture films (16mm color) were made on board the two test vehicles, as well as from accompanying ships and a Navy-furnished helicopter. Written observations were made during the tests describing crew reactions and airplane behavior in wind and waves.

TEST CONFIGURATION OF AIRPLANE

The vertical float seaplane, with normal test crew and stores aboard, had a gross weight of 45,700 lb., while the standard (control) seaplane, under the same conditions, weighed 36,000 lb. The first two open sea tests were conducted with the 9,700 lb. weight difference between the two seaplanes. To minimize the effect of weight differences, the weight of the standard seaplane was increased to 44,000 lb. through use of water ballast during the last two tests. The dissimilar weights of the standard seaplane did not noticeably change its seakeeping qualities in similar waves, although no precise measurements were made.

The principal differences between the vertical float version and the control seaplane were as follows:

Item	Hull Configuration	Vertical Float Configuration
Seaplane model and S/N	PBM-5 No. 9148	PBM-5 No. 9158
Testing gross wt.	36,000 lb. 44,000 lb. (with water ballast)	45,700 lb.
C.G. location, % MAC	30	30
Damping plate area	None	64 sq. ft. (each float)
Metacentric height (roll)	10 ft.	8 ft.
Design waterline	Hullborne	120 in. below keel

Item	Hull Configuration	Vertical Float Configuration
Pitch waterplane area	—	18.3 sq. ft. float
Roll waterplane area	—	10.5 sq. ft. float

TEST OPERATIONS

The Wilson Cove area of San Clemente Island, 60 miles off the California coast, was used as a base of test operations. This semi-protected harbor provided a relatively sheltered area not too distant (4 to 5 n. mi.) from the rough water usually prevalent at the north end of the island. From this location, the two seaplanes were towed to deep water (400 - 600 fathoms) for the tests. Towing was done at speeds of from three to four knots, as reported by towing vessels, and was accomplished without incident other than a two to three-degree, nose-down trim condition. A typical test period required approximately seven hours time — much of which was used during the towing operation to and from the open ocean location. Once on station, the towlines were slacked so that the two test vehicles would drift freely. While drifting, the instrumentation was activated on both seaplanes to obtain simultaneous recordings of data. Control of the test operation was maintained by VHF radio communication between the test vehicles and ships.

From visual observations, the control seaplane drifted approximately two to three times as fast as the vertical float configuration in 12 to 15-knot winds. The differential drift rate required constant maneuvering of one towing vessel to keep the two seaplanes close together for photographic coverage.

During the drifting mode, the photopanel cameras on both aircraft were activated for selected 10 to 15-minute intervals. Continuous photography of instrument readings was not practical because of film limitations. Through all test periods, instrumentation readings were monitored by crew members to note any unusual indications not recorded on film. Figures 6 through 13 show comparisons in pitch, roll and accelerations. These figures were constructed by plotting photopanel data for identical two-minute periods during each test. Tests "A" and "B" took place on 21 May 1963, while tests "C" and "D" occurred on 28 May. The approximate sea condition for each test was as follows:

Test	Sea Conditions
A (dry run)	Sea State I into II
B	Sea State I and II
C	Sea State II
D	Sea State II and lower spectrum of Sea State III

Since the combination of motion amplitude and frequency is the primary factor in the habitability of any surface operating vehicle, perhaps the most significant comparison of the relative motions of the two seaplanes is shown in Figure 13. This plot compares the average amplitude multiplied by the frequency of pitch and roll for a given sea state.

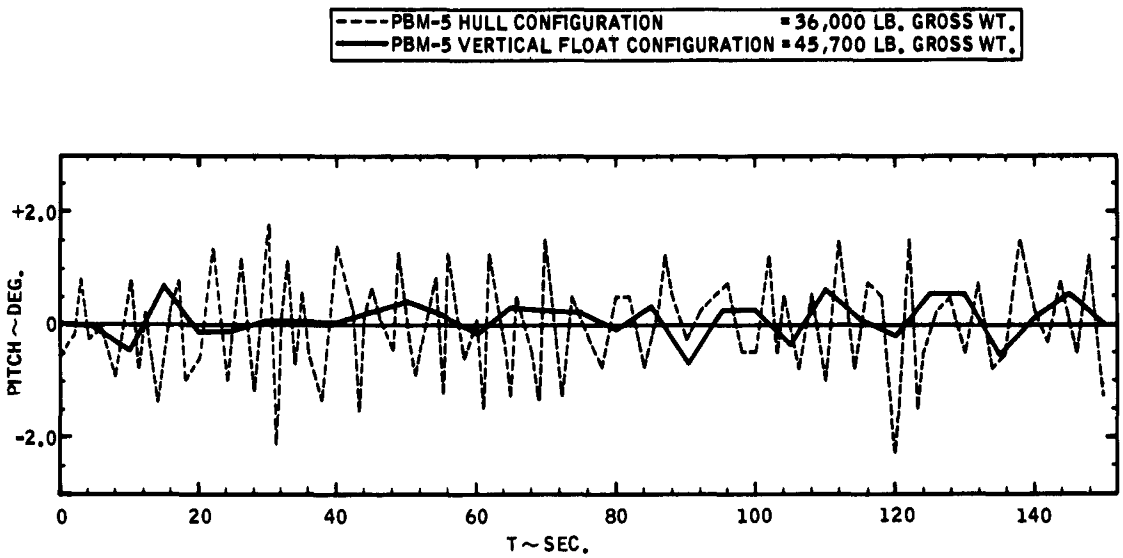


Figure 6. Test B — Motions in Pitch, 21 May 1963

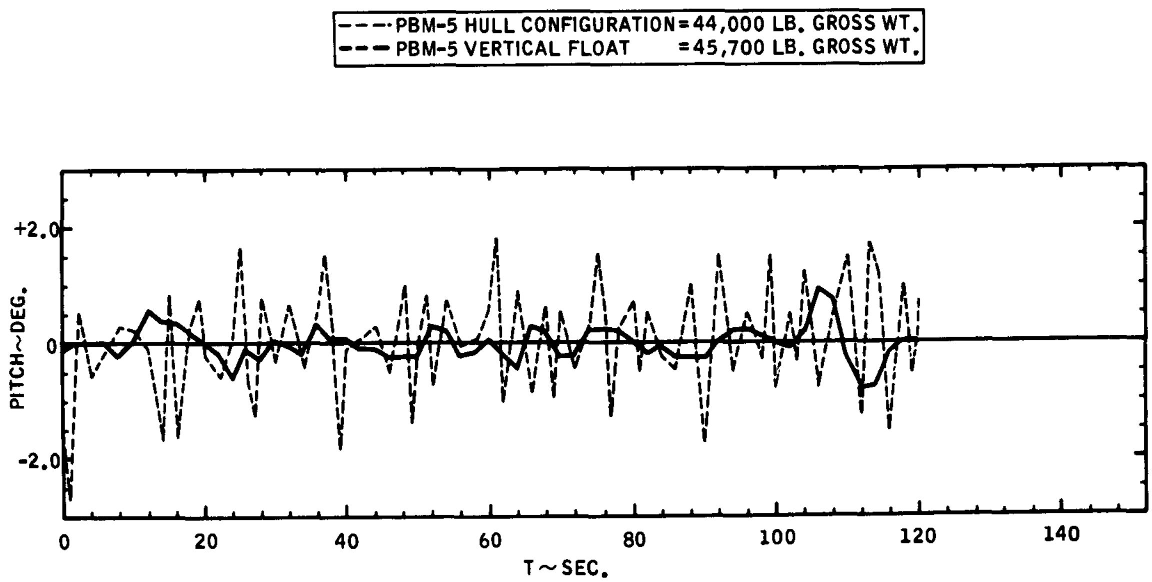


Figure 7. Test C — Motions in Pitch, 28 May 1963

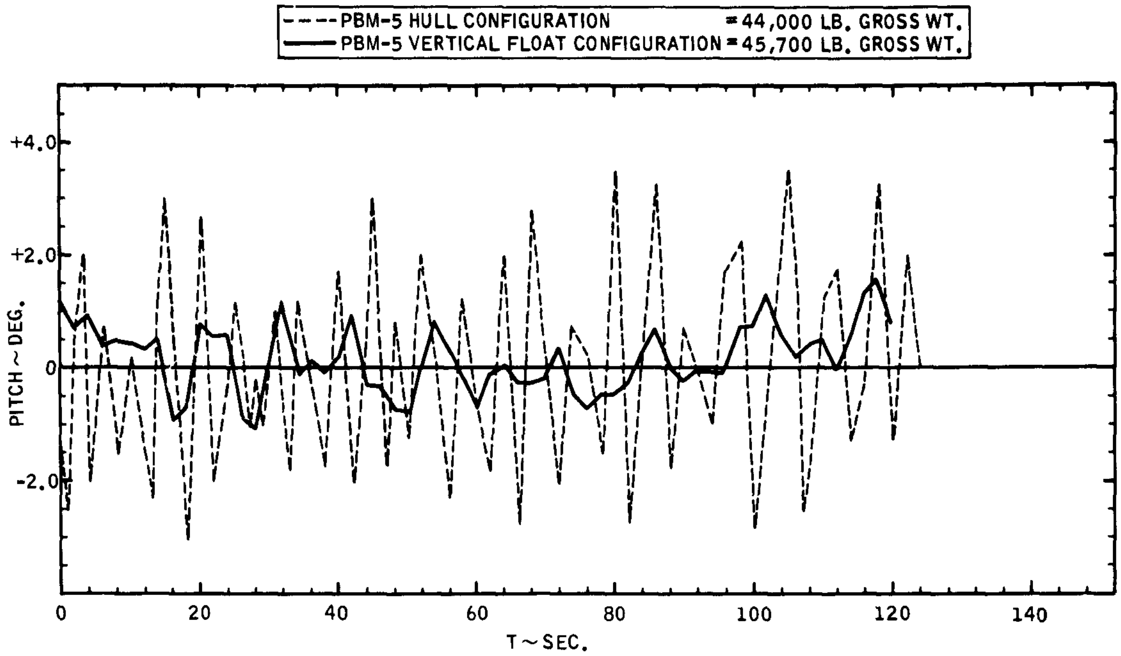


Figure 8. Test D — Motions in Pitch, 28 May 1963

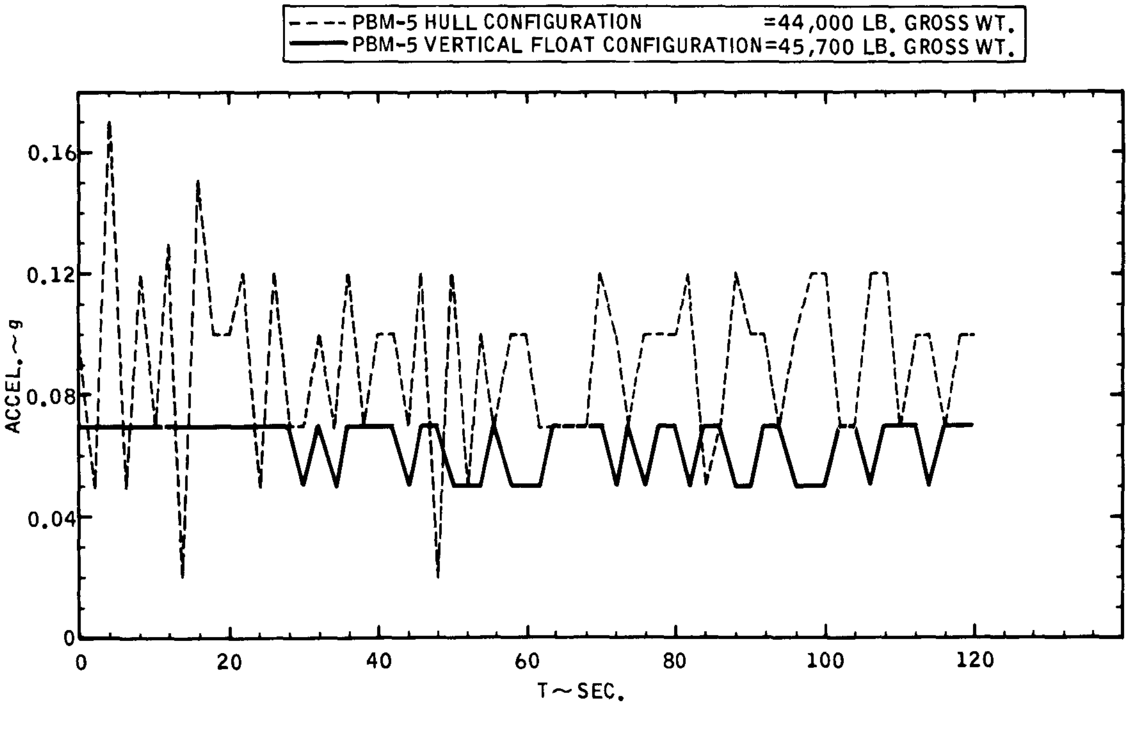


Figure 9. Test D — Accelerations, 28 May 1963

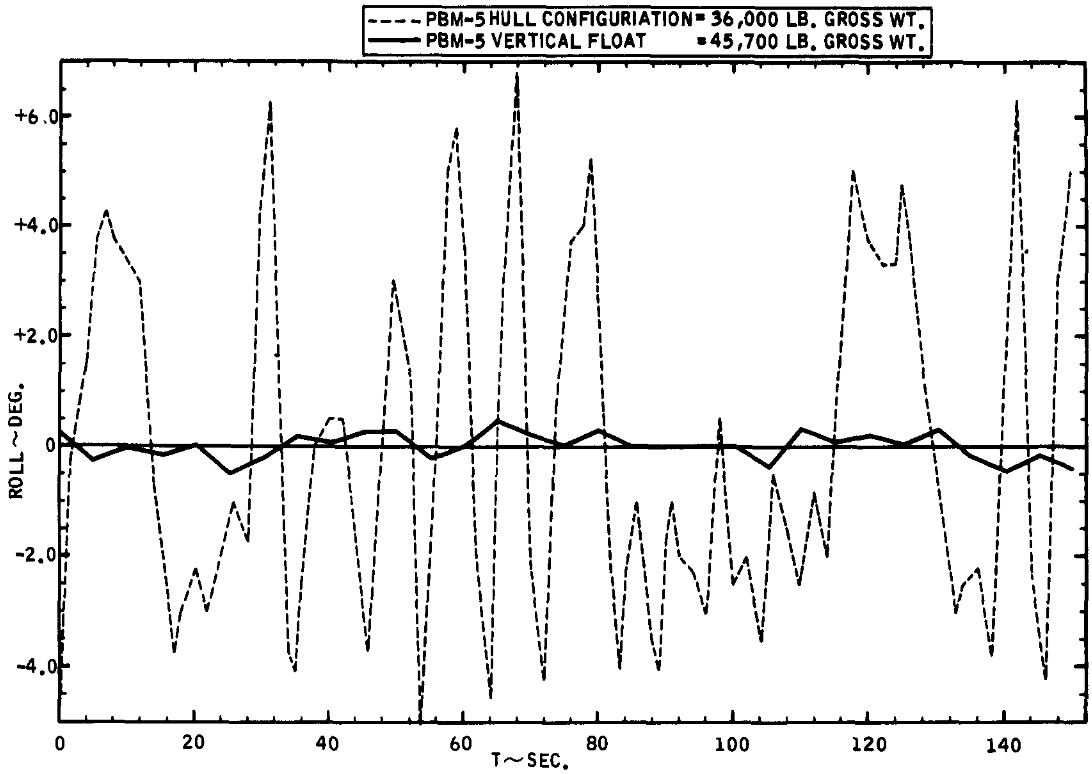


Figure 10. Test B — Motions in Roll, 21 May 1963

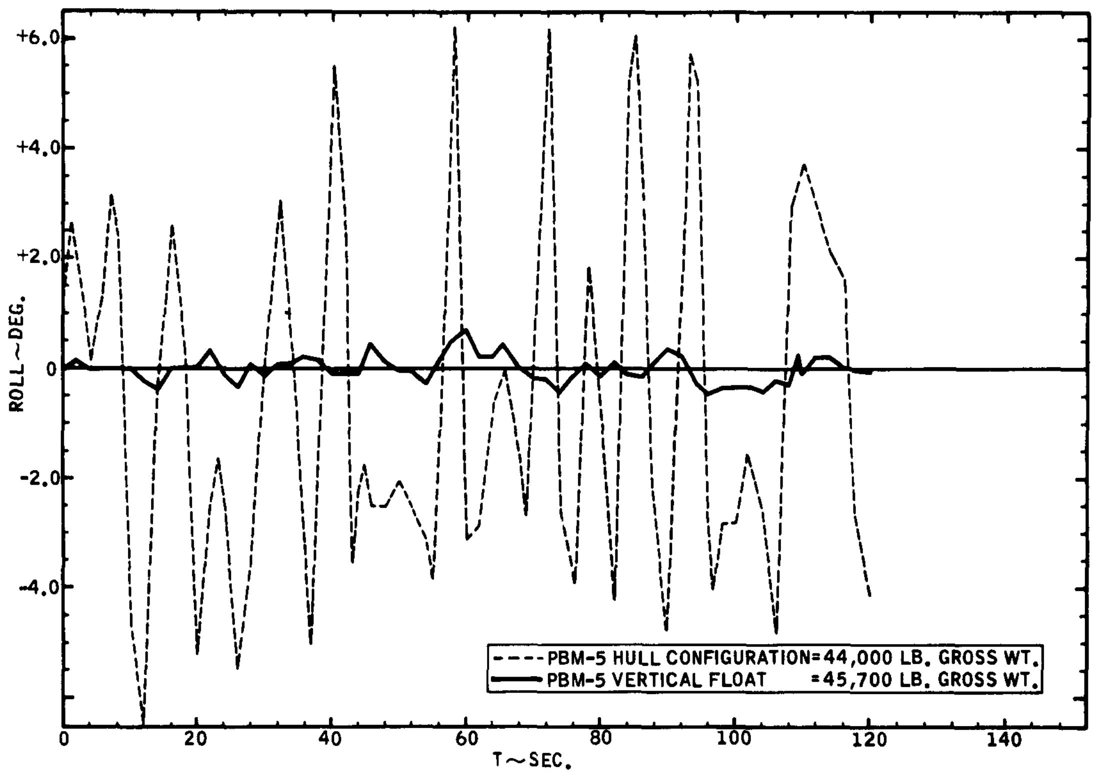


Figure 11. Test C — Motions in Roll, 28 May 1963

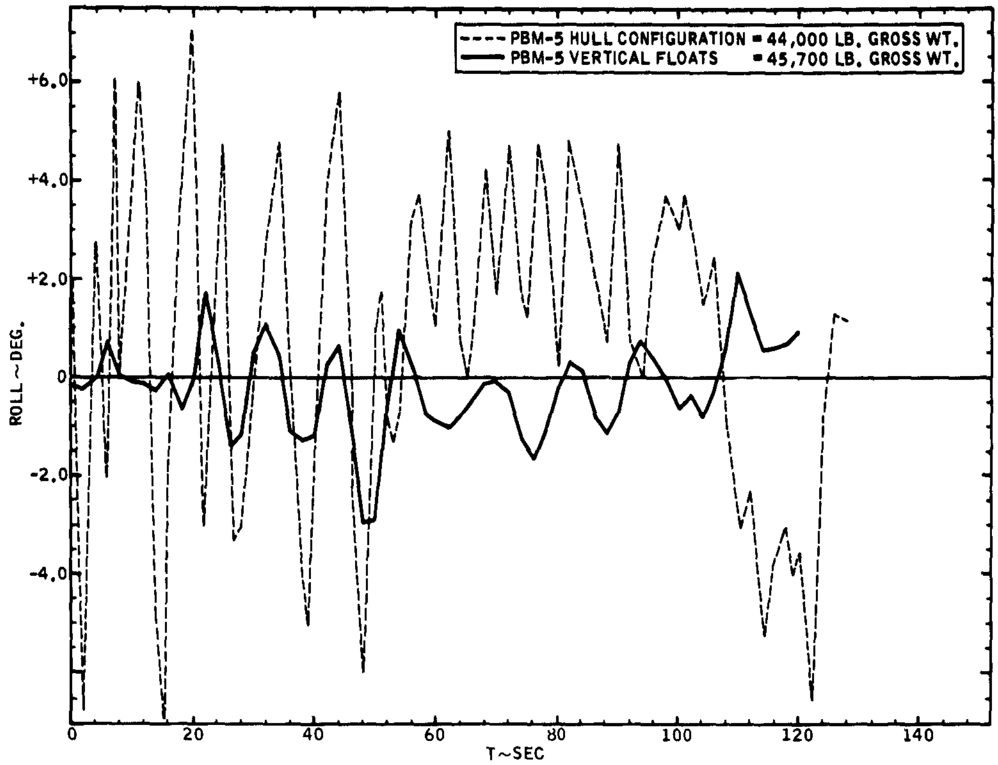


Figure 12. Test D — Motions in Roll, 28 May 1963

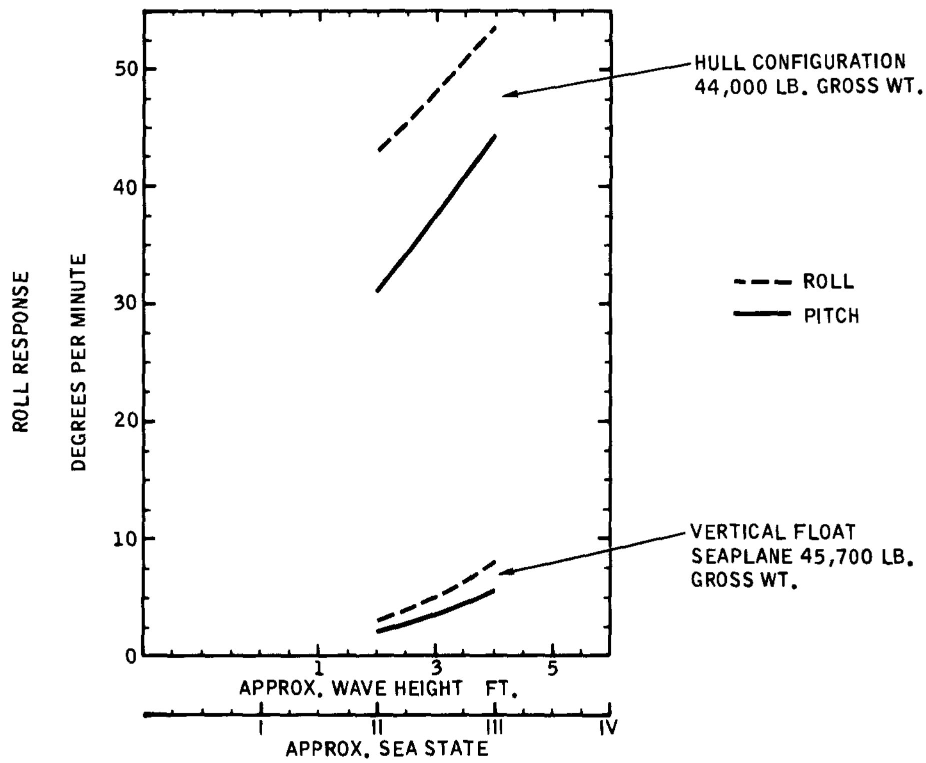


Figure 13. Roll Response Vs. Sea State

TECHNICAL DISCUSSION

TECHNICAL DISCUSSION

Throughout this test program, the major problems encountered were operational in nature rather than associated with the vertical float installation per se. Future test programs can benefit from the experience gained during the May 1963 tests — especially with regard to ship support, communications and towing techniques.

The vertical float-equipped seaplane behaved as predicted in the seas that were encountered. The plots of comparative motions included in this report re-emphasize the effectiveness of the concept even in moderate seas. Some minor changes in towing rigging are indicated to make a more rugged installation for future test work in higher sea states.

The two seaplanes were exposed to a variety of sea conditions ranging from no wind and nearly calm water to a maximum of 20-knot winds with 5-ft.-high waves.

Based on recorded and observed data, sea conditions during tests fell into the following general categories:

Wind velocity	-	Maximum	20 kt.
		Average	12 kt.
Wave height	-	Maximum	5 ft.
		Average	3 ft.
Wave period	-	Maximum	8 sec.
		Average	6 sec.

Wave steepness L/H	- Average	18
Wave length	- Maximum	100 ft.
	Average	55 ft.

Wind velocities were measured by anemometers mounted high on each test vehicle. Wave lengths were measured by comparison with the aircraft dimensions, and average periods were timed in the same manner. Wave heights were noted as they passed by the marked wing floats.

Wave forms encountered were very irregular, with length to height ratios of 15 to 18. The ocean roughness experienced during these tests could be classified as local, wind-generated seas rather than old swells coming from other areas. The seas observed showed reasonably good correlation with the following tables taken from U.S. Navy Hydrographic Office H.O. Publication No. 602. The range of sea and wind conditions observed during the May 1963 tests are noted in Tables 1, 2 and 3.

Table 1. Average Length of Waves, Observed at Sea, According to the Strength of the Wind

	Beaufort Scale	Description	Velocity N.Mi. Per/Hr.	Waves Average Length in Feet
Range experienced during May 1963 V.F. tests	2	Light breeze	11	52
	4	Moderate breeze	20	124
	6	Stiff breeze	30	261
	8	Moderate gale	42	383
	10	Strong gale	56	827

Table 2. Probable Maximum Heights of Waves with Winds of Different Strengths Combined From Various Observations at Sea

	N.Mi./Hr.	Ht., Ft.
Range experienced during May 1963 V. F. tests	8	2.6
	12	4.6
	16	7.9
	19	11.5
	27	19.7
	31	24.6
	35	29.9
	39	36.0
	43	39.4

Table 3. The Heights of Waves, in Feet, Theoretically Produced by Winds of Various Strengths Blowing for Different Lengths of Time[1]

	Wind Velocity N.Mi. per Hr.	Duration in Hours 5	10	15	20	30	40	50
Range experienced during May 1963 V.F. tests	10	2.0	2.0	2.0	2.0	2.0	2.0	2.0
	15	3.0	4.0	4.5	5.0	5.5	5.5	5.5
	20	4.0	6.5	8.0	8.5	9.5	10.0	10.0
	30	8.5	12.0	14.5	16.5	19.0	20.5	21.5
	40	13.0	19.0	24.0	26.5	31.0	34.0	35.0
	50	17.5	26.0	32.5	37.5	45.0	54.0	54.0
	60	22.0	33.0	42.0	50.0	60.0	67.0	72.0

[1] Based on a study of the basic energy relationships between wind and waves, by Dr. H. U. Sverdrup and Mr. W. H. Munk at the Scripps Institution of Oceanography. The calculated heights are the averages of about the highest 30 per cent of the waves. These higher waves are of the most practical significance, and the lower waves observed are likely to be of most recent origin.

According to the U. S. Navy Hydrographic Office Sea State Code, the sea states observed during the May 1963 vertical float tests varied from Sea State I and II into the lower spectrum of Sea State III. The majority of testing took place during Sea State II conditions, and in water 400 to 600 fathoms deep. It is hoped that future testing can be done both in high short-period waves, as well as in long-period swells. Indications are that the greatest potential operational problems for the future ASW seaplane will come from resting on the ocean dominated by short, steep waves rather than long-period swells.

Each seaplane was manned by a Convair test crew and three Navy volunteers from VP squadrons at NAS, North Island, San Diego. All volunteers were aircrewmen with considerable experience in the P5M seaplane. The purpose of manning each seaplane with experienced crewmen was to obtain a comparison of motion sickness, if any, between the two test vehicles. Each crew was assigned regular duties on board, such as radio communications, observation of instrumentation, operation of electrical system, etc., under the supervision of Convair test personnel. During the tests, motion sickness was reported by two crew members aboard the conventional seaplane hull even though the sea state seldom exceeded II. No motion sickness or other discomfort was noted on the vertical float-equipped seaplane. Future studies are planned by aeromedical specialists to measure actual personnel performance decrement due to vehicle motions in rough seas.

From the human factor standpoint, the allowable amplitude of motions cannot be precisely defined because individual tolerances to motion will vary considerably. The presence of sea-experienced aircrewmen aboard the test seaplanes provided some qualitative information on comfort limits. Experience with ships and boats in various wave conditions has established some general requirements which serve to indicate the upper limits of tolerable motion. For example, angular motions of approximately 10 degrees per second have been described as very uncomfortable, and motions below 4 degrees per second as quite comfortable[2].

From test observations and the accompanying data it is apparent that roll motions on the hull configuration approached the limit defined as acceptable. However, motions of the vertical float-equipped seaplane remained well within the "acceptable" spectrum throughout the tests. Since frequency as well as amplitude of motion is an important contributing factor to comfort and efficiency, Figure 13 shows the average amplitude (in degrees) experienced during a typical test period multiplied by the average frequency (in cycles per minute) for each configuration and for two sea conditions. The resulting comparison shows the dramatic difference in degrees per minute traveled by each test vehicle.

Tape recordings of underwater noises made during the May 1963 test were inconclusive and are not submitted with this report. It is planned to include this material and the strain gauge load measuring data in the report covering the open ocean tests planned for the winter of 1963-64.

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[2] "Symposium on Ship Operation," Part I, How They Perform; Transactions of the Society of Naval Architects and Marine Engineers (1955).

FUTURE DEVELOPMENT

To more fully explore the potential of the vertical float stabilization system, it is recommended that further full-scale testing be initiated. Such tests should investigate exposure of the seaplanes to higher sea states and with increased gross weights. It is desireable to test the vertical float installation at lower aircraft operating heights to determine the practical limit in this direction.

A more sensitive underwater sound listening device should be designed and built to qualitatively compare underwater noises generated by the two configurations in waves.

In conjunction with the full-scale investigation, it is recommended that an experimental program be undertaken using dynamic models to explore the following areas:

a. Effects of varying metacentric height.

b. Relationship of variable-sized damping plates to damping effectiveness.

c. Use of fairings on vertical floats to reduce maneuvering drag.

d. The application and effects of inflatable systems.

e. Limit sea state conditions.

Any dynamic model program should be augmented by the use of the analog computer.

An obvious application of a vertical float system is its use with the long-range VTOL or GETOL-type vehicle. Such an aircraft could perform ASW missions, where the combined requirements of speed, long range, large payload, and endurance on station are necessary. Existing classes of vehicles do not appear adaptable to all of these requirements. The ability to not only land but to survive and operate on the surface of the turbulent ocean would greatly enhance our ASW/Air-Sea rescue efforts.

Surveillance of the oceans for hostile submarines has become an integral part of our defense system. The combined advantages of vertical floats and VTOL could provide us with a sensor-bearing system that possesses not only the station-keeping ability of a small ship, but also the superior speed and mobility of the airborne vehicle.

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FULL-SCALE DEMONSTRATION OF THE VERTICAL FLOAT SEA-STABILIZATION CONCEPT by D. B. Dewey, Jr.,
Sept. 1963; 28 pages, illustrations, photos, graphs, tables.
Issued under Contract NOw-63-0793f.

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