

AN ANALYSIS OF THE SKIPPING CHARACTERISTICS OF SOME FLYING BOATS

by

Mitch Mayborn

During and immediately after World War II the National Advisory Committee for Aeronautics conducted tests designed to improve aircraft performance, develop new techniques, and to promote flying safety. These tests during the war were classified in nature and it was not until several years later that they were released to the public, or at least to general knowledge sources.

As would be expected of this type of material, it is technical in nature to a large extent. However there are portions in most of the papers that readily lend themselves to the adaptation for the layman. This paper is one of them. Many of the formulas, technical terms and methods have been deleted. Presented here are only the general problem and the results.

In all fairness the credit for the original work must go to F.W.S. Locke, Jr., of the Navy Department. His work, originally known as Advance Restricted Report 5J24 (AAR 5J24) was released as W-104 by the N.A.C.A.

Skipping may be defined as an unstable oscillation of hydrodynamic origin, predominantly heaving in character, which can occur just after landing or just prior to take-off. Skipping is associated with conditions whereby the forebody carries most of the water-borne load and at the same time a large amount of water is washing over the afterbody bottom. (See Reference 1 for description of mechanism of skipping).

Too numerous a series of serious accidents to both large and small flying boats has been traced to skipping. Because of the fact that hulls with quite violent skipping tendencies can be safely handled by experienced and careful pilots, there has been in the past, some tendency on the part of the designers to minimize the inherent danger. The accumulated experience of the average pilot is decreasing during the war; furthermore there is tactical need for operations under increasingly adverse conditions. New airplanes should be designed to take into account these two factors which have an important effect on the landing characteristics of a long-range military flying boat. Not only may the pilot be relatively inexperienced, but he may also be fatigued or wounded. Further, because of lack of fuel at the end of a long flight, it may be necessary to set down in rough water. Hence, it would seem to be very important for new military flying boats to have especially good landing characteristics under adverse conditions.

In Table I the pertinent particulars and specifications, and a single word describing the skipping characteristics are given for each hull. In some cases this one word represents an interpretation of a flight test report. In others it is the interpretation of opinions expressed by different pilots who had flown the particular airplane. In a few cases, opposite views were obtained from different pilots. The viewpoint appears to be related to the amount of experience the dissenting pilot has had with the airplane. A good example is the Catalina, about which one pilot said, "It can be landed under any circumstances without skipping." He had a great deal of experience with them. Another pilot who had a great deal of experience with Mariners said, "I get the 'willies whenever I have to land a Catalina." Actually, neither

pilot was entirely wrong. The first man was able to make stable landings instinctively by virtue of experience which the latter pilot did not have. A third pilot, who liked the Catalina, stated that, "he could land it without skipping any time he wished, but that it would skip very unpleasantly when landed improperly." This man had more experience with the different types of flying boats than either of the other two. It seemed proper, then, to rate the skipping characteristics of the Catalina as "fair".

Similarly, the other hulls are rated as "good" when, under most circumstances, they could make stable landings. The "poor" hulls are those which, in most cases, are unstable on landing. In nearly all cases, both stable and unstable landings are possible depending on pilot technique. The method of rating, therefore, is to some degree the inverse of the amount of pilot experience required to make stable landings.

The behavior on landing was chosen as the criterion of comparison because, on the basis of experience, it seems to be somewhat easier to induce skipping accidentally on landing than on take-off. Any flying boat that showed any evidence of inadvertent skipping on take-off was automatically rated as poor.

The following listing gives the details of the skipping characteristics of the various flying boats tested. They are listed according to gross weight, as will be seen in Table I.

SKIPPING CHARACTERISTICS

AMPHIBIANS P-III-B (Poor): The following is quoted from a hydrodynamic data report by C. E. Kahlka, Jr., in 1942: "It was usually possible to check oscillations during the high-speed portion of the run before they acquired appreciable amplitude, but at times this was decidedly tricky and involved skipping over the water surface much like a skipping stone."

GRUMMAN J4F-2 (Good): As far as could be determined, no trouble has been experienced with skipping. The airplane apparently has a tendency to nose over when landed at too low a trim angle, but this is more likely to be connected with the low dead-rise bow sections and convex curved water planes of the forebody, than with the skipping characteristics.

VOUGHT CS2U-1 (Good): This airplane has a considerable amount of lower-limit porpoising during take-off unless skillfully handled. No reports of skipping on landing have been found however.

SARO 37 (Good): See References 3 and 11. Fairly complete tests indicated some danger of skipping if the pilot allowed the airplane to get into abnormal attitudes. The worst condition appeared to be the full-stall landing; otherwise landings were stable. Rough water aggravates matters.

FAIREY SEAL (Poor): See Reference 3. This twin-float seaplane apparently has no stable range or else a very narrow one. Conditions are worse in rough water than in smooth.

GRUMMAN J2F-5 (Fair): According to pilot's opinions, full-stall and flat-power-on landings are stable, but there is a rather wide range of intermediate angles which are unstable.

CURTISS XSC-1 (Good): Preliminary reports indicate good landing characteristics.

GRUMMAN JRF-4 (Fair): See Reference 1. Full-stall landings are quite stable, and intermediate angles moderately unstable. Fast, flat, power-on landings are very unstable. The landing stability of this aircraft has been considerably improved by moving the step aft, thereby increasing the step height. Landings over quite a wide range of trims are now stable. The altered aircraft is the JRF-5.

SUPERMARINE SEA OTTER (Poor): See Reference 9. A little rough water would set up violent skipping during take-off. Structural damage to the engine mount was experienced after skipping during one rough landing.

HALL ALUMINUM PH-3 (Good): Full-stall and moderate angle landings quite stable according to one pilot. This may well be partially attributable to the very low wing loading.

CONSOLIDATED PBV-5 (Fair): Full-stall and flat power-on landings are stable, but there is a rather wide range of intermediate angles which are moderately unstable.

NAVAL AIRCRAFT FACTORY PBN-1 (Fair): Landings made at low trims are quite unstable, but some skipping encountered at higher trims. Full-stall is unstable. Ventilation, using 1.7 square feet of ventilation area, helped a little. There is disagreement as to whether this airplane is better or worse than the PBV, from which it was derived.

SHORT SINGAPORE IIc and III (Good): See Reference 3. Behavior quite similar to the Hall Aluminum PH-3, of which the Singapore is a contemporary. The stable range of trims for this hull is about 8° wide.

SARO LERWICK (Ia - Poor, Ib - Good): See Reference 13. According to Reference 13 the shallow transverse step in the Lerwick Ia was exceedingly unstable in all attitudes. After lowering the forebody in Lerwick Ib, and incorporating a V-step, a full-scale stable form was produced.

SHORT SUNDERLAND I (Good): See Reference 14. The airplane has a wide range of attitudes (from 4° to 9°), for stable landings.

CONSOLIDATED 31 (Poor): Consolidated flight tests indicate skipping during both take-off and landing.

CONSOLIDATED XP4Y-1 (Fair): Consolidated flight tests indicate a very marked improvement over the Consolidated Model 31 from which the XP4Y-1 was developed. However there was apparently still some skipping on landing.

MARTIN PBM-3 (Good): It is possible to land this aircraft over a wide range of trims without any difficulty from skipping.

SHORT SUNDERLAND III (Good): Even with a 1:4 step fairing, deliberate attempts to get skipping were quite unsuccessful. In Reference 10, it is stated that by making violent full-stall landings an occasional skip would be encountered, but not enough to define a stability limit. Service usage has indicated that the full-stall landing is unstable in rough water. However, a fairly large number of the aircraft have been in service for about four years, and by landing at intermediate angles have had no trouble from skipping.

MARTIN PBM-5 (Fair): The aircraft has been considerably overloaded. Mild skipping can be found between trim angles of 10° and 14° . The intensity of this skipping increases with increasing gross weight.

BOEING XPBB-1 (Good): See Reference 1. It is possible to get upper-limit porpoising with this flying boat, but, as far as is known, there is no skipping on landing at any attitude or load. It is looked upon with great enthusiasm as far as skipping is concerned, by all pilots who have flown it. It is believed to be the most stable aircraft in service today. (1943).

CONSOLIDATED PB2Y-3 (Poor): See Reference 1. Violent skipping was found over a wide range of trims. After production had started, the skipping was alleviated by the introduction of ventilation ducts. Some pilots have stated, under controlled test conditions that they could not tell from the instability on landing whether the ducts were open or closed. Other pilots have reported considerable improvement due to the step ventilation.

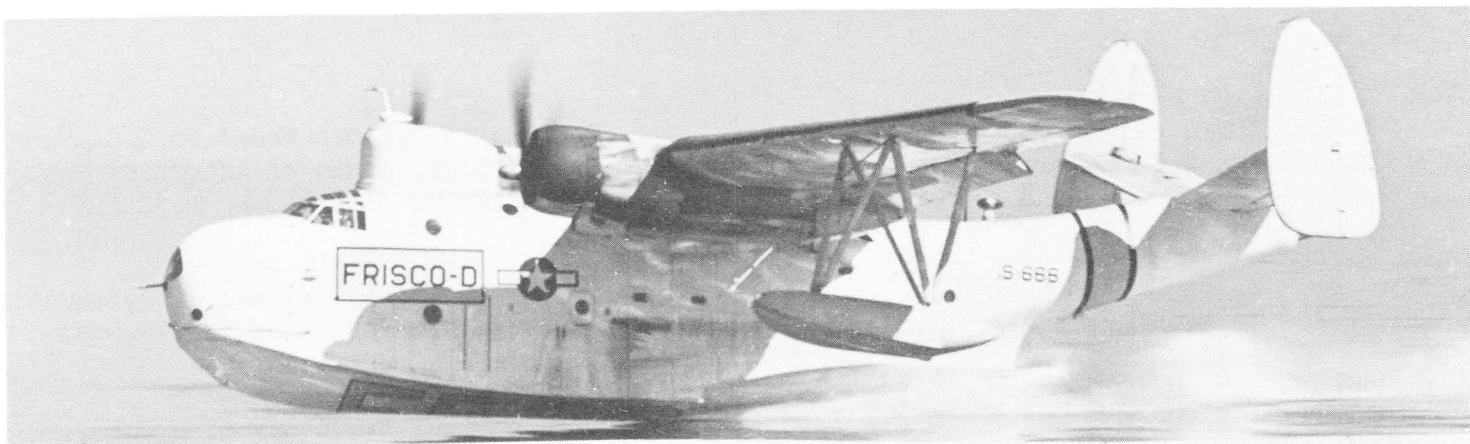
SHORT G (Fair): See Reference 3 and 15. At low attitudes no instability occurs on landing. As the trim increases, skipping is progressively introduced until, at high attitudes it is quite bad. According to Reference 15, no trouble will be encountered if the aircraft is landed fast with a little power.

BOEING 314 (Poor), A-314 (Fair): See Reference 1. The 314 model flying boat was violently unstable just after landing at high trims. By moving the step aft in the A-314, thereby increasing the depth because of the angle between the forebody and afterbody keels, a great improvement in landing at high trims resulted.

MARTIN XPB2M-1 (Fair): At trim angles below about 6° this airplane is stable. Above this trim, violent skipping can be obtained. Because of the large size of the airplane, the motion is quite slow and is very easy to control and may not be objectionable to the pilot. However, it should be noted that a large number of the pilots have been men with years of flying boat experience. Model experience with this airplane (see Reference 3) indicates that performance would be better with a deeper step.

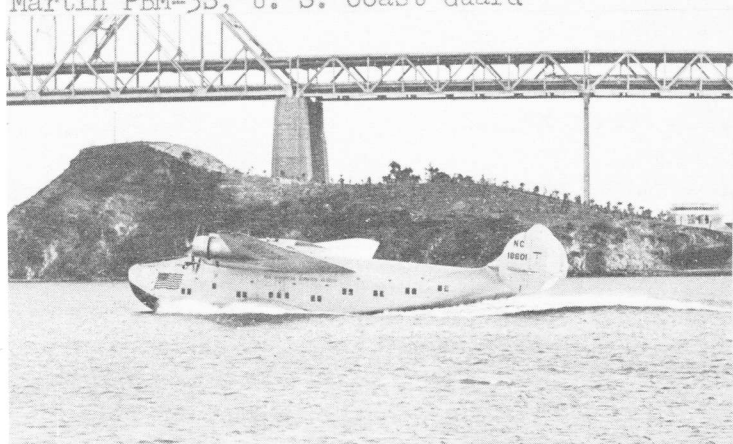
REFERENCES

1. Parkinson, John B.: Notes on Skipping of Seaplanes. NACA RB No. 3127, 1943.
2. Locke, Fred W. S. Jr.: A Correlation of the Dimensions, Proportions, and Loadings of Existing Seaplane Floats and Flying-Boat Hulls. NACA AAR, March 1943.
3. Smith, A. G. : and White, H. G.: A Review of Porpoising Instability of Seaplanes. Report No. H/Res/173, MAEE, Feb 29, 1944.
4. Truscott, Starr, and Olsen, Roland E.: The Longitudinal Stability of Flying Boats as Determined by Tests of Models in the NACA Tank. II - Effect of Variations in form of Hull on Longitudinal Stability. NACA AAR, November 1942.
5. Locke, F. W. S., Jr.: and Hugli, W. C. Jr.: A Method for Studying the Longitudinal Dynamic Stability of Flying-Boat-Hull Models at High Planing Speeds and During Landing. NACA AAR No. 4H31, 1944.



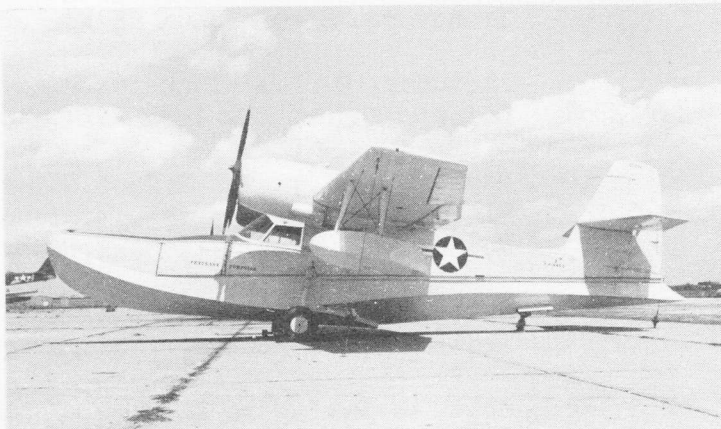
Martin PBM-3S, U. S. Coast Guard

Gordon S. Williams



Boeing A-314

W.T.Larkins



Grumman J4F-2, NACA Test Hull Howard Levy



Hall-Aluminum PH-3, #V-169

G.S.Williams



Grumman JRF-5, #37803

H.G.Martin



Columbia J2F-6, #36967

W.T.Larkins



Boeing XPBB-1

G.S.Williams

6. Land, Norman S., and Linn, Lindsay, J.: Tests of a Dynamic Model in NACA Tank No. 1 to Determine the Effect of Length of Afterbody, Angle of Afterbody Keel, Gross Load, and a Pointed Step on Landing and Planing Stability. NACA AAR, March 1943.
7. Davidson, Kenneth S. M., and Locke, F. W. S., Jr.: Some Analyses of Systematic Experiments on the Resistance and Porpoising Characteristics of Flying-Boat Hulls. NACA AAR No. 3106, 1943.
8. Parkinson, John B., and Land, Norman S.: The Landing Stability of a Powered Dynamic Model of a Flying Boat with a 30° V-step and with two Depths of Transverse Step. NACA RB No. 4E14, 1944.
9. Fletcher, G. L.: Tank Tests on the Water Stability of the Supermarine Sea Otter. Report No. Aero 1927, R.A.E., March 1944.
10. Naylor, P. E.: The Effect of Weight Variation on the Water Stability, Trim and Elevator Effectiveness of a Sunderland III Aircraft during Take-Off and Landing. Report No. H/Res/171, MAEE, Feb. 19, 1944.
11. White, H. G., and Smith, A. G.: Stability Tests on a Large Scale Model of the Shetland Hull Bottom. Report No. H/Res/159, MAEE, Dec. 1942.
12. Gott, J. P.: Note on the Technique of Tank Testing Dynamic Models of Flying Boats as Affected by Recent Full Scale Experience. Report B. A. 1572, R.A.E., December 1939.
13. MacPhail, D. C., Tye, W. D., and Llwyn-Davies, D.I.T.P.: Model Investigation on the Effect of Slipstream on the Longitudinal Stability of Flying Boats on the Water. Report No. Aero 1792, R.A.E., January 1943.
14. White, H. G., Smith, A. G., and Shaw, R. A.: Attitude and Stability Measurements on a Half Scale Sunderland Hull Fitted to the Scion Seaplane. Report No. H/Res/158, MAEE, December 1942.
15. Shaw, R. A., and Evans, G. J.: Porpoising Tests on the "G" Class Flying Boat. Report No. H/Res/141, MAEE, March 1941.

TABLE I - SKIPPING CHARACTERISTICS OF VARIOUS FLYING BOATS

Manufacturer	Model	Gross Weight (lb)	Wing Area (ft ²)	Landing Merit	Source
Amphibians	P-IIIIB	3,200	224	Poor	Owner's Flight Tests
Grumman	J4F-2	4,500	245	Good	Opinions
Vought	OS2U-1	4,841	261	Good	Opinions
Saro	Model 37	5,700	340	Good	RAF Flight Tests
Fairey	Seal	6,400	445	Poor	RAF Flight Tests
Grumman	J2F-5	6,651	409	Fair	Opinions
Curtiss	XSC-1	7,641	281	Good	Opinions
Grumman	JRF-4	8,000	375	Fair	NACA RB No. 3127
Grumman	JRF-5	8,000	375	Good	Opinions
Supermarine	Sea Otter	10,200	610	Poor	Royal Navy Flight Tests
Hall Aluminum	PH-3	16,150	1170	Good	Opinion
Consolidated	PBY-5	26,000	1400	Fair	Opinions and RAF Flight Tests
Short	Singapore II	26,600	1760	Good	RAF Flight Tests
Naval A/c Fac.	PBN-1	28,000	1400	Fair	NAF Flight Tests
Short	Singapore III	31,150	1760	Good	RAF Flight Tests
Saro	Lerwick Ia	33,000	845	Poor	RAF Flight Tests
Saro	Lerwick Ib	33,000	845	Good	RAF Flight Tests
Short	Sunderland I	43,000	1487	Good	RAF Flight Tests
Consolidated	Model 31	46,000	1048	Poor	Consolidated Flight Tests
Consolidated	XP4Y-1	46,000	1048	Fair	Consolidated Flight Tests
Martin	PBM-3	46,500	1406	Good	Martin, NACA Flight Tests
Short	Sunderland III	50,000	1487	Good	RAF Flight Tests
Martin	PBM-5	56,000	1406	Fair	Opinions
Boeing	XPBB-1	62,000	1826	Good	Navy Flight Tests, NACA RB 3127
Consolidated	PB2Y-3	68,500	1780	Poor	Consolidated, NAF & RAF Flt.
Short	Model G	73,500	2390	Fair	RAF Flight Tests
Boeing	314	82,500	2867	Poor	NACA RB. No. 3127
Boeing	A-314	82,500	2867	Fair	NACA RB. No. 3127
Martin	XPB2M-1R	140,000	3683	Fair	Navy Flight Tests & Opinions