NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE

No. 1387

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A PRELIMINARY CORRELATION OF THE BEHAVIOR OF WATER RUDDERS ON SEAPLANES AND FLYING BOATS

By F. W. S. Locke, Jr.

Bureau of Aeronautics, Navy Department

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SUMMARY

This report presents a rough correlation of the dimensions of water rudders of various actual seaplanes and flying boats as related to their behavior. The correlation should be useful for determining the size of a water rudder which will give adequate control for maneuvering at low speeds.

INTRODUCTION

Practically all single-engine seaplanes and flying boats depend on a water rudder for maneuvering at very low speeds on the water. It has usually been considered that adequate directional control could be obtained by using asymmetrical power and by "blipping" the engines of multiengine flying boats. In recent years the inboard propellers of four-engine flying boats have been capable of reversing pitch. (See reference 1.) This has provided the pilot with positive control over the speed when maneuvering in close quarters and is generally very well liked. However, it is still necessary to apply asymmetrical power to make a turn.

Despite the ability to use asymmetrical power, a surprisingly large number of accidents have resulted in the past few years from running into breakwaters, ramps, buoys, moored aircraft, and so forth, when taxying at low speeds. Reference 2 indicates that about 10 percent of all on-the-water accidents to flying boats without ability to reverse pitch of their propellers may be attributed to lack of a water rudder. British experience indicates an even higher percentage. It is noteworthy that only a very few records of maneuvering accidents could be found which happened to flying boats which had fast positive control over their speed while taxying. Apparently, what happens frequently in accidents to flying boats without reversible propellers is that at a crucial moment additional power is applied to make the aircraft turn. The turn is started but the aircraft speeds up despite the sea anchors and smashes into whatever obstacle the pilot was trying to avoid.

Sea anchors are quite generally used for maneuvering when reversible pitch propellers are not available. The chief disadvantage of sea anchors appears to be that the pilot has to relay his commands with a subsequent lag before action can be taken. Because it even takes a certain amount of time to reverse pitch, maneuvering with the aid of the propellers may be slightly awkward with twin-engine flying boats, though maneuvering accidents should be a thing of the past. Since the air rudder is very ineffective for low-speed operation, when it is not possible to reverse pitch and use asymmetrical power, the simplest and most positive means of providing directional control appears to be a water rudder.

The purpose of this report is to record readily available information on water rudders and to present a rough correlation of the behavior of water rudders as affected by their size and location.

The courtesy of Lt. S. J. Miller, RCNR, in supplying the British data analyzed in this report is greatly appreciated.

NOTATION AND DATA

The following notation is used throughout this report:

Δ_o initial design gross weight, pounds

S_r projected water-rudder area (area of both water rudders in case of twin-float seaplanes having two water rudders), feet^2

l water-rudder arm, measured from center of gravity of aircraft to water-rudder hinge line along a line parallel to tangent to forebody keel at main step, feet

The dimensions were taken from manufacturers' drawings. It is believed that the areas are accurate within 5 percent and the lengths about 3 percent. The data on performance have generally been taken from flight-test reports of the U. S. Navy and the British Marine Aircraft Experimental Establishment. These reports usually merely state whether the water rudder was or was not satisfactory. In the case of the U. S. Navy reports, this means that the water rudder was of sufficient size to provide adequate control of the airplane while taxying on the water. On the other hand, the British have, in many cases, actually measured the diameter of the turning circles and the time required to make a 360° turn.

In one of the cases, accident reports indicated that a more powerful water rudder would have aided in avoiding trouble. In this case, the particular water rudder was labeled "Marginal" even though the flight-test report said satisfactory.

The available information on water rudders has been tabulated in table I together with a single word describing the behavior of the rudder. On figure 1 will be found sketches of some of the different kinds of water rudders that have been used in the past.

DISCUSSION

The information given in table I has been plotted on figure 2. The form adopted of plotting a rudder "volume" versus the gross weight appears to serve the purpose of a crude correlation quite satisfactorily. Provided that the rudder area is at least

$$S_r = 0.005 \frac{\Delta_0}{l}$$

it appears that satisfactory directional control will be assured. While there are refined methods for designing the rudders of surface vessels, it is believed that, for the present at least, the above equation should serve as a useful guide to the designers of flying boats and seaplanes.

The location and shape of the water rudder should be chosen so that it acts on as much undisturbed water as possible. The case of the rudder on the SB2C-2 should be particularly noted. According to the chart (fig. 2), this rudder might have been expected to be satisfactory. It seems possible that the reason the rudder was only marginal was at least partially due to the rather low aspect ratio compared to other rudders. The effective aspect ratio was undoubtedly reduced still further by the fact that at low taxying speeds the entire rudder is usually not fully submerged in the conventional float arrangement. Most of the rudders considered in this report have at least part of their area behind the afterbody sternpost. Ordinarily a good deal of dead water is being dragged along by the hull in this region. The effectiveness of a water rudder forced to operate in this dead water is considerably reduced, both because of the reduced relative speed and because the entire rudder is not submerged. The location behind the afterbody sternpost has usually been chosen for the water rudder to insure adequate ground clearance and to prevent damage from floating debris. Hydrodynamically, a much better location is on the afterbody bottom near the sternpost. Some unpublished tests at Stevens Institute of Technology on water rudders located on the afterbody bottom have indicated that the effective aspect ratio is about twice the geometric aspect ratio as far as the rudder "lift" forces are concerned. Thus, if the rudder is located on the afterbody bottom, the area of the rudder can probably be somewhat less than indicated by the above equation, but it is then necessary that the rudder be retractable. This is not only to prevent damage and provide ground clearance, but also to prevent the rudder from overcontrolling the aircraft when traveling at high speeds on the water. A good scheme is to make the rudder drag force automatically retract the rudder at about one-quarter to one-third of the getaway speed.

A water rudder should not be considered as a means for curing or overcoming the type of directional instability described by Pierson in reference 3. Quite large fixed fins usually have little or no effect on this type of instability. Some of the unpublished tests on water rudders made at Stevens Institute of Technology in the critical speed range have indicated that a very large rudder deflection is required to displace the curve of yawing moments by even 2° or 3° of yaw. Basically, the purpose of a water rudder is to provide maneuvering control at low taxying speeds and, presumably, not much more should be expected of it.

CONCLUDING REMARKS

A rough preliminary correlation has been made which will provide the designer with means for estimating the size of a water rudder, for either small seaplanes or large flying boats, which should provide adequate directional control at low taxying speeds. Water rudders appear to constitute a field in which a little systematic research would be quite fruitful. Until that has been done, the present information should be useful.

Bureau of Aeronautics, Navy Department
Washington, D. C., November 1946

REFERENCES

1. Chillson, C. W.: Reversible Pitch Propellers as Applied to Water Handling of Multi-Engine Flying Boats. Journal Aero. Sci., vol. 7, no. 7, May 1940.

2. Locke, F. W. S., Jr.: A Survey of the Factors Contributing to the Landing and Take-off Accidents to U. S. Navy Flying Boats in the Last 22 Months. NavAer A.D.R. Report M-32, Dec. 1944 (available from Publications Branch, Department of Commerce as PB No. 8172).

3. Pierson, J. D.: Directional Stability of Flying Boat Hulls During Taxiing. Journal Aero. Sci., vol. 11, no. 3, July 1944.

TABLE I

WATER-RUDDER DATA

Manufacturer	Model	Type	Gross weight (lb)	Water-rudder area (ft^2)	Water-rudder arm (ft)	Remarks	Source
Taylorcraft	Auster	Twin	1,800	0.75	8.5	Satisfactory	MAEE
Republic	Seabee	Hull	3,000	1.85	11.5	Satisfactory	USN
Vought	OS2U-1	Single	4,800	1.6	12.5	Satisfactory	USN
Edo	XOSE-1	Single	5,900	2.3	13.0	Satisfactory	USN
Fairey	III F	Twin	6,300	2.50	12.0	Unsatisfactory	MAEE
Fairey	III F	Twin	6,300	4.10	12.0	Satisfactory	MAEE
Vickers	Vivid	Twin	6,300	1.4	12.0	Satisfactory	MAEE
Parnall	Pike	Twin	6,350	1.40	12.7	Unsatisfactory	MAEE
Fairey	S.9/30	Single	6,500	1.00	15.5	Satisfactory	MAEE
Grumman	J2F-5	Single	6,650	1.1	13.9	Marginal	USN
Supermarine	Walrus	Hull	7,260	1.68	22.0	Satisfactory	MAEE
Supermarine	Spitfire	Twin	7,580	3.92	12.2	Satisfactory	MAEE
Curtiss	SC-1	Single	7,600	2.6	15.5	Satisfactory	USN
Blackburn	Ripon	Twin	8,000	2.74	12.0	Satisfactory	MAEE
Supermarine	Sea otter	Hull	10,200	1.2	22.0	Unsatisfactory	MAEE
Supermarine	Sea otter	Hull	10,200	1.7	22.0	Satisfactory	MAEE
Curtiss	SB2C-2	Twin	18,700	5.0	17.5	Marginal	USN
Boeing	314	Hull	80,000	3.1	33.9	Unsatisfactory	PAA

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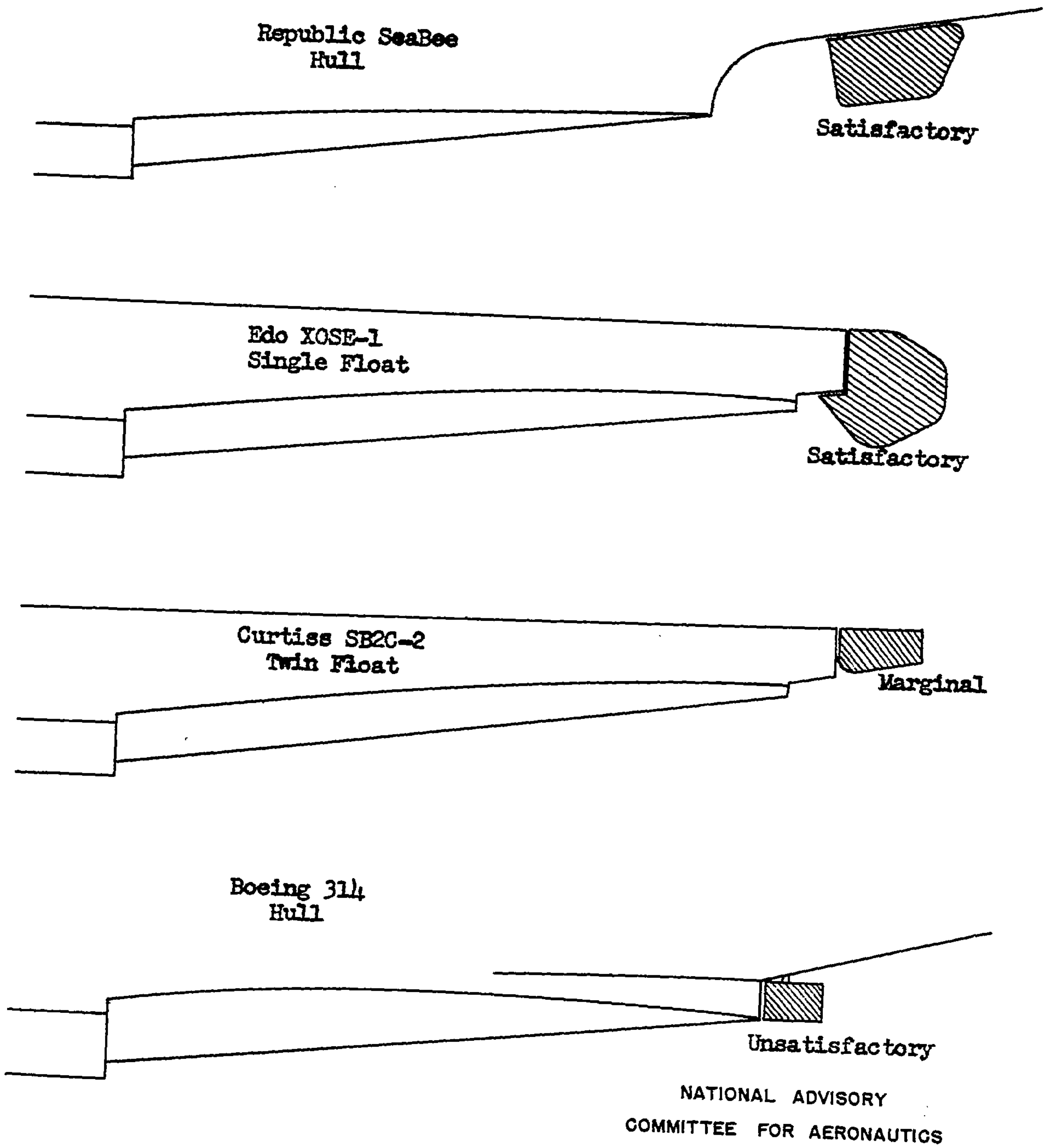
Republic SeaBee
Hull
Satisfactory
Edo XOSE-1
Single Float
Satisfactory
Curtiss SB2C-2
Twin Float
Marginal
Boeing 314
Hull
Unsatisfactory
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Figure 1

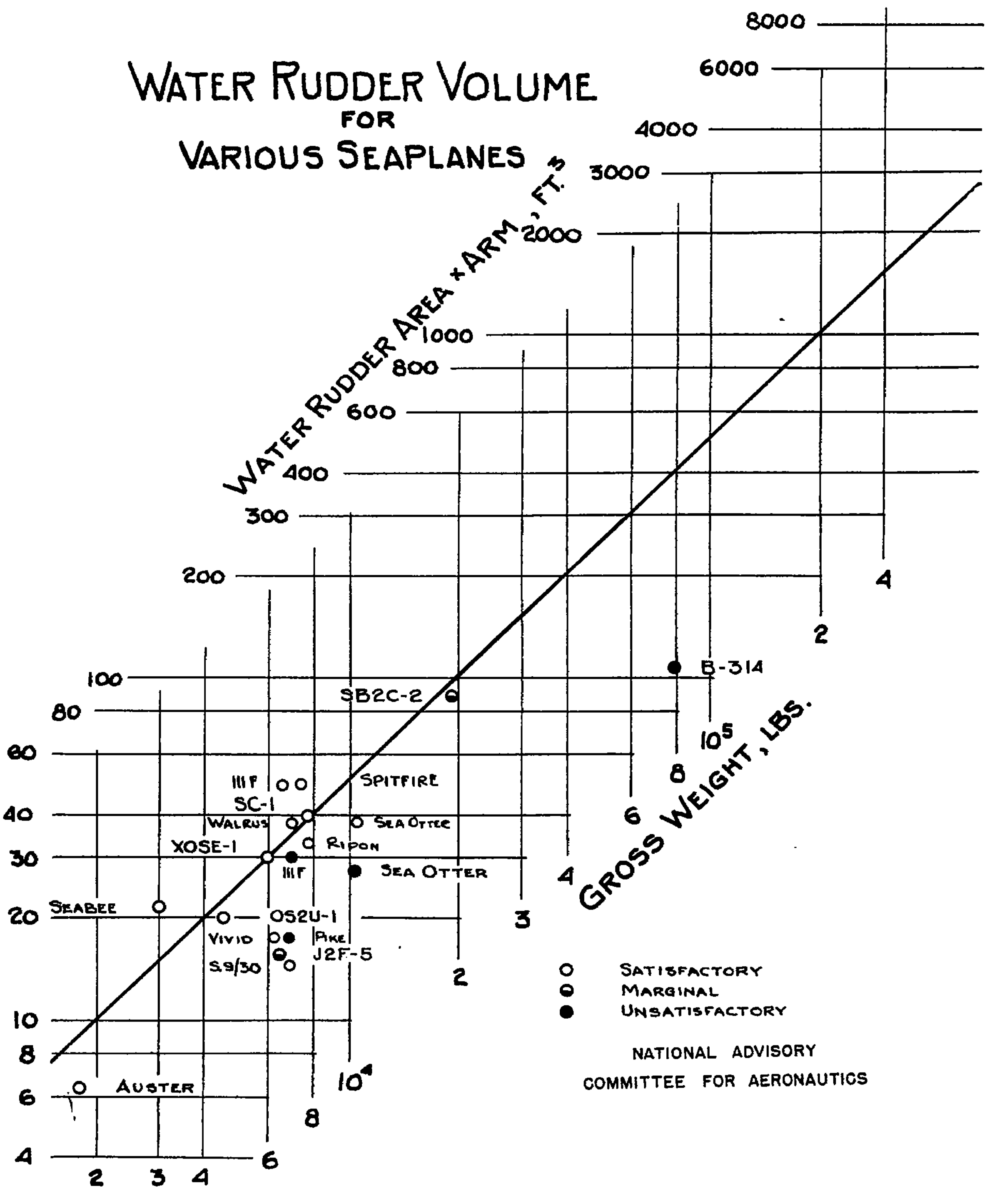
WATER RUDDER VOLUME
FOR
VARIOUS SEAPLANES
WATER RUDDER AREA × ARM, FT.³
GROSS WEIGHT, LBS.
SEABEE
AUSTER
XOSE-1
WALRUS
SC-1
IIIF
SPITFIRE
SEA OTTER
RIPON
OS2U-1
VIVID
PIKE
J2F-5
S.9/30
SB2C-2
B-314
SATISFACTORY
MARGINAL
UNSATISFACTORY
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Figure 2