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NAVY DEPARTMENT
DAVID TAYLOR MODEL BASIN

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EVALUATION OF THE STATIC YAWING STABILITY OF THE AN/SQS-22 SONAR VEHICLE WITH THREE DIFFERENT TAIL CONFIGURATIONS

by

Samuel M. Y. Lum and Reece Folb

[redacted]

HYDROMECHANICS LABORATORY
RESEARCH AND DEVELOPMENT REPORT

JANUARY 1961 REPORT 1488

DEPARTMENT OF THE NAVY
DAVID TAYLOR MODEL BASIN
WASHINGTON 7, D.C.

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> On Figure 3, Page 6, Configurations 3, 2, 1, change the "Angle of Drift" scale to read from left to right, -8, -4, 0, 4, 8.

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NOTATION

A	Projected area of the vertical tail
a	Derivative of the lift of the tail with respect to the angle of drift (lift curve slope)
N	Yawing moment
N'	Yawing moment coefficient, N/QSw
N_{β}'	Derivative of yawing moment with respect to the angle of drift in degrees, $\partial N'/\partial\beta$
ℓ	Distance between body pivot point and quarter chord of tail
Q	Dynamic pressure, $\frac{1}{2}\rho U^2$
S	Projected area of the bare body (height times length)
U	Velocity
w	Width of body
β	Angle of drift
η	Tail efficiency factor, Q_v/Q
ρ	Mass Density of fluid medium

Subscripts

b	Bare body
v	Vertical tail

ABSTRACT

The static yawing stability of the AN/SQS-22 sonar body with three different tail configurations, designed by the U. S. Navy Underwater Sound Laboratory, was determined at the David Taylor Model Basin. Basin tests indicate that one of the three proposed configurations is statically stable, one marginally stable, and one unstable. Theoretical approximations of the yawing stability tend to confirm the experimental data.

INTRODUCTION

The David Taylor Model Basin was requested to conduct an experimental program to determine the static yawing stability of the AN/SQS-2 sonar body.[1,2,3] The body was designed by the U. S. Navy Underwater Sound Laboratory to operate at speeds up to 25 knots. The body will be attached by faired strut to the forefoot of a merchant ship, in contrast to variable-depth sonars which are cable towed. To avoid excessive side loads on the body and thus minimize the bending moments on the strut during maneuvers of the ship, the body will be free to pivot in the yaw plane about a bearing installed at the bottom of the strut.

For successful operation of such a system, it is necessary for the body to maintain alignment with respect to the flow resulting from the maneuvers of the ship. To accomplish this, it is necessary that the bod be statically stable about the pivot point. A body is said to be statically stable in some equilibrium orientation about a given axis if it tends to return to this orientation after a slight disturbance. Thus, for a body to be statically stable in yawing motion, the slope of its yawing moment versus drift angle curve must be negative; that is, the yawing moment must always oppose an increasing angle, either positive or negative. Since most streamlined bodies are known to be inherently unstable with respect to any point along the body, three different tail designs were proposed as a means of yaw stabilization.

This report presents the yawing moment characteristics of the body equipped separately with each of the three tail configurations, as determined from model experiments. The experimental results are compared with values estimated on the basis of available theory. Drag data derive from the model tests are also presented.

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[1] References are listed on page 12

GEOMETRICAL CHARACTERISTICS

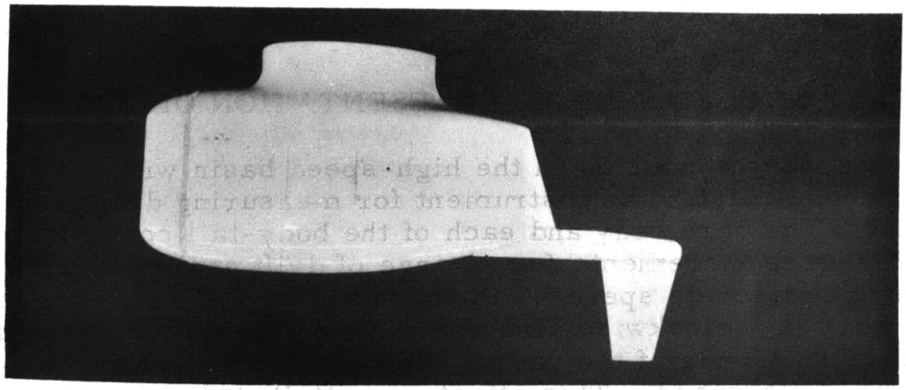
A 1/4-scale model of the AN/SQS-22 sonar body, including three ifferent detachable tail assemblies, was furnished to the Model Basin y the Underwater Sound Laboratory. The bare body is a wall-sided treamlined housing with a length-to-beam ratio of approximately 3. ach tail assembly consists of a vertical stabilizer fin mounted on a oom. The boom, in turn, is attached to the bottom side of the trailing dge of the body. The three complete assemblies, composed of the bare ody and one of the proposed tail designs, are designated herein as Conigurations 1, 2, and 3 and are shown in Figure 1. It may be noted that he tail boom of Configuration 3 has circular cross-sections whereas the ther two booms are flat plates. Consequently, it has relatively more ateral rigidity than the tail boom of Configuration 2 which is of about the ame length. The principal dimensions of the various configurations are isted in Table 1.

TABLE 1

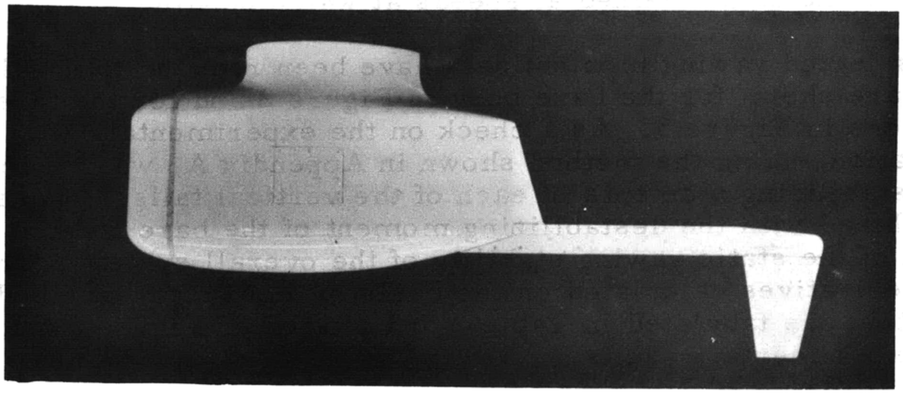
Principal Dimensions of 1/4-Scale AN/SQS-22 Body

ength of bare body, ft	2.5
idth of bare body, ft	0.854
eight of bare body, ft	1.464
ocation of pivot point aft of nose, ft	1.208
ength overall with Tail 1, ft	3.50
ength overall with Tail 2, ft	4.50
ength overall with Tail 3, ft	4.58
rojected area of Tail 1, sq ft	0.235
rojected area of Tail 2, sq ft	0.235
rojected area of Tail 3, sq ft	0.463
rojected area of the bare body (reference area), sq ft	3.66
pan of Tail 1, ft	0.8
pan of Tail 2, ft	0.8
pan of Tail 3, ft	1.3
oment arm of Tail 1, ft	2.0
oment arm of Tail 2, ft	3.0
oment arm of Tail 3, ft	3.0

ote: All three vertical tails have NACA 0015 sections.



Configuration No. 1



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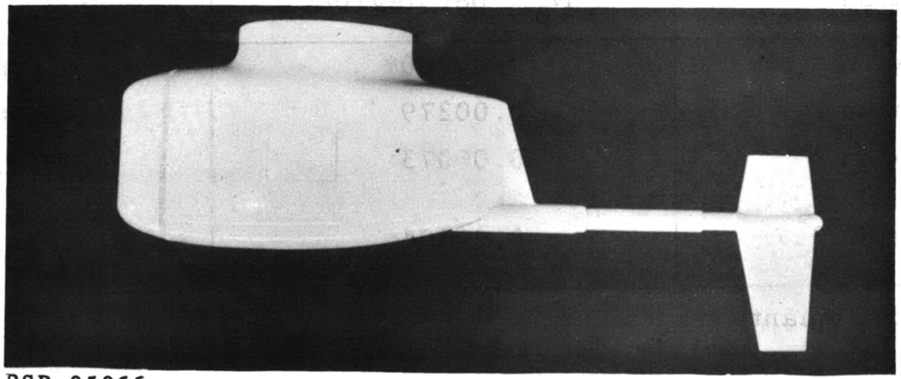

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Configuration No. 3

Figure 1 - One Quarter-Scale Model of the AN/SQS-22 Sonar Body with Three Different Tails

TEST PROCEDURES AND PRESENTATION OF DATA

The tests were conducted in the high-speed basin with the three-component dynamometer, an instrument for measuring drag, cross-force, and moment. The bare body and each of the body-tail configurations were tested at 2-degree increments for a range of drift angles of ± 8 degrees at each of several discrete speeds. Positive angles and moments tended to rotate the body in a clockwise direction. It was noted for Configurations 1, 2, and 3 that the trends of the yawing moment coefficient versus drift angle curves varied with speed. This effect was attributed to bending of the tail boom due to the forces exerted on the fin which became progressively larger, for a given angle, at higher speeds. Since no attempt was made, apparently, to scale the stiffness of the model, and since it was assumed that adequate rigidity can be obtained on the full-scale tail boom, preference was given to the data obtained at speeds at which bending was less significant.

The selected yawing moment data have been reduced to nondimensional form and are shown for the bare body in Figure 2 and for the three body-tail combinations in Figure 3. As a check on the experimental data, a theoretical approximation, using the method shown in Appendix A, was made to determine the stabilizing moments of each of the vertical tails. These moments were combined with the destabilizing moment of the bare body to provide an indication of the static yawing stability of the overall system. The yawing moment derivatives calculated on the basis of theory for each body-tail configuration are tabulated in Table 2 and plotted on Figure 3 for comparison with the experimental results.

TABLE 2

Calculated Yawing Stability of the Three Tail Configurations

Configuration	N_β', per degree	Static Stability
Bare Body	0.00980*	Unstable
Configuration 1	0.00279	Unstable
Configuration 2	-0.00073	Marginally Stable
Configuration 3	-0.01494	Stable

* Measured quantity

Views of Configuration 3, the only configuration exhibiting adequate system stability, are shown in Figure 4. The drag coefficients of the bare body and Configuration 3, based on the projected area of the bare body, were determined from recorded model drag data taken at zero drift angle ($\beta = 0$).

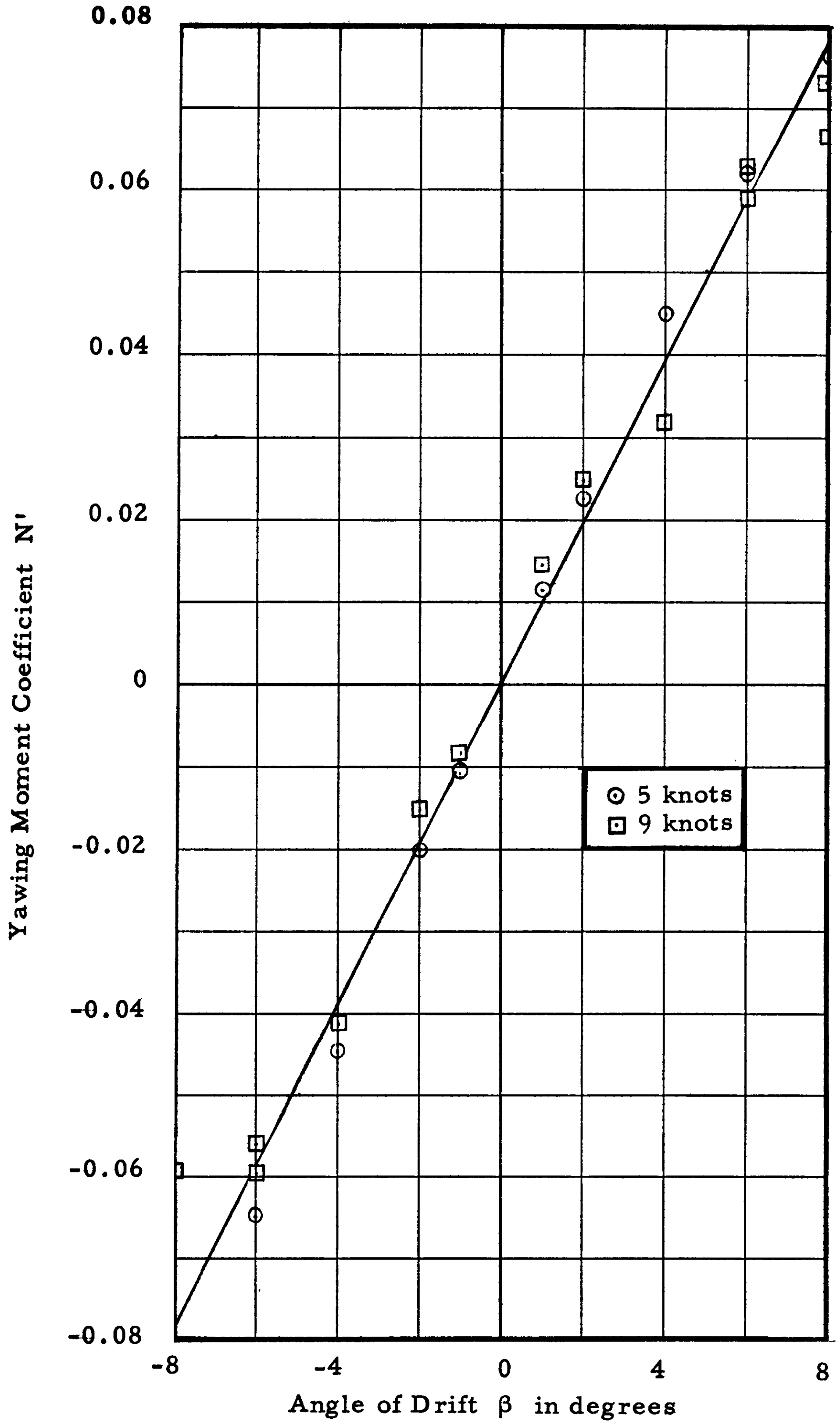

Figure 2 - Yawing Moment Coefficient N' versus Angle of Drift β for the Bare Body

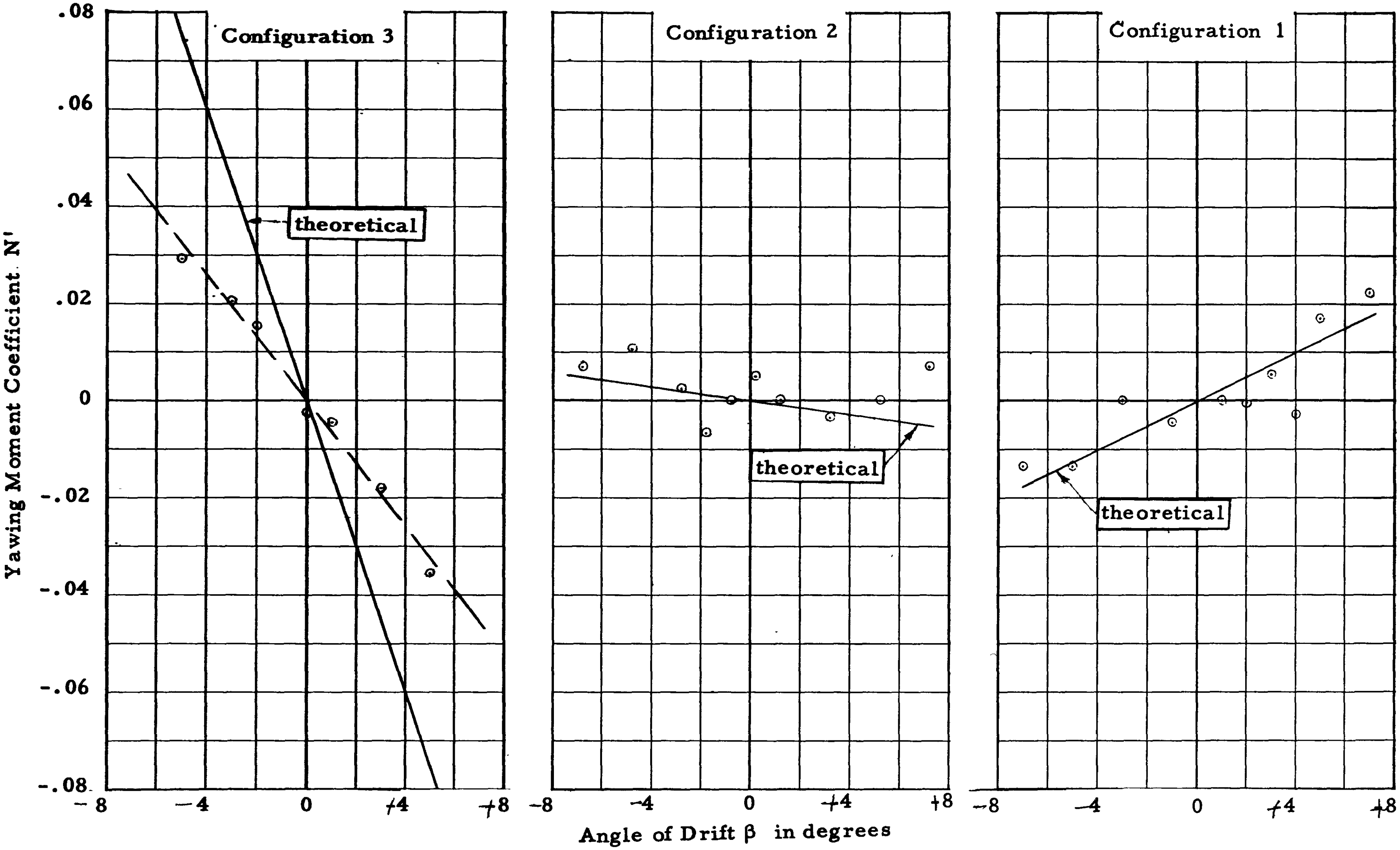

Figure 3 - Yawing Moment Coefficient N' versus Angle of Drift β for Each Body-Tail Configuration

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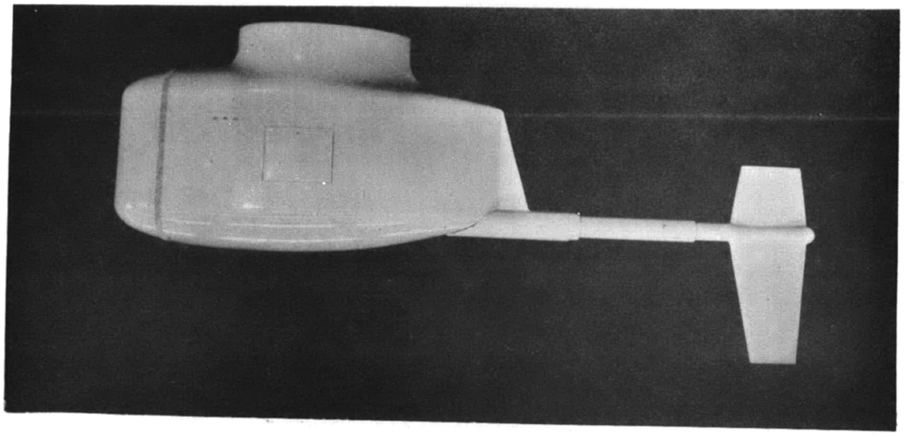
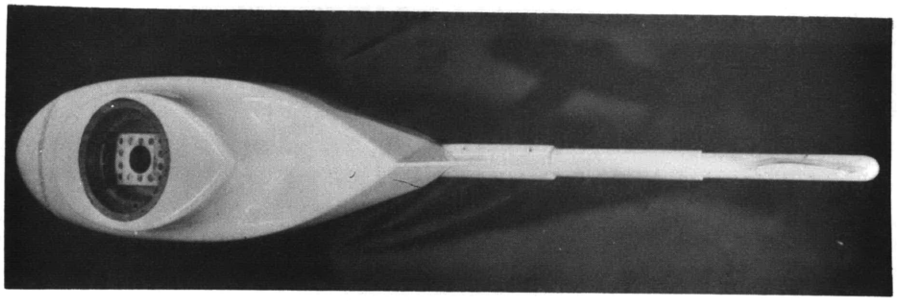
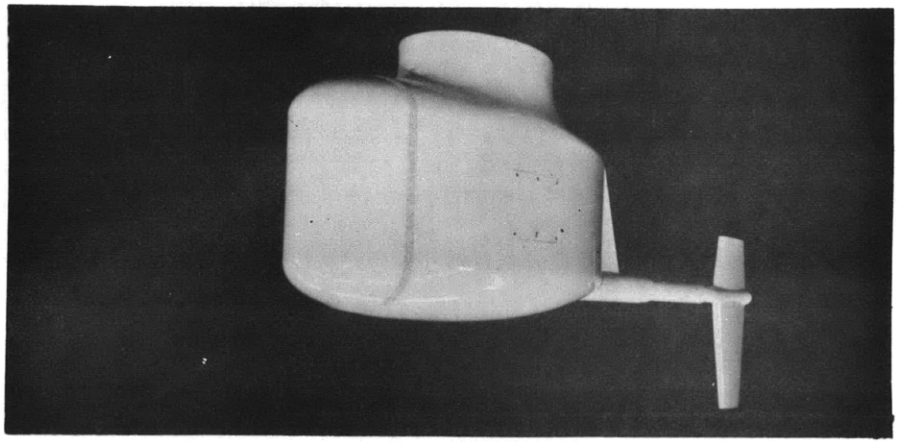


Profile View



Overhead View



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Perspective View

Figure 4 - Stable Configuration of the AN/SQS-22 Sonar Body

The full-scale drag was computed for standard sea conditions of 3.5 percent salinity and 59 degrees Fahrenheit water temperature and is presented in Figure 5.

DISCUSSION OF RESULTS

The static yawing stability of the SQS-22 sonar system may be evaluated from a curve of the yawing moment coefficient N' versus drift angle β. If the system is to be statically stable, it is necessary that he tail supply a sufficiently large stabilizing moment to compensate for he destabilizing moment of the bare body.

The experimental test points generally indicate that Configuration 1 is statically unstable, Configuration 2 is marginal, and Configuration 3 is statically stable. The theoretical approximations tend to agree with the experimental data. Configurations 1 and 2, exhibiting near neutral stability, have considerable scatter of the test points. This scatter might be expected since the forces caused by trailing vortices behind the bluff body are probably of the same order of magnitude as the resultant stabilizing or destabilizing forces. In contrast, Configuration 3 and the bare body have stabilizing and destabilizing forces of greater magnitude which tend o minimize the effects of the vortex induced perturbations.

CONCLUSIONS AND RECOMMENDATIONS

The results of the static yawing stability investigation of the AN/SQS-22 sonar system indicate that Configuration 3 is the only one of the proposed ail designs that provides for a statically stable system. It is felt that Configuration 3 would be satisfactory in an operational system. However, t is recommended that greater rigidity be provided on the full-scale tail boom to minimize any bending occurring if the body is subjected to large drift angles. It is also recommended that trim tabs be incorporated in the ail design to compensate for any asymmetries in construction.

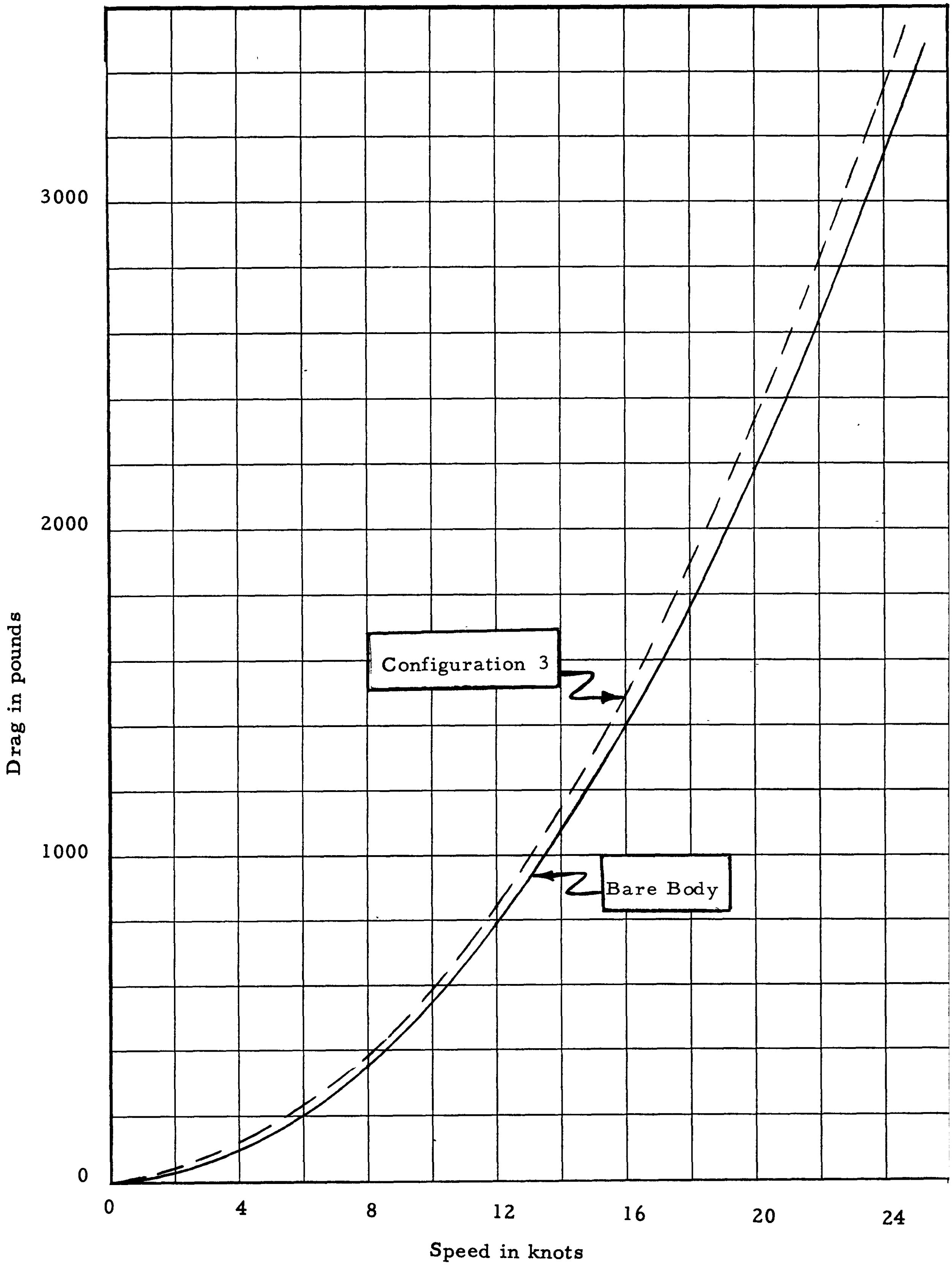

Figure 5 - Comparison of Full-Scale Drag of the Bare Body and Configuration 3

APPENDIX A

ESTIMATE OF STATIC STABILITY CHARACTERISTICS OF THE AN/SQS-22 SONAR CONFIGURATIONS

The static stability of a submerged body can be considered to be governed by the contribution of the bare body and the contribution of the tail. In the case of the AN/SQS-22 sonar body, the bare-body contribution was determined from the slope of the experimentally determined curve of yawing moment coefficient N' versus drift angle β shown in Figure 3. The contribution of each of the vertical tails was estimated from the equation,[4]

$$N_{\beta}' = -a\,(A/S)(\ell/w)\,\eta$$

where

N_{β}'	is the derivative of the yawing moment due to the tail with respect to drift angle,
a	is the derivative of the lift of the tail with respect to angle of drift (lift curve slope),
A	is the projected area of the tail,
S	is the projected area of the bare body (height times length),
ℓ	is the distance between body pivot point and quarter chord of tail,
w	is the width of body, and
η	is the tail efficiency factor equal to the ratio of dynamic pressure at tail to dynamic pressure free stream, Q_v/Q.

The foregoing procedure can be illustrated by the following numerical example involving Configuration 3.

First, reading the slope from Figure 2, the bare-body contribution is found to be

$$0.00980/\text{degree}.$$

Then, utilizing the geometrical information given in Table 1, taking a tail lift-curve slope from Reference 4, and assuming a tail efficiency factor of 0.9, the tail contribution obtained from the foregoing equation is

$$N_{\beta v}' = -(0.062)(0.463/3.66)(3.0/0.854)(0.9)$$
$$= -0.02474/\text{degree}.$$

Thus, the yawing moment derivative for the body-tail combination is

$$N_{\beta}' = N_{\beta b}' + N_{\beta v}'$$
$$= 0.00980 - 0.02474$$
$$= -0.01494/\text{degree},$$

where the minus sign indicates that Configuration 3 is statically stable and the magnitude is an indication of the degree of static stability. The assumed value of 0.9 for the tail efficiency factor may be slightly high for such a blunt body and, consequently, the moment derivative N_{β}' may be slightly lower.

REFERENCES

1. U. S. Navy Underwater Sound Laboratory letter Ser 1230-114-58 of 3 September 1958 to David Taylor Model Basin.

2. Bureau of Ships letter S67/14(689A) over Ser 689A-147 of 23 October 1958 to David Taylor Model Basin.

3. David Taylor Model Basin letter L1 over S67/13-7 over S67/13-11 over '548:SMYL:jw) of 14 November 1958 to U. S. Navy Underwater Sound Laboratory.

4. Perkins, C. D. and Hage, R.E., "Airplane Performance Stability and Control," Wiley and Sons, Inc., New York, N. Y. (1949).

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