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THE EFFECT OF INTERACTION AND TRANSFER LINE FORCES ON AE23 CLASS REPLENISHMENT SHIPS

by

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[redacted]

HYDROMECHANICS LABORATORY

RESEARCH AND DEVELOPMENT REPORT

OCTOBER 1957

REPORT 1179

PRNC-TMB-648 (11-56)

THE EFFECT OF INTERACTION AND TRANSFER LINE FORCES ON AE23 CLASS REPLENISHMENT SHIPS

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NS715-102

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ABSTRACT

The effect of a new high-tension transfer rig on replenishment operations between an ammunition ship and an aircraft carrier was investigated in a series of model tests. Line pulls of 16,000 and 32,000 pounds, and a ship speed of 12 knots were represented. It is concluded from the data presented that the ships can maintain station under the combined effects of the interaction and transfer-line forces.

INTRODUCTION

A constant-tension transfer rig of exceptional capacity has been recently developed for use in replenishment operations between AE23 Class and CVA9 Class vessels. As the capacity of this rig was beyond the scope of any actual experience at sea, a series of model tests was requested by the Bureau of Ships,[1*] to determine its effect on the performance of the ships.

The principal objective of the model test program was to determine whether the vessels could sustain the replenishment-rig forces, in addition to the interaction forces, and yet retain an adequate margin of control for station keeping.

A basic feature of the proposed rig was a counterweight tensioning device which was designed to permit the vessels to operate at different distances apart with freedom in yaw or roll without affecting the tension of the transfer lines.

A similar counterweight tensioning device has been used to fuel a destroyer in a rough sea[2], and has been evaluated for a line pull of 6,000 pounds in fueling-at-sea trials.[3] A device of this type is shown in Figure 1 - a drawing reproduced from Reference 4. This particular device has a tensioning capacity of about 8,000 pounds, which is representative of current practice. An automatic locking arrangement is provided to prevent the weights from falling in the event that a line breaks. On the USS PAWCATUCK (AO108) the counterweight tensioning device is contained within a well in the deck of the vessel, Figure 2. An alternative location for tensioning counterweights on replenishment ships is along the kingposts.

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[1] References are listed on page 13

MODELS AND PROTOTYPES

Model 4521 of the USS NITRO (AE23) was fitted with kingposts to represent the arrangement shown in Figure 3, which has been reproduced from Reference 5. The longitudinal location of the kingposts on this class of replenishment ships is as follows: the first and second pairs are approximately 140 feet and 75 feet forward of amidships respectively, and the third pair is approximately 130 feet aft of amidships. The lines were attached to the posts at a height that corresponded to a full-scale elevation of 72 feet above the designed waterline of the ship (according to the enclosure of Reference 1).

Model 3894, an existing CVA9 model, was used for economy even though it was 8.54 per cent too small in its linear dimensions, and thus represented a 750-ft instead of an 820-ft aircraft carrier. This difference in length was not particularly significant since the principal objective of the tests was to observe the performance of the auxiliary vessel - which was smaller and consequently more affected by the forces than the aircraft carrier.

The lines on the aircraft carrier model were attached at a height corresponding to that of the flight deck level, and for these tests the longitudinal location of the replenishment stations was assumed to be the same with respect to the midship section as for the AE23.

Both models were self propelled and were fitted with rudders and bilge keels. The linear ratio of ship to model was 25. The principal particulars of the models and the prototype are given in Table 1.

TEST CONDITIONS AND PROCEDURES

The tests represented the vessels at a speed of 12 knots in alongside replenishment operations using from 1 to 3 transfer lines, or "high lines," connected between them. The lines were counterweight tensioned for full-scale line pulls of 16,000 and 32,000 pounds. Hence, the maximum total line pull represented was 96,000 pounds. The various conditions investigated are summarized in Table 2.

The test procedure was as follows: the aircraft-carrier model was restrained on a straight course under the carriage and the AE23 model was free to maneuver beside it, Figure 4. Both the propulsion motor and the rudder of the AE23 model were governed by remote control. A pin, which extended from one of a number of holes in a rack under the carriage into a wide slot on the bow of the AE23 model served to approximately position the model until the motor and rudder were regulated. The propulsion could be controlled so that the model would keep its designated longitudinal position without difficulty. However, the steering by remote control was not usually fine enough to maintain a constant separation from the aircraft

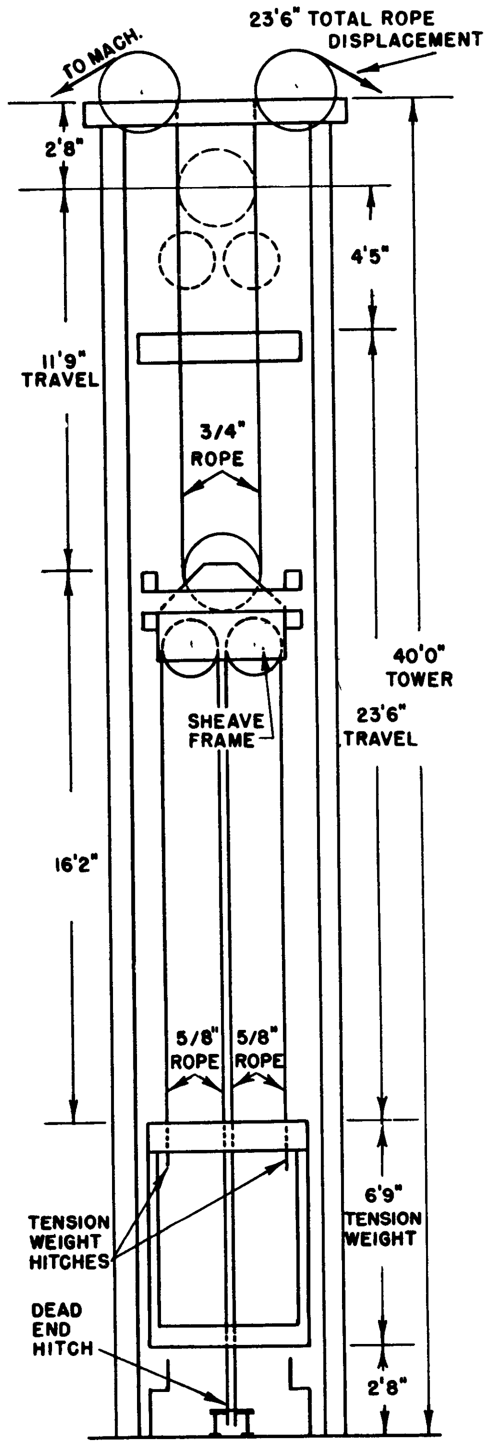

Figure 1 - Arrangement of a Counterweight Tensioning Device

TABLE 1

Principal Particulars of Models and Prototypes

AE23 CLASS AMMUNITION SHIP

CHARACTERISTIC	PROTOTYPE	MODEL
Length, Overall, ft	512.00	20.48
Length between Perpendiculars, ft	487.00	19.48
Beam, Molded, ft	72.25	2.89
Draft, ft	26.58	1.06
Displacement	12,625 tons	1760 pounds
Metacentric Height, GM, ft	6.00	0.24

750-FT AIRCRAFT CARRIER*

CHARACTERISTIC	PROTOTYPE	MODEL
Length, Overall, ft	813.00	32.52
Length between Perpendiculars, ft	750.00	30.00
Beam, Molded, ft	85.00	3.40
Draft, ft	26.98	1.08
Displacement	28,230 tons	4047 pounds

* Similar to CVA9

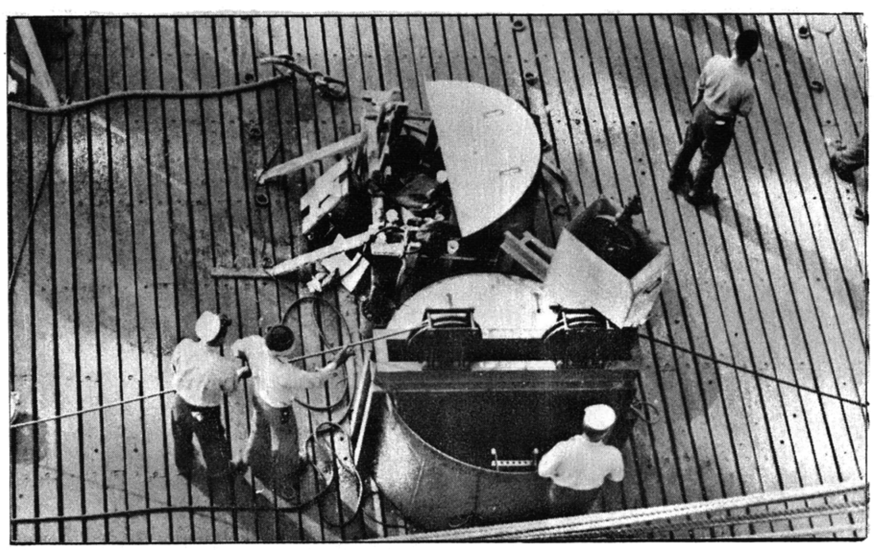

Figure 2 - The Counterweight Tensioning Device Aboard the USS PAWCATUCK (AO108) (The device is located in a well in the deck of the vessel)

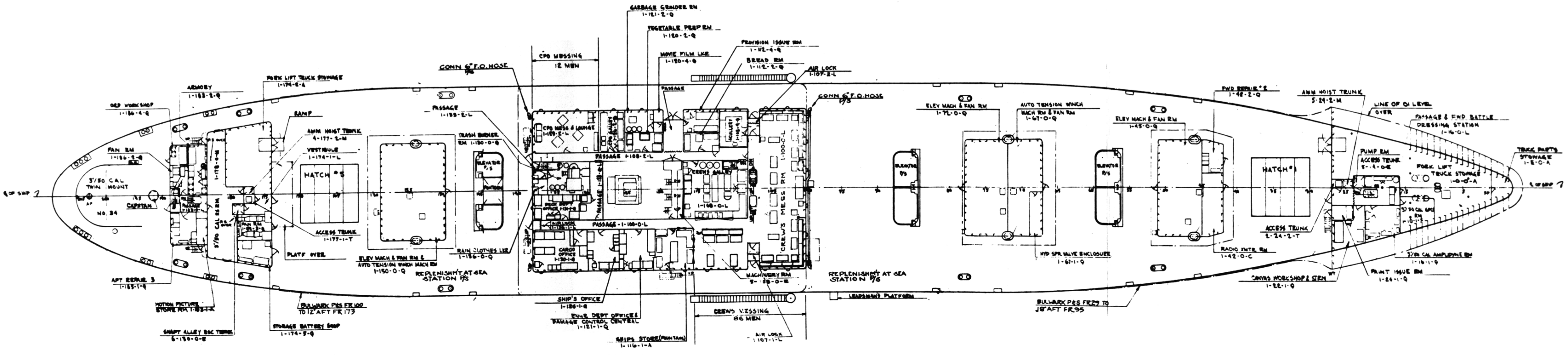

Figure 3 - Main Deck of AE23 Class Replenishment Ship

carrier model. Still, the "equilibrium rudder angle" could be determined with sufficient accuracy for a rudder movement of about 1 degree to make the model bear in or out from the mean position.

Horizontal and vertical gyroscopes were installed in the model to record the yaw and heel respectively. These instruments were caged and oriented before each run. The separation and longitudinal position of the AE23 model with respect to the aircraft-carrier model were obtained by measurements, which also gave a check on the yaw angle.

In conducting these tests the procedure specified by the Bureau of Ships in Reference (1) was followed.

DISCUSSION OF RESULTS

The results of the tests showing equilibrium yaw angles and rudder angles of the AE23 for the different conditions are given in Table 2. Studies of the interaction forces themselves are being made independently and will form the subject of a separate report. An observation of basic interest is that where the wave trains of the two vessels are superimposed along the side of the hull there are significant pressure effects, which in some instances are augmented by the reflection of the bow wave of one ship from the side of the other. Because of these wave effects there is no uniform relationship between the separation of the ships and the yaw and rudder angles. The results as a whole show that small yaw and rudder angles are generally adequate to maintain station under the combined effect of the interaction and transfer-line forces.

The results of the tests with the models abreast amidships, Figure 4, show that in general the proposed line pulls of 16,000 and 32,000 pounds can be sustained without difficulty by the ships. Under these conditions the rudder of the AE23 is generally directed inward toward the carrier.

The tests in which the ships are represented with a single rig between the No. 1 stations were accomplished with ease and appeared to represent an optimum replenishment arrangement. However the No. 2 stations were connected briefly with much the same results and therefore are not shown in the table. As the Nos. 1 and 2 rigs are attached near the pivot point of the AE23 Class ships, the turning movements of the hull are practically uninhibited.

The tests in which the vessels were represented with the No. 1 replenishment station of AE23 connected to the No. 3 station of the carrier presented no difficulty. The stern of the AE23 model extended beyond the stern of the other model, as shown in Figure 5, and could therefore swing through a larger arc than when the models were abreast. The AE23 model handled very well at this station usually with the rudder turned a few degrees outward from the other ship. Tests that the Model Basin is presently conducting show, nevertheless, that there are stations off the stern quarter of the aircraft carrier where the interaction force tends to draw the bow of the auxiliary ship into collision. This is particularly true at high speeds and therefore it is desirable to maintain the heading of the replenishment ship either parallel or away from the carrier. The hazards of this position have been demonstrated by the OLYMPIC-HAWKE collision,[6] by the near collision described on page 6 of Reference (3), and by other incidents of a similar nature.

The tests in which the vessels were represented, as shown in Figure 6, with the No. 3 station of the replenishment ship opposite the No. 1 station of the aircraft carrier showed that the AE23 required an inward rudder angle of 7 to 10 degrees since the pull of the line on the after end of the AE23 was partly supported by the action of the rudder. The direction in which the rudder was turned would cause the ship to sheer inward toward the aircraft carrier if the line broke, but the yaw angle was such that the initial movement would be outward. Consequently there would be an interval of time during which the helm could be corrected before there would be any actual convergence of the ships. This replenishment position appears to be somewhat hazardous, nevertheless, because the interaction forces tend to draw the AE23 across the bow of the carrier.

The maximum heel recorded for any condition was about 3 degrees. There is a general reduction in the level of the water between the ships which causes them to heel toward each other even when they are not connected by transfer lines. For most practical purposes this angle of heel could be computed with sufficient accuracy from the pull of the lines alone. Attention is called to the fact that even a 3-degree heel may appear as an appreciable slope to those on the deck of the vessel.

According to the visual observations of Bureau of Ships personnel in actual operations at sea, the heel angle of replenishment ships increases when a load is suspended from the transfer lines. The fact that the heel changes at all may appear to be an anomaly, since the transfer lines are counterweight tensioned presumably for a constant pull and the only effect of the load on the lines should be to increase the sag. However, the lifting of a load from the deck causes a sudden transfer of weight to the kingpost sheave, and the change in the elevation at which the weight is supported affects the metacentric height (GM). This and the initial effect of the sudden application of the load at the new level may cause a perceptible change in heel angle. Also, the action of the elevators in simultaneously raising weights from the hold, the vertical reaction of the transfer lines at the off-center location of the kingposts, and the momentary effect of a sudden change in course may be contributing factors. Furthermore, full-scale observations indicate that the pull of the lines is actually not constant. In fact, the chart following page 53 of Reference 3

TABLE 2

Yaw and Rudder Angles of AE23 Class Ships During Alongside Replenishment of 750-ft Aircraft Carrier at a Speed of 12 knots (Data derived from model tests)

Test	Tension Lines	Station	Separation of Ships Between Centerline (ft)	Separation of Ships Between Sides (ft)	Yaw[2] Angle (deg)	Rudder[3] Angle (deg)
1	None	Abreast[1]	131	48	2.0	3-6L.
2	None	Abreast	167	84	1.5	2-3L.
3	None	Abreast	229	146	1.2	2-3L.
	Between All 3 Stations:					
4	3 - 16,000 lbs.	Abreast	122	39	2.7-4.1	5-8L.
5	3 - 16,000 lbs.	Abreast	136	53	3.2	5-6L.
6	3 - 16,000 lbs.	Abreast	151	68	2.2	6-7L.
7	3 - 16,000 lbs.	Abreast	165	82	2.0	4-5L.
8	3 - 16,000 lbs.	Abreast	180-193	97-110	1.0	4-5L.
9	3 - 16,000 lbs.	Abreast	198-205	115-122	3.0-4.8	2-5L.
10	3 - 16,000 lbs	Abreast	217-225	134-142	1.0-2.3	3-4L.
	Between All 3 Stations:					
11	3 - 32,000 lbs.	Abreast	127-136	44-53	1.9-4.5	8-10L.
12	3 - 32,000 lbs.	Abreast	179	96	4.8	6L.
13	3 - 32,000 lbs.	Abreast	205	122	4.8	4-5L.
14	3 - 32,000 lbs.	Abreast	223	140	2.9	5L.
	Between No. 1 Stations:					
15	1 - 16,000 lbs.	Abreast	126	43	2.0-2.5	2-4L.
16	1 - 32,000 lbs.	Abreast	124	41	3.0	2-3L
17	1 - 16,000 lbs.	Abreast	198	115	1.6	1-3L.
18	1 - 32,000 lbs.	Abreast	194	111	2.0	1-3L.
	Between No. 3 Stations:					
19	1 - 16,000 lbs.	Abreast	127	44	1.0	7L.
20	1 - 32,000 lbs.	Abreast	131	48	1.5	9L.
21	1 - 32,000 lbs.	Abreast	192	109	1.6	4L.
	Between AE Sta.1 and CVA Sta.3:					
22	1 - 16,000 lbs.	AE Sta.1 Opp. CVA Sta.3	132	49	1.0	0-1R.
23	1 - 32,000 lbs.	AE Sta.1 Opp. CVA Sta.3	127	44	2.0	2-3R.
24	1 - 32,000 lbs.	AE Sta.1 Opp. CVA Sta.3	225	142	2.0	1-2R.
	Between AE Sta.3 and CVA Sta.1:					
25	1 - 16,000 lbs.	AE Sta.3 Opp. CVA Sta.1	122	39	2.2	6L.
26	1 - 32,000 lbs.	AE Sta.3 Opp. CVA Sta.1	121	38	2.5	7-10L.
27	1 - 32,000 lbs.	AE Sta.3 Opp. CVA Sta.1	228	145	1.0	7L.

[1] Abreast with respect to the midship section

[2] The yaw angle is outward in each instance

[3] The rudder directions, left and right, are for the auxiliary ship when on the starboard side of the aircraft carrier.

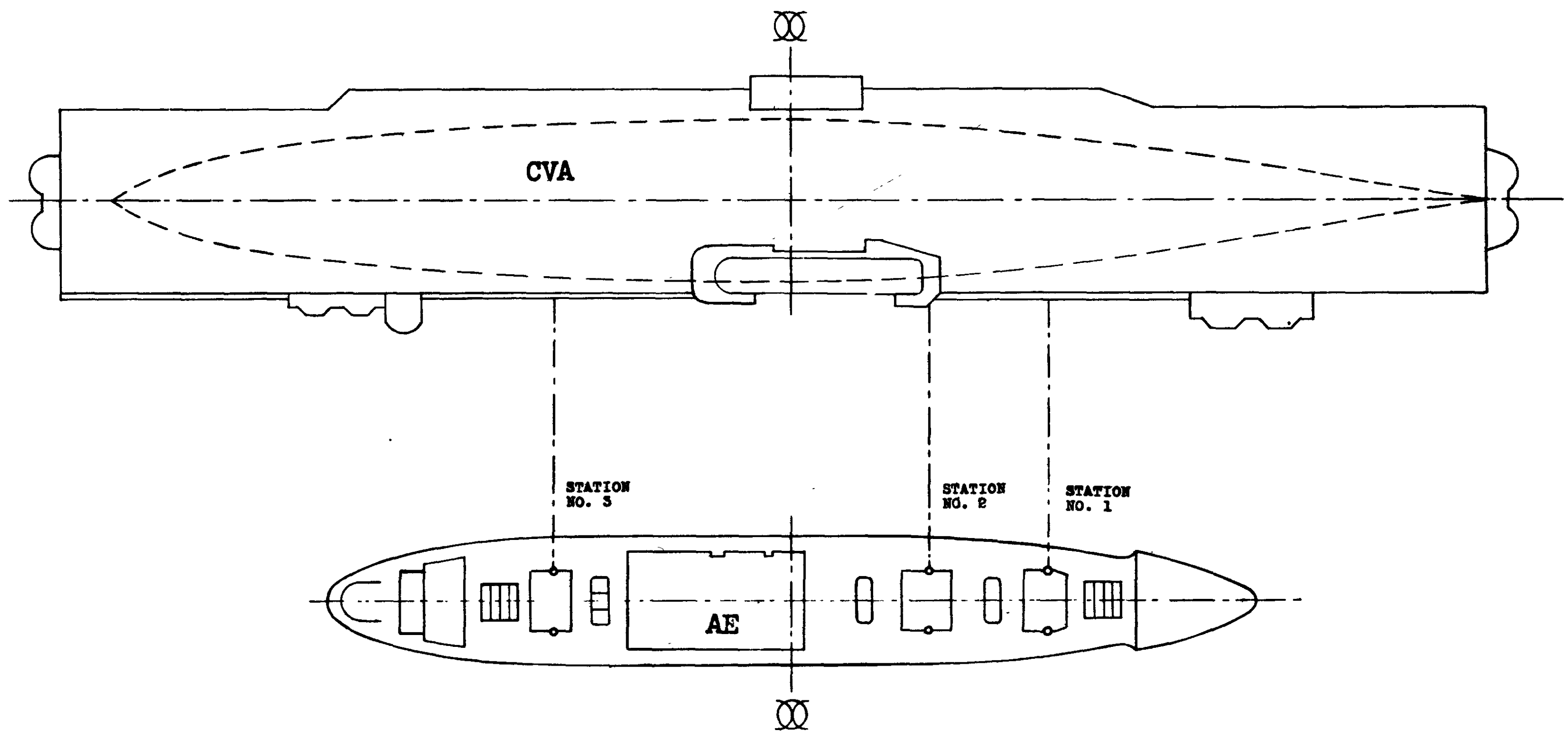

Figure 4 - The Aircraft Carrier with the Auxiliary Ship Alongside and Abreast Amidships

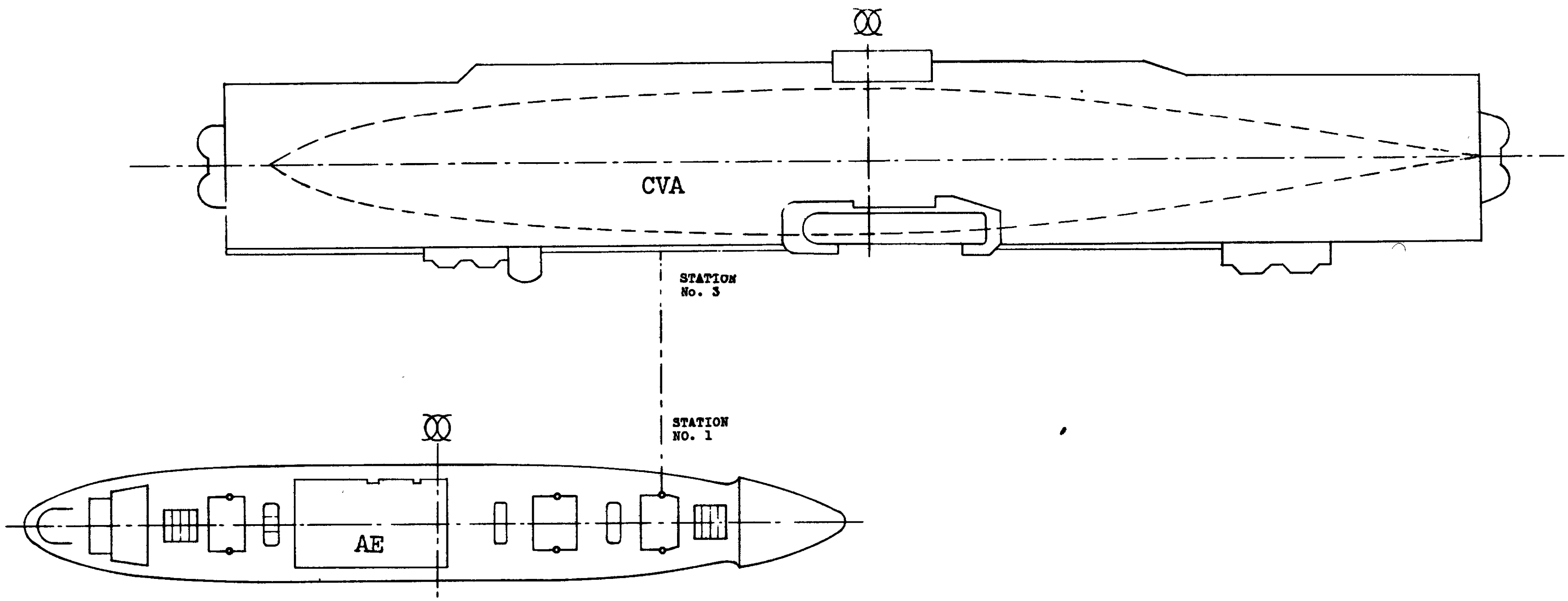

Figure 5 - The No. 1 Replenishment Station of the Auxiliary Ship Connected to the No. 3 Station of the Aircraft Carrier

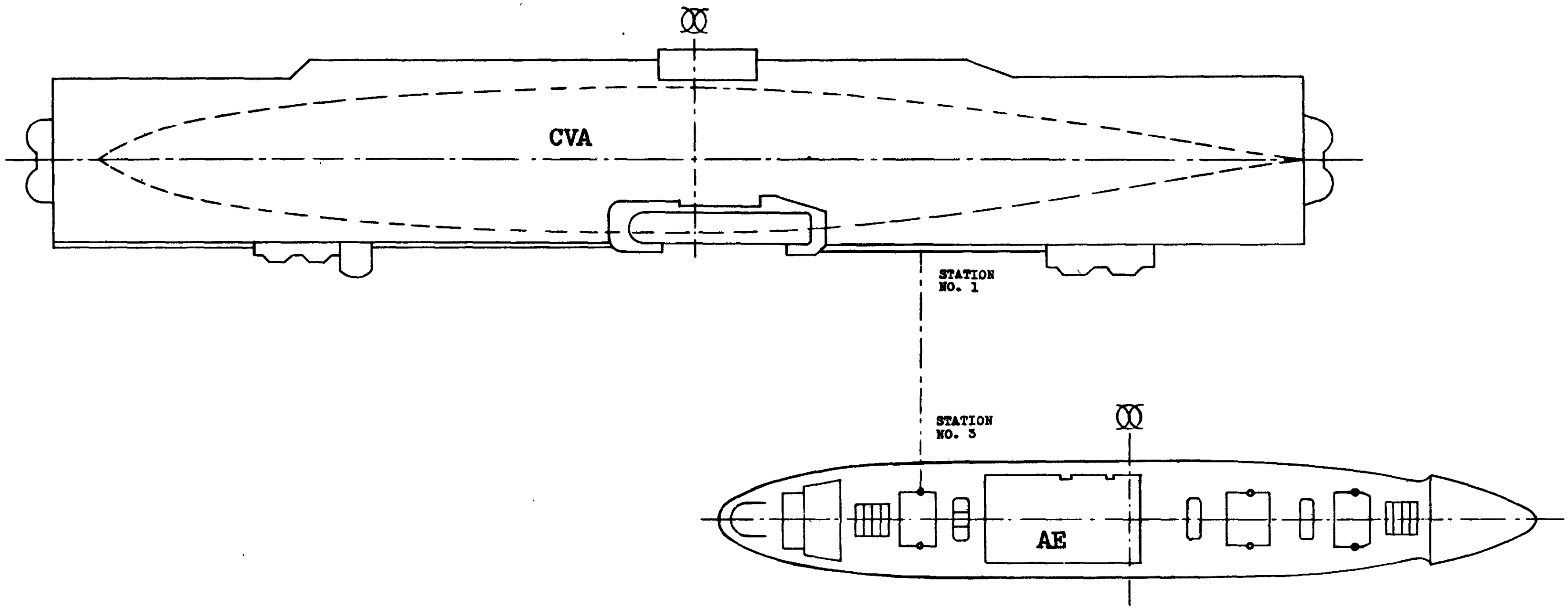

Figure 6 - The No. 3 Replenishment Station of the Auxiliary Ship Connected to the No. 1 Station of the Aircraft Carrier

shows that there are appreciable variations amounting to about 30 to 50 percent in the measured tension. Thus, it is concluded that the friction of the counterweight system can cause variations in tension that affect the heel angle.

The model tests of the new rig described in this report were based on the assumption that there would be constant tension pull. Because of the large forces involved, this is considered to be an essential feature of the proposed full-scale replenishment-at-sea rig.

CONCLUSIONS

The model test program described in this report has demonstrated that the proposed 16,000 - and 32,000 - pound constant-tension transfer line, or "high-line," pulls are feasible for replenishment operations between ammunition ships and aircraft carriers. The principal results of the study may be summarized as follows:

1. The resultant forces and moments due to combined effect of the interaction and transfer-line forces can be efficiently sustained by the ships; only small yaw and rudder angles are required to maintain equilibrium.

2. Wave effects as well as flow effects must be considered in determination of interaction forces and optimum positions.

3. Stations off the bow and stern quarters of aircraft carriers are somewhat hazardous and should be avoided notwithstanding the ease with which they can be maintained under favorable conditions.

REFERENCES

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5. AE21-22 Booklet of General Plans, Bureau Ships No. AE21-S0103-H-1457927 (Ammunition Ships).

6. Taylor, D. W. (testimony of-from transcript of official judgment), "On HAWKE-OLYMPIC COLLISION," Proceedings of the U. S. Naval Institute, Vol. 38, No. 141, page 283 (1912).

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