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TECHNICAL MEMORANDUM NO. 6-71

DSRV ALVIN WEIGHT REPORT, 1971

Arnold G. Sharp
Clifford L. Winget
Andrew H. Eliason

WOODS HOLE, MASSACHUSETTS

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WOODS HOLE OCEANOGRAPHIC INSTITUTION
Woods Hole, Massachusetts

TECHNICAL MEMORANDUM NO. 6-71

DSRV ALVIN WEIGHT REPORT, 1971

prepared by

Arnold G. Sharp
Clifford L. Winget
Andrew H. Eliason

August 1971

This work has been carried out under Contract
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ABSTRACT

Complete weight and stability calculations are presented for the newly rebuilt research submarine ALVIN. Longitudinal and vertical components of the BG distance are given for the vehicle in its normal condition, and in a number of emergency conditions. Some of the post-refit certification trials also are described and test results are given. Experimentally determined values of BG are compared with the computed values.

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I. Introduction

The following pages present the complete weight and stability report for the research submarine ALVIN as of May 1971. As in the past, one section of the report is devoted to the weight and stability computations, while a second section deals with the certification trials. The trials covered here are the surface and submerged inclining experiments, and the trim dive.

The weight and stability calculations are in the usual form, showing a tabulation of weights, displacements, moment arm values (both longitudinal and vertical), and first moments. Weight, displacement, and moment summations yield values which locate the center of gravity G and the center of buoyancy B of the vehicle. Finally, longitudinal and vertical components of the BG distance are computed. The computer printout sheets have been reproduced and are included in this report. The computations were performed using the W.H.O.I. Sigma-7 computer made by Xerox Data Systems, Inc.

Following the loss of ALVIN in October 1968 and her subsequent recovery in August 1969 the submarine was completely dismantled and rebuilt. While the plan was to restore ALVIN as nearly as possible to her original configuration, certain minor changes were inevitable. The completely new aluminum frame is an almost exact copy of the old one but it incorporates some minor improvements. During rebuilding, small blocks of syntactic foam of various shapes were fitted into recesses in the frame and other open spaces where there had been none before.

The lift propulsion system was redesigned in an effort to provide a simpler, more reliable mechanism. A result of this design is an oil-filled pressure-compensated propulsion box located on the upper skin just aft of the conning tower. This box weighs about 280 pounds (including oil) and represents weight which was in a lower position in 1968. Large syntactic foam blocks have been placed under the three battery boxes and the syntactic blocks on the sides of the upper skin (just below the lift propellers) were increased in size.

The increased amount of syntactic foam was expected to improve the payload capability of ALVIN but it was not clear at the beginning what the effect would be on ALVIN's stability. This effect has been determined by means of the stability computations and the dockside trials, and the results are presented in the following sections of the report.

II. Weight and Stability Computations

- A. Explanation of Procedure In computing the weight and stability of ALVIN, two separate force systems were considered. The weights, acting downward, were summed to find the total weight, which acts at the center of gravity G. Similarly, the buoyancy forces, which act upward, were summed to find the total buoyant force or displacement, which acts at the center of buoyancy B. The locations of G and B were determined by summing the moments of weights and displacements with respect to the forward perpendicular and the base plane. Points G and B are assumed to lie in a vertical plane which passes through the longitudinal centerline of the submarine.

For the computer run, data was obtained for the separate components (or packages) and a data card was punched for each. The items were broken down into sub-groups as follows (refer to computer printout sheets):

1. Pressure hull plus contents
2. Other forebody
3. Afterbody
4. Variable load
5. Emergency conditions

At the end of each sub-group the weight, displacement and moment summations were made, and the locations of G and B were determined. At the end of Section 4 (variable load) cumulative summations were made which yielded G and B values for the entire submarine in what is called the "normal submerged" condition. In this condition the main ballast tanks are flooded, the variable ballast oil is divided 25 percent to the hard tanks and 75 percent to the rubber bags, and the trim mercury is divided 50 percent forward and 50 percent aft.

Following the results for the normal submerged vehicle there are presented results for 8 different modifications to that condition. The first of these is designated as the "normal surfaced" condition, which consists of the normal submerged condition but with the main ballast blown. The remaining 7 modifications deal with a series of vehicle emergency conditions.

Included in the computer program was a section which enabled the computer, using the longitudinal and vertical components of the BG distance, to plot a diagram of the static equilibrium

position of the submarine in any given condition. These diagrams have been reproduced and are included following the summations for the entire vehicle, the released forebody, and the 8 modified conditions.

B. Definition of Symbols The following symbols which appear on the computer printout sheets are defined here for convenience.

- W - weight of item in air, lbs.
- X - distance of center of gravity of item from forward perpendicular, feet (positive x means aft of F.P.; see Figure 1.)
- Y - distance of center of gravity of item above base plane, feet (see Figure 1.)
- MX - product of W times X, foot-lbs.
- MY - product of W times Y, foot-lbs.
- D - displacement of item, lbs. of seawater
- XP - distance of center of buoyancy of item from forward perpendicular, feet
- YP - distance of center of buoyancy of item above base plane, feet
- MXP - product of D times XP, foot-lbs.
- MYP - product of D times YP, foot-lbs.
- BG longitudinal - distance between center of buoyancy B and center of gravity G, longitudinal component, feet (negative value indicates tendency for up-angle of trim; see Figure 2.)
- BG vertical - distance between center of buoyancy B and center of gravity G, vertical component, feet (positive value indicates vertical stability of submerged vehicle; see Figure 2.)

The following additional terms and symbols appear in various places in this report:

Forward Perpendicular - vertical plane passing through foremost edge of front window cone of ALVIN (see Figure 1.)

Figure 1. Longitudinal Section of ALVIN Showing Sample of Data Used in Computations

Figure 2. Longitudinal Section of ALVIN Showing Components of BG Distance

Base Plane - horizontal plane passing through bottom of skids of ALVIN (see Figure 1.)

B' - new position of center of buoyancy B. Lateral shift occurs due to change of underwater form when vehicle is inclined on the surface (see Figure 3.)

Metacenter M - point found by extending line of action of vertical buoyancy force through B' to intersect with original vertical centerline of vehicle inclined on the surface (see Figure 3.)

GM - vertical distance from center of gravity G to metacenter M (M above G indicates positive stability of surfaced vehicle; (see Figure 3.)

C. Outline of Programmed Computations

1. Total weight = summation W
2. Total displacement = summation D
3. Distance to center of gravity, longitudinal
$$XW = (\text{summation } MX) / (\text{summation } W)$$
4. Distance to center of gravity, vertical
$$YW = (\text{summation } MY) / (\text{summation } W)$$
5. Distance to center of buoyancy, longitudinal
$$XPD = (\text{summation } MXP) / (\text{summation } D)$$
6. Distance to center of buoyancy, vertical
$$YPD = (\text{summation } MYP) / (\text{summation } D)$$
7. BG longitudinal = $XPD - XW$
8. BG vertical = $YPD - YW$

Figure 3. Transverse Section of ALVIN Showing Locations of Points K, G, B, B' and M

D. Computer Printout

RUN

ALVIN WEIGHT AND STABILITY COMPUTATIONS

PAGE 1

SPHERE ONLY

IDENTIFICATION	W	X	Y	MX	MY	D	XP	YP	MXP	MYP
P. HULL MINUS INSTS	6152.35	4.97	4.89	30577.18	30084.99	10668.99	4.50	4.75	48010.45	50677.70
HULL INSERT-FWD	500.00	1.14	4.75	570.00	2375.00	16.79	1.14	4.75	19.14	79.75
HULL INSERT-B8TTSM	500.00	3.72	1.42	1860.00	710.00	16.79	3.72	1.42	62.46	23.84
HULL INSERTS=P AND S	1000.00	2.39	3.46	2390.00	340.00	33.58	2.39	3.46	80.26	116.19
HATCH INSERT	266.00	4.50	8.11	1197.00	2157.26	12.92	4.50	8.11	58.14	104.78
WINDSW-FWD	9.81	1.14	4.75	11.18	46.60	.00	.00	.00	.00	.00
WINDSW-B8TTSM	9.81	3.72	1.44	36.49	14.13	.00	.00	.00	.00	.00
WINDSW=P AND S	19.62	2.39	4.36	46.89	85.54	.00	.00	.00	.00	.00
WINDSW RET. RING-FW	8.37	1.14	4.75	9.54	39.76	1.09	1.14	4.75	1.24	9.18
WINDSW RT RING B8T	8.69	3.72	1.30	32.33	11.30	1.14	3.72	1.30	4.24	1.48
WINDSW RT RINGS P&S	16.74	2.39	3.46	40.01	57.92	2.18	2.39	3.46	5.21	7.54
SPHERE REL.-UPPER	59.04	4.50	1.33	265.68	78.52	5.49	4.50	1.21	24.70	6.64
HATCH	220.00	4.50	8.11	990.00	1784.20	.00	.00	.00	.00	.00
HINGE ARMS	8.00	4.21	8.28	33.68	66.24	1.04	4.21	8.28	4.38	9.61
HINGE SHAFT	5.68	4.00	8.28	22.72	47.03	.74	4.00	8.28	2.96	6.13
INSIDE HANDLE	4.50	4.91	7.94	22.09	35.73	.00	.00	.00	.00	.00
OUTSIDE HANDLE	9.00	4.91	8.28	44.19	74.52	1.17	4.91	8.28	5.74	9.69
SPRING RETAINER	4.67	4.14	8.28	19.33	38.67	.61	4.14	8.28	2.53	5.05
INT-SWING CLAMP	2.66	4.60	7.94	12.24	21.12	.00	.00	.00	.00	.00
MISC	1.19	4.50	8.11	5.35	9.65	.00	.00	.00	.00	.00
HINGE SPRINGS	11.25	4.00	8.28	45.00	93.15	1.47	4.00	8.28	5.88	12.17
HATCH WINDSW	1.19	4.50	8.19	5.35	9.75	.00	.00	.00	.00	.00
HATCH WIND RET-RING	3.78	4.50	8.10	17.01	30.62	.49	4.50	8.10	2.20	3.97
HINGE BLOCKS	11.50	3.92	8.05	45.08	92.57	1.50	3.92	8.05	5.88	12.07
PENETRATORS(7) FWD	72.45	1.06	4.75	76.80	344.14	4.43	1.06	4.75	4.70	21.04
PENETRATORS(5)B8TT	51.75	4.29	1.42	222.01	73.48	3.16	4.29	1.42	13.56	4.49
LIFT PADS	17.86	4.50	8.17	80.37	145.92	2.33	4.50	8.17	10.48	19.04
CONN. HALVES-UPPER	35.00	4.50	1.09	157.50	38.15	3.02	4.50	1.09	13.59	3.29
MISC. OUTSIDE	10.00	4.50	8.10	45.00	81.00	1.30	4.50	8.10	5.85	10.53
STRAZA M8D 100	32.00	3.13	5.53	93.90	165.90	.00	.00	.00	.00	.00
STRAZA M8D 200	40.00	4.04	5.96	129.28	190.72	.00	.00	.00	.00	.00
STRAZA M8D 300	40.00	4.37	6.67	174.80	266.80	.00	.00	.00	.00	.00
UHER 4000	8.50	4.13	7.08	35.10	60.18	.00	.00	.00	.00	.00
02 ANALYZER	3.50	5.38	6.70	18.83	23.45	.00	.00	.00	.00	.00
02 B8TTLE	33.00	6.71	3.79	221.43	125.07	.00	.00	.00	.00	.00
LIGH CANISTER	20.00	6.29	5.71	125.80	114.20	.00	.00	.00	.00	.00
CABIN LIGHT	1.00	5.67	6.79	5.67	6.79	.00	.00	.00	.00	.00
RATIONS	2.00	4.29	7.17	8.58	14.34	.00	.00	.00	.00	.00
FACE MASKS, VEST	6.80	5.33	5.88	36.24	39.98	.00	.00	.00	.00	.00
PILOTS CHAIR	9.31	2.88	2.88	26.81	26.81	.00	.00	.00	.00	.00

RUN

ALVIN WEIGHT AND STABILITY COMPUTATIONS

PAGE 1

SPHERE ONLY

IDENTIFICATION	W	X	Y	MX	MY	D	XP	YP	MXP	MYP
P. HULL MINUS INSTS	6152.35	4.97	4.89	30577.18	30084.99	10668.99	4.50	4.75	48010.45	50677.70
HULL INSERT-FWD	500.00	1.14	4.75	570.00	2375.00	16.79	1.14	4.75	19.14	79.75
HULL INSERT-BOTTOM	500.00	3.72	1.42	1860.00	710.00	16.79	3.72	1.42	62.46	23.84
HULL INSERTS-P AND S	1000.00	2.39	3.46	2390.00	340.00	33.58	2.39	3.46	80.26	116.19
HATCH INSERT	266.00	4.50	8.11	1197.00	2157.26	12.92	4.50	8.11	58.14	104.78
WINDOW-FWD	9.81	1.14	4.75	11.18	46.60	.00	.00	.00	.00	.00
WINDOW-BOTTOM	9.81	3.72	1.44	36.49	14.13	.00	.00	.00	.00	.00
WINDOWS- P AND S	19.62	2.39	4.36	46.89	85.54	.00	.00	.00	.00	.00
WINDOWS RET. RING-FW	8.37	1.14	4.75	9.54	39.76	1.09	1.14	4.75	1.24	9.18
WINDOW RT RING BOT	8.69	3.72	1.30	32.33	11.30	1.14	3.72	1.30	4.24	1.48
WINDOW RT RINGS P&S	16.74	2.39	3.46	40.01	57.92	2.18	2.39	3.46	5.21	7.54
SPHERE REL.-UPPER	59.04	4.50	1.33	265.68	78.52	5.49	4.50	1.21	24.70	6.64
HATCH	220.00	4.50	8.11	990.00	1784.20	.00	.00	.00	.00	.00
HINGE ARMS	8.00	4.21	8.28	33.68	66.24	1.04	4.21	8.28	4.38	8.61
HINGE SHAFT	5.68	4.00	8.28	22.72	47.03	.74	4.00	8.28	2.96	6.13
INSIDE HANDLE	4.50	4.91	7.94	22.09	35.73	.00	.00	.00	.00	.00
OUTSIDE HANDLE	9.00	4.91	8.28	44.19	74.52	1.17	4.91	8.28	5.74	9.69
SPRING RETAINER	4.67	4.14	8.28	19.33	38.67	.61	4.14	8.28	2.53	5.05
INT-SWING CLAMP	2.66	4.60	7.94	12.24	21.12	.00	.00	.00	.00	.00
MISC	1.19	4.50	8.11	5.35	9.65	.00	.00	.00	.00	.00
HINGE SPRINGS	11.25	4.00	8.28	45.00	93.15	1.47	4.00	8.28	5.88	12.17
HATCH WINDOW	1.19	4.50	8.19	5.35	9.75	.00	.00	.00	.00	.00
HATCH WIND RET-RING	3.78	4.50	8.10	17.01	30.62	.09	.00	.00	.00	.00
HINGE BLOCKS	11.50	3.92	8.05	45.08	92.57	1.50	3.92	8.05	2.20	3.97
PENETRATORS(7) FWD	72.45	1.06	4.75	76.80	344.14	4.43	1.06	4.75	5.88	12.07
PENETRATORS(S)BOTT	51.75	4.29	1.42	222.01	73.48	3.16	4.29	1.42	4.70	21.04
LIFT PADS	17.86	4.50	8.17	80.37	145.92	2.33	4.50	8.17	13.56	4.49
CONN. HALVES-UPPER	35.00	4.50	1.09	157.50	38.15	3.02	4.50	1.09	13.59	19.04
MISC. OUTSIDE	10.00	4.50	8.10	45.00	81.00	1.30	4.50	8.10	5.85	10.53
STRAZA M8D 100	30.00	3.13	5.53	93.90	165.90	.00	.00	.00	.00	.00
STRAZA M8D 200	32.00	4.04	5.96	129.28	190.72	.00	.00	.00	.00	.00
STRAZA M8D 300	40.00	4.37	6.67	174.80	266.80	.00	.00	.00	.00	.00
UHER 4000	8.50	4.13	7.08	35.10	60.18	.00	.00	.00	.00	.00
O2 ANALYZER	3.50	5.38	6.70	18.83	23.45	.00	.00	.00	.00	.00
O2 BATTLE	33.00	6.71	3.79	221.43	125.07	.00	.00	.00	.00	.00
L10H CANISTER	20.00	6.29	5.71	125.80	114.20	.00	.00	.00	.00	.00
CABIN LIGHT	1.00	5.67	6.79	5.67	6.79	.00	.00	.00	.00	.00
RATIONS	2.00	4.29	7.17	8.58	14.34	.00	.00	.00	.00	.00
FACE MASKS,VEST	6.80	5.33	5.88	36.24	39.58	.00	.00	.00	.00	.00
PILOTS CHAIR	9.31	2.88	2.88	26.81	26.81	.00	.00	.00	.00	.00

ALVIN WEIGHT AND STABILITY COMPUTATIONS
 SPHERE ONLY (CONTINUED)

IDENTIFICATION	W	X	Y	MX	MY	D	XP	YP	MXP	MYP
TRIM INDICATOR	30	1.63	5.50	.49	1.65	.00	.00	.00	.00	.00
CABIN LIGHTS,P/S(2)	2.00	3.67	5.46	7.34	10.92	.00	.00	.00	.00	.00
MAP LIGHTS (4)	4.00	2.58	6.50	10.32	26.00	.00	.00	.00	.00	.00
FLOOR BOARDS	8.00	4.58	2.12	36.64	16.96	.00	.00	.00	.00	.00
MISC WIRING,HDWR	10.00	4.55	4.75	45.50	47.50	.00	.00	.00	.00	.00
PENETRATOR LEADS	80.00	4.50	4.75	360.00	380.00	.00	.00	.00	.00	.00
URINALS(3)	3.00	5.50	2.50	16.50	7.50	.00	.00	.00	.00	.00
CAMERAS	6.00	5.80	5.20	34.80	31.20	.00	.00	.00	.00	.00
T66L KIT	4.00	5.50	2.40	22.00	9.60	.00	.00	.00	.00	.00
SCUBA REGULATORS(3)	7.80	5.80	2.50	45.24	19.50	.00	.00	.00	.00	.00
FLASHLIGHTS(6)	4.80	5.50	2.40	26.40	11.52	.00	.00	.00	.00	.00
SOUND PHONES(2)	6.00	4.30	7.00	25.80	42.00	.00	.00	.00	.00	.00
CUSHIONS	4.00	4.60	2.20	18.40	8.80	.00	.00	.00	.00	.00
RELEASE T-BAR	4.00	5.60	2.40	22.40	9.60	.00	.00	.00	.00	.00
RACK ASSEMBLIES	35.00	4.60	5.00	161.00	175.00	.00	.00	.00	.00	.00
EMERG WATER	5.00	6.00	2.80	30.00	14.00	.00	.00	.00	.00	.00
ALUM. BATTERY RACK	17.00	5.50	2.34	93.50	39.78	.00	.00	.00	.00	.00
DISTR PANEL	44.50	6.00	3.75	267.00	166.87	.00	.00	.00	.00	.00
PORT WING PANEL	12.50	2.90	6.25	36.25	78.12	.00	.00	.00	.00	.00
RADIO	11.25	4.58	5.96	51.52	67.05	.00	.00	.00	.00	.00
FATHOMETER	9.00	4.38	5.62	39.42	50.58	.00	.00	.00	.00	.00
U Q C	31.00	4.29	6.75	132.99	209.25	.00	.00	.00	.00	.00
INSTR PANEL	17.00	1.75	6.25	29.75	106.25	.00	.00	.00	.00	.00
LOWER SHELVES(3)	12.50	2.90	5.50	36.25	68.75	.00	.00	.00	.00	.00
GYRO,CNTR UNIT	33.50	5.91	5.46	197.98	182.91	.00	.00	.00	.00	.00
POWER SUPPLY 6V	7.00	7.00	5.12	49.00	35.84	.00	.00	.00	.00	.00
STATIC INVERTER	39.00	6.67	3.54	260.13	138.06	.00	.00	.00	.00	.00
STBD WING PANEL	6.30	2.90	6.25	18.27	39.37	.00	.00	.00	.00	.00
SHELF UPPER STBD	2.00	4.35	6.75	8.70	13.50	.00	.00	.00	.00	.00
SHELF UPPER PORT	3.50	4.35	6.75	15.22	23.63	.00	.00	.00	.00	.00
SCUBA BOTTLE,BRKT	27.00	5.92	3.54	159.84	95.58	.00	.00	.00	.00	.00
SHELF OVER IND PANEL	1.50	1.70	6.60	2.55	9.90	.00	.00	.00	.00	.00
SHELF OVER LEAK DET.	2.00	3.83	7.04	5.76	14.08	.00	.00	.00	.00	.00
FATHOMETER SCOPE	7.00	2.83	6.29	26.81	44.03	.00	.00	.00	.00	.00
FATHOMETER X-MTR	17.00	4.38	5.62	74.46	95.54	.00	.00	.00	.00	.00
SCUBA BBT BRKS(2)	54.50	6.62	3.63	360.79	197.83	.00	.00	.00	.00	.00
O2 BOTT BRKT	2.00	6.71	3.79	13.42	7.58	.00	.00	.00	.00	.00
AIR REGEN UNIT	13.50	6.38	4.50	86.13	60.75	.00	.00	.00	.00	.00
SPHERE STEP HDWR	6.00	5.00	6.50	30.00	39.00	.00	.00	.00	.00	.00
BATTERY SHELF	3.00	5.63	7.33	16.89	21.99	.00	.00	.00	.00	.00

ALVIN WEIGHT AND STABILITY COMPUTATIONS

(CONTINUED)

SPHERE ONLY

IDENTIFICATION	W	X	Y	MX	MY	D	XP	YP	MXP	MYP
FIRE EXTING	10.50	5.57	4.50	58.48	47.25	.00	.00	.00	.00	.00
EMERG LIGHT BATT	5.00	6.50	4.50	32.50	22.50	.00	.00	.00	.00	.00
MISC SHEET METAL	5.00	4.50	4.50	22.50	22.50	.00	.00	.00	.00	.00
GYRB REPEATER	2.00	1.54	4.83	3.08	9.66	.00	.00	.00	.00	.00
FLARE B&X FLARES	6.00	5.38	5.87	32.28	35.22	.00	.00	.00	.00	.00
PLOTS CNTR B&X	7.00	2.00	7.00	14.00	49.00	.00	.00	.00	.00	.00
CLINOMETERS(2)	1.00	3.50	6.25	3.50	6.25	.00	.00	.00	.00	.00
FIRST AID KIT	1.00	6.20	2.79	6.20	2.79	.00	.00	.00	.00	.00
EMERG BATTERIES(2)	18.00	5.50	2.34	99.00	42.12	.00	.00	.00	.00	.00
PINGER BATTERIES(2)	12.00	5.50	2.34	66.00	28.08	.00	.00	.00	.00	.00

SPHERE ONLY

SUMMARY	NO. ITEMS	SUM W	S MXW	S MYW	SUM MX	SUM MY	SUM D	S MXP	S MYP	SUM MXP	SUM MYP
90		9837.97	4.37	4.68	42969.51	46024.58	10780.23	4.48	4.74	48343.60	51139.19
BG LONGITUDINAL			.12		BG VERTICAL	.07					

ALVIN WEIGHT AND STABILITY COMPUTATIONS

OTHER FOREBODY

IDENTIFICATION	W	X	Y	MX	MY	D	XP	YP	MXP	MYP
SAIL,ETC	1323.35	4.64	7.02	6140.34	9289.92	1714.00	4.34	6.65	7438.76	11398.10
BOW BUOYANCY,NEW	863.00	.38	7.00	327.94	6041.00	1505.00	.38	7.00	571.90	10535.00
LG BUOYANCY RING	1135.00	4.42	3.43	5016.70	3893.05	1570.00	4.42	3.43	6939.40	5385.10
FRONT WINDROW CONE	102.00	.75	4.75	76.50	484.50	154.00	.75	4.75	115.50	731.50
MAIN BALLAST WATER	1493.76	4.50	6.00	6721.92	8962.56	1493.76	4.50	6.00	6721.92	8962.56
FIBERGLASS CLAMP	4.00	2.39	3.46	9.56	13.84	2.22	2.39	3.46	5.31	7.68
SONAR UNIT	130.00	.50	8.00	65.00	1040.00	50.00	.50	8.00	25.00	400.00
MAIN BALLAST CENTRAL	65.00	7.93	7.43	515.45	482.95	42.00	7.93	7.43	333.06	312.06
NDT PLUGS(8)	6.40	4.50	1.33	28.80	8.51	.83	4.50	1.33	3.73	1.10
MAGNETIC COMPASS	9.07	7.00	10.13	63.49	91.88	8.33	7.00	10.13	58.31	8.38
EXTERIOR LIGHTS	24.00	2.50	5.40	60.00	129.60	8.00	2.50	5.40	20.00	43.20
SEVENIUS ROTAR	8.00	3.50	13.20	28.00	155.60	2.00	3.50	13.20	7.00	26.40
PRECISION DEPTH TRAN	14.00	6.50	7.30	91.00	102.20	5.00	6.50	7.30	32.50	36.50

OTHER FOREBODY

SUMMARY	NB, ITEMS	SUM W	S	MXW	S	MYW	SUM MX	SUM MY	SUM D	S	MXPD	S	MYPD	SUM MXP	SUM MYP
13		5177.58		3.70		5.92	19144.70	30645.61	6585.14		3.40		5.79	22272.39	37923.59
BG LONGITUDINAL		--30					BG VERTICAL	--13							

ALVIN WEIGHT AND STABILITY COMPUTATIONS
AFTERBODY

IDENTIFICATION	W	X	Y	MX	MY	D	XP	YP	MXP	MYP
FRAME	447.50	9.18	2.77	4108.05	1239.57	169.00	9.18	2.77	1551.42	468.13
LG BUGYANCY PKG	2475.00	14.42	5.25	35689.50	12993.75	4120.00	14.42	5.25	59410.40	21630.00
SM BUGYANCY PK CTR	516.00	10.25	6.33	5289.00	3266.28	946.00	10.25	6.33	9696.50	5988.18
SIDE BUGYANCY PK(2)	410.00	10.40	6.75	4264.00	2767.50	656.00	10.40	6.75	6822.40	4428.00
V/BPKG UPPER PART	748.30	10.18	5.70	7617.69	4265.31	1314.00	10.18	5.70	13376.52	7488.80
V/B PKG UPPER STBD	748.30	10.18	5.70	7617.69	4265.31	1314.00	10.18	5.70	13376.52	7488.80
V/B SPHERE LOWER POR	237.00	6.78	1.42	1606.86	336.54	265.00	6.78	1.42	1796.70	376.30
V/B SPHERE LOWER STB	237.00	6.78	1.42	1606.86	336.54	265.00	6.78	1.42	1796.70	376.30
V/B BAGS AND OIL	774.00	10.10	3.67	7817.40	2840.58	900.00	10.10	3.67	9090.00	3303.00
V/B BXX AND OIL	310.00	5.15	1.00	1596.50	310.00	206.00	5.15	1.00	1060.90	206.00
V/B SPHERES PLUMBING	25.00	9.16	4.31	229.00	107.75	3.24	9.16	4.31	29.68	13.96
HG SPHERES FWD (2)	24.00	1.79	1.90	42.96	45.60	4.170	1.79	1.90	74.64	79.23
HG FRAME FWD	12.00	1.79	1.90	21.48	22.80	4.54	1.79	1.90	8.13	8.63
HG FRAME SYNT FWD	5.00	1.79	1.90	8.95	9.50	8.00	1.79	1.90	14.32	13.20
HG SPHERES AFT (2)	24.00	17.50	3.92	420.00	94.08	4.170	17.50	3.92	729.75	163.46
HG FRAME AFT	10.00	17.50	3.92	175.00	39.20	3.78	17.50	3.92	66.15	14.82
HG FWD	245.25	1.79	1.90	435.00	45.97	.00	1.79	1.90	.00	.00
HG AFT	245.25	17.50	3.92	4291.87	951.38	.00	17.50	3.92	.00	.00
HG SYSTEM PLUMBING	25.00	11.00	2.00	275.00	50.00	5.00	11.00	2.00	55.00	10.00
SKIDS & BELTS(2 STS)	46.50	8.67	.25	403.15	11.62	17.60	8.67	.25	152.59	4.40
CONTROL CENTER	293.00	10.21	4.63	2991.53	1336.59	209.00	10.21	4.63	2133.89	967.67
SPHERE REL. GUIDES(2)	19.00	4.50	1.20	85.50	22.80	2.50	4.50	1.20	11.25	3.00
SPHERES REL DGS, ET	33.00	4.50	1.20	148.50	39.60	4.36	4.50	1.20	19.62	5.23
SPHERE POSTLS & PADS	13.50	4.50	2.00	60.75	27.00	5.10	4.50	2.00	22.95	10.20
SPHERE RELEASE SHIMS	2.50	4.50	.50	11.25	1.25	.95	4.50	.50	4.27	.47
PROPULSION BXX & OIL	849.00	13.50	2.30	11461.50	1932.70	510.00	13.50	2.30	6885.00	1173.00
PROP BXX SUPPORTS	8.00	13.50	2.30	108.00	18.40	2.00	13.50	2.30	27.00	4.60
PROP BXX FRAME SUPP	3.00	13.50	2.30	40.50	6.90	1.00	13.50	2.30	13.50	2.30
FRAME REAR SPT STS	35.50	15.75	2.42	559.13	85.91	12.00	15.75	2.42	189.00	29.04
CONN HALVES LOWER	35.00	4.50	2.00	157.50	70.00	14.22	4.50	2.00	63.99	25.44
LIFT PRBP UNITS(2)	272.00	8.40	7.72	2284.80	2099.84	118.00	8.40	7.72	940.80	864.64
STERN PRBP ASSEMBLY	950.00	20.20	4.63	19190.00	4398.50	158.00	20.20	4.63	9251.60	2120.54
LIFT PRBP OIL	225.00	8.40	7.72	1890.00	1737.00	.00	8.40	7.72	.00	.00
LIFT PRBP BXX	55.00	10.25	7.72	563.75	424.60	10.00	10.25	7.72	102.50	77.20
STERN PRBP OIL	82.68	20.20	4.63	1670.14	382.81	.00	20.20	4.63	.00	.00
BATTERY & BXX FWD	1495.00	8.68	2.80	12976.60	4185.00	929.00	8.68	2.80	8063.72	2601.20
BATTERY & BXX MID	1495.00	10.00	2.80	14950.00	4186.00	929.00	10.00	2.80	929.00	2601.20
BATTERY & BXX AFT	1495.00	11.40	2.80	17043.00	4186.00	929.00	11.40	2.80	10590.60	2601.20
BATTERY CUTOFF COVER	44.50	10.21	.90	434.34	40.05	24.70	10.21	.90	252.19	22.23
BATTERY DRPS(2)FWD	56.00	8.68	3.03	486.08	169.68	7.15	8.68	3.25	62.06	23.24

ALVIN WEIGHT AND STABILITY COMPUTATIONS
AFTERBODY

IDENTIFICATION	W	X	Y	MX	MY	D	XP	YP	MXP	MP
FRAME	447.50	9.18	2.77	4108.05	1239.57	169.00	9.18	2.77	1551.42	468.13
LG BUGYANCY PKG	2475.00	14.42	5.25	35689.50	12993.75	4120.00	14.42	5.25	59410.40	21630.00
SM BUGYANCY PK CTR	516.00	10.25	6.33	5289.00	3266.28	946.00	10.25	6.33	9696.50	598.18
SIDE BUGYANCY PK(2)	410.00	10.40	6.75	4264.00	2767.50	656.00	10.40	6.75	6822.40	4428.00
V/BPKG UPPER PRT	748.30	10.18	5.70	7617.69	4265.31	1314.00	10.18	5.70	13376.52	7483.80
V/B PKG UPPER STED	748.30	10.18	5.70	7617.69	4265.31	1314.00	10.18	5.70	13376.52	7483.80
V/B SPHERE LOWER PDR	237.00	6.78	1.42	1606.86	336.54	265.00	6.78	1.42	1796.70	376.30
V/B SPHERE LOWER STB	237.00	6.78	1.42	1606.86	336.54	265.00	6.78	1.42	1796.70	376.30
V/B BAGS AND BIL	774.00	10.10	3.67	7817.40	280.58	500.00	10.10	3.67	9090.00	3303.00
V/B BXX AND BIL	310.00	5.15	1.00	1596.50	310.00	206.00	5.15	1.00	1060.90	206.00
V/B SPHERES PLUMBING	25.00	9.16	4.31	229.00	137.75	3.24	9.16	4.31	29.68	13.96
HG SPHERES FWD (2)	24.00	1.79	1.90	42.96	45.60	4.170	1.79	1.90	74.64	8.13
HG FRAME FWD	12.00	1.79	1.90	21.48	22.80	4.54	1.79	1.90	4.132	13.20
HG SPHERES SYNT FWD	5.00	1.79	1.90	8.95	9.50	8.00	1.79	1.90	14.32	14.82
HG SPHERES AFT	24.00	17.50	3.92	420.00	94.08	4.170	17.50	3.92	729.75	163.46
HG FRAME AFT	10.00	17.50	3.92	175.00	39.20	3.78	17.50	3.92	66.15	14.82
HG FWD	245.25	1.79	1.90	439.00	465.97	.00	1.79	1.90	.00	.00
HG AFT	245.25	17.50	3.92	4291.87	961.38	.00	17.50	3.92	.00	.00
HG SYSTEM PLUMBING	25.00	11.00	2.00	275.00	50.00	5.00	11.00	2.00	55.00	10.00
SKIDS & BELTS(2 STS)	46.50	8.67	.25	403.15	11.62	17.60	8.67	.25	152.59	4.40
CONTRAL CENTER	293.00	10.21	4.63	2991.53	1356.59	209.00	10.21	4.63	2133.89	947.67
SPHERE REL. GUIDES(2)	19.00	4.50	1.20	85.50	22.80	2.50	4.50	1.20	11.25	3.00
SPHERES REL DRGS, ET	33.00	4.50	1.20	148.50	39.60	4.36	4.50	1.20	19.62	5.23
SPHERE POSTLS & PADS	13.50	4.50	2.00	60.75	27.00	5.10	4.50	2.00	22.95	10.20
SPHERE RELEASE SHIMS	2.50	4.50	.50	11.25	1.25	.95	4.50	.50	4.27	.47
PROPULSION BXX & BIL	849.00	13.50	2.30	11461.50	1522.70	510.00	13.50	2.30	6885.00	1173.00
PRBP BXX SUPPRTS	8.00	13.50	2.30	108.00	18.40	2.00	13.50	2.30	2.00	4.60
PRBP BXX FRAME SUPP	3.00	13.50	2.30	0.50	16.90	1.00	13.50	2.30	13.50	2.30
FRANE REAR SPT STS,	35.50	15.75	2.42	559.13	85.91	12.00	15.75	2.42	189.00	29.04
CONN HALVES LOWER	35.00	4.50	2.00	157.50	70.00	14.22	4.50	2.00	63.99	28.44
LIFT PRBP UNITS(2)	272.00	8.40	7.72	2284.80	2399.84	112.00	8.40	7.72	940.80	864.64
STERN PRBP ASSEMBLY	950.00	20.20	4.63	19190.00	4398.50	458.00	20.20	4.63	9251.60	2120.54
LIFT PRBP 9IL	255.00	8.40	7.72	1890.00	1737.00	.00	8.40	7.72	.00	.00
LIFT PRBP BXX	55.00	10.25	7.72	563.75	424.60	10.00	10.25	7.72	102.50	77.20
STERN PRBP 9IL	82.68	20.20	4.63	1670.14	382.81	.00	20.20	4.63	.00	.00
BATTERY & BXX FWD	1495.00	8.68	2.80	12976.60	4186.00	929.00	8.68	2.80	8063.72	2601.20
BATTERY & BXX MID	1495.00	10.00	2.80	14950.00	4186.00	929.00	10.00	2.80	9290.00	2601.20
BATTERY & BXX AFT	1495.00	11.40	2.80	17043.00	4186.00	929.00	11.40	2.80	10530.60	2601.20
BATTERY CUTOUT COVER	44.50	10.21	.90	454.34	40.05	24.70	10.21	.90	22.19	22.23
BATTERY DROPS(2)FWD	56.00	8.68	3.03	486.08	169.68	7.15	8.68	3.25	62.06	23.24

ALVIN WEIGHT AND STABILITY COMPUTATIONS

AFTERBODY (CONTINUED)

IDENTIFICATION	W	X	Y	MX	MY	D	XP	YP	MXP	MYP
BATTERY DRPPS(2) MID	56.00	10.00	3.03	560.00	169.68	7.15	10.00	3.25	71.50	23.24
BATTERY DRPPS(2) AFT	56.00	11.40	3.03	638.40	169.68	7.15	11.40	3.25	81.51	23.24
BATTERY SYNTACTIC FW	57.50	8.68	1.10	498.10	53.25	92.00	8.68	1.10	798.56	101.20
BATTERY SYNTACTIC MI	57.50	10.00	1.10	575.00	63.25	92.00	10.00	1.10	920.00	101.20
BATTERY SYNTACTIC AF	57.50	11.40	1.10	655.50	63.25	92.00	11.40	1.10	1048.80	101.20
SPHERE SUP SYNTACTIC(2)	3.00	4.30	2.00	12.90	6.00	4.80	4.30	2.00	20.64	9.60
FRAME SYNTACTIC(9)	17.00	9.00	3.50	153.00	59.50	27.20	9.00	3.50	244.80	95.20
FRAME BBT SYNT STR 4	52.25	8.50	.30	444.13	15.67	83.60	8.50	.30	710.60	25.08
V/B BOX BRKT	1.50	17.50	5.00	26.25	7.50	.56	17.50	5.00	9.80	2.80
LWR BASKET HINGE (2)	4.50	4.00	.30	18.00	1.35	1.70	4.00	.30	6.80	.51
WT & BSKT REL BRKT 3	2.00	4.62	2.75	9.24	5.50	.76	4.62	2.75	3.51	2.09
V/B SPHERE BRAC (2)	2.00	6.78	1.42	13.56	2.84	.76	6.78	1.42	5.15	1.08
CTR V/B PKG BRAC 2	4.00	10.50	5.00	42.00	20.00	1.52	10.50	5.00	15.96	7.60
BUOY PKG HBLDDBWS 6	3.00	15.00	5.00	45.00	15.00	1.13	15.00	5.00	16.95	3.65
H0ISTING PIN	2.50	12.50	7.44	31.25	18.60	.95	12.50	7.44	11.87	7.07
FWD FRAME SIDE BBS(2)	22.50	7.00	1.50	157.50	33.75	11.90	7.00	1.50	83.30	17.85
FRAME SIDE BD SKIN(2)	11.50	7.00	1.50	80.50	17.25	6.10	7.00	1.50	42.70	9.15
TIE DOWNS (4)	20.00	13.50	4.67	270.00	93.40	7.40	13.50	4.67	99.90	34.56
HANDLING PADS(6)	15.00	8.00	6.50	120.00	97.50	1.98	8.00	6.50	15.84	12.87
BATTERY CHG CABLE TR	10.00	10.70	7.83	107.00	78.30	3.70	10.70	7.83	39.59	28.97
BATTERY CHG CABLES	14.50	10.70	7.67	155.15	111.21	7.25	10.70	7.67	77.57	55.61
MARSH MARINE CABLES	62.50	9.35	4.67	584.37	291.87	31.25	9.35	4.67	292.19	143.94
INSTRUMENT CASE	17.00	6.30	.83	107.10	14.11	3.34	6.30	.83	21.04	2.77
BTBTM WINDOW CONE	12.50	3.50	1.00	43.75	12.50	6.95	3.50	1.00	24.32	6.95
WEIGHT DRPPERS(3)	30.00	4.62	2.75	138.60	82.50	7.50	4.62	2.75	34.65	20.62
BATTERY RESERVEIR B0	182.00	7.00	1.40	1274.00	254.80	215.10	7.00	1.40	1505.70	301.14
BATTERY RES B0X BAG	32.00	7.00	1.40	224.00	44.80	17.80	7.00	1.40	124.60	24.92
BATTERY RES B0X BRKT	1.40	7.00	1.40	9.80	1.96	.37	7.00	1.40	2.59	.52
RUBBER GASKETS(3)	10.00	4.50	2.60	45.00	26.00	8.33	4.50	2.60	37.48	21.66
MISC PLUMBING	24.00	10.10	3.67	242.40	88.08	3.14	10.10	3.67	31.71	11.52

AFTERBODY

SUMMARY	NO. ITEMS	SUM W	S MXW	S MYW	SUM MX	SUM MY	SUM D	S MXP	S MYPD	SUM MXP	SUM MYP
	70	15867.93	11.21	3.89	177935.34	61750.04	15185.93	11.42	4.37	173431.92	66402.42
BG LONGITUDINAL		.21			BG VERTICAL	.48					

ALVIN WEIGHT AND STABILITY COMPUTATIONS

PAGE 7

VARIABLE LOAD(NORMAL)

IDENTIFICATION	W	X	Y	MX	MY	D	XP	YP	MXP	MYP
MECHANICAL ARM	438.55	-0.30	2.70	-131.56	1184.08	143.00	.00	2.70	.00	386.10
MECH ARM REL	96.50	.80	3.00	77.20	289.50	30.50	.80	3.00	24.40	91.50
MECH ARM CNTR BOX	3.00	1.00	7.00	3.00	21.00	.00	.00	.00	.00	.00
ARM OFFSET BRKTS	13.00	1.00	3.00	13.00	39.00	3.00	1.00	3.00	3.00	9.00
SAMPLE TRAY, TBLS	50.00	2.00	1.00	100.00	50.00	12.50	2.00	1.00	25.00	12.50
PERSONNEL (3)	500.00	5.86	4.13	2930.00	2065.00	.00	.00	.00	.00	.00
ASCENT WEIGHT	100.00	.39	2.75	39.00	275.00	9.00	.39	2.75	3.51	24.75
OTHER PAY LOAD	630.00	5.86	4.13	3691.80	2601.90	.00	.00	.00	.00	.00

VARIABLE LOAD(NORMAL)

SUMMARY	NO. ITEMS	SUM W	S MXW	S MYW	SUM MX	SUM MY	SUM D	S MXPD	S MYPD	SUM MXP	SUM MYP
8		1831.05	3.67	3.56	6722.43	6525.48	198.00	.28	2.65	55.91	523.85
BG LONGITUDINAL		-3.39			BG VERTICAL	-.92

Entire Vehicle (Normal Submerged)

ALVIN WEIGHT AND STABILITY COMPUTATIONS

RELEASED FOREBODY

IDENTIFICATION	W	X	Y	MX	MY	D	XP	YP	MXP	MYP
SPHERE ONLY	9837.97	4.37	4.68	42991.93	46041.70	10780.23	4.48	4.74	48295.43	51098.29
OTHER FOREBODY	5177.58	3.70	5.92	19157.05	30651.27	6585.14	3.40	5.79	22287.48	37954.26
PERSONNEL (3)	500.00	5.86	4.13	2930.00	2065.00	.00	.00	.00	.00	.00
MECH ARM CONTR. 88X.	3.00	1.00	7.00	3.00	21.00	.00	.00	.00	.00	.00

RELEASED FOREBODY

SUMMARY	NO. ITEMS	SUM W	S	MX _W	S	MY _W	S	MX	SUM MX	SUM MY	SUM D	S	MXPD	S	MYPD	SUM MXP	SUM MYP
4		15518.55		4.19		5.08		65081.97		78778.97	17335.37		4.07		5.14	70582.91	89052.55
BG LONGITUDINAL								BG VERTICAL									
										.06

Released Forebody

ALVIN WEIGHT AND STABILITY COMPUTATIONS

EMERGENCY CONDITIONS (1)

IDENTIFICATION	W	X	Y	MX	MY	D	XP	YP	MXP	MYP
IN NORMAL CONDITION	32714.53	7.54	4.43	24667.56	144925.37	32719.30	7.46	4.77	244085.98	156071.06
BLOW MAIN BALLAST	-1493.76	4.50	6.00	-6721.92	-8962.56	.00	.00	.00	.00	.00

EMERGENCY CONDITIONS (1)

SUMMARY	NB, ITEMS	SUM W	S	MXW	S	MYW	S	MX	SUM MX	SUM MY	SUM D	S	MXPD	S	MYPD	S	MXPD	SUM MXP	SUM MYP		
	2	31220.77		7.69		4.35		239945.64		135962.81		32719.30		7.46		4.77		244085.98		156071.06	
BG LONGITUDINAL										BG VERTICAL											
										.42											

BG LONGITUDINAL -.23 BG VERTICAL .42

ALVIN WEIGHT AND STABILITY COMPUTATIONS

EMERGENCY CONDITIONS (2)

IDENTIFICATION	W	X	Y	MX	MY	D	XP	YP	MXP	MYP
IN NORMAL CONDITION	32714.53	7.54	4.43	246667.56	144925.37	32719.30	7.46	4.77	244085.98	156071.06
DREP HG FWD	-245.25	1.79	1.90	-439.00	-455.97	.00	.00	.00	.00	.00
DREP HG AFT	-245.25	17.50	3.92	-4291.87	-951.38	.00	.00	.00	.00	.00

EMERGENCY CONDITIONS (2)

SUMMARY	NO. ITEMS	SUM W	S	MXW	S	MYW	S	MX	SUM MX	SUM MY	SUM D	S	MXPD	S	MYPD	SUM MXP	SUM MYP
3		32224.03		7.51		4.45		241936.68		143498.01	32719.30		7.46		4.77	244085.98	156071.06
BG LONGITUDINAL								BG VERTICAL		.32

Emergency Conditions (2)

ALVIN WEIGHT AND STABILITY COMPUTATIONS

EMERGENCY CONDITIONS (3)

IDENTIFICATION	W	X	Y	MX	MY	D	XP	YP	MXP	MYP
IN NORMAL CONDITION	32714.53	7.54	4.43	246667.56	144925.37	32719.30	7.46	4.77	244085.98	156071.06
DROP MID BATTERY	-1495.00	10.00	2.80	-14950.00	-4186.00	-929.00	10.00	2.80	-9290.00	-2601.20

EMERGENCY CONDITIONS (3)

SUMMARY	NO. ITEMS	SUM W	S MXW	S MYW	SUM MX	SUM MY	SUM D	S MXP	S MYP	SUM MXP	SUM MYP
	2	31219.53	7.42	4.51	231717.56	140739.37	31790.30	7.39	4.83	234795.98	153469.86

BG LONGITUDINAL -0.04

BG VERTICAL .32

Emergency Conditions (3)

EMERGENCY CONDITIONS (4)

IDENTIFICATION	W	X	Y	MX	MY	D	XP	YP	MXP	MYP
IN NGRML CONDITON	32714.53	7.54	4.43	246667.56	144925.37	32719.30	7.46	4.77	244035.98	156071.06
DRBP FWD BATTERY	-1495.00	8.68	2.80	-12976.60	-4186.00	-329.00	8.68	2.80	8083.72	-2501.20
DRBP AFT BATTERY	-1495.00	11.40	2.80	-17043.00	-4186.00	-329.00	11.40	2.80	-10590.60	-2401.20

EMERGENCY CONDITIONS (4)

SUMMARY	NO. ITEMS	SUM W	S	MXW	S	MYW	SUM MX	SUM MY	SUM D	S	MXPD	S	MYPD	SUM MXP	SUM MYP
	3	29724.53		7.29		40.59	216647.96	136553.37	30861.30		7.30		40.89	225431.66	150888.66
BG LONGITUDINAL															
BG VERTICAL															
.02															
.29

ALVIN WEIGHT AND STABILITY COMPUTATIONS

EMERGENCY CONDITIONS (5)

IDENTIFICATION	W	X	Y	MX	MY	D	XP	YP	MXP	MYP
IN NORMAL CONDITION	32714.53	7.54	4.43	246667.56	144925.37	32719.30	7.46	4.77	244085.98	156071.06
DR8P FWD BATTERY	-1495.00	8.68	2.80	-12976.60	-4186.00	-929.00	8.68	2.80	-8063.72	-2601.20
DR8P MID BATTERY	-1495.00	10.00	2.80	-14950.00	-4186.00	-929.00	10.00	2.80	-9290.00	-2601.20
DR8P AFT BATTERY	-1495.00	11.40	2.80	-17043.00	-4186.00	-929.00	11.40	2.80	-10550.60	-2601.20

EMERGENCY CONDITIONS (5)

SUMMARY	NB. ITEMS	SUM W	S	MXW	S	MYW	S	MX	SUM MX	SUM MY	SUM D	S	MXPD	S	MYPD	S	MXPD	SUM MXP	SUM MYP
4		28229.53		7.14		4.69		201697.96		132367.37		29332.30		7.22		4.95		21614.66	
BG LONGITUDINAL								BG VERTICAL											

BG LONGITUDINAL .08

BG VERTICAL .26

Emergency Conditions (5)

ALVIN WEIGHT AND STABILITY COMPUTATIONS

EMERGENCY CONDITIONS (6)

IDENTIFICATION	W	X	Y	MX	MY	D	XP	YP	MXP	MYP
IN NORMAL CONDITION	32714.53	7.54	4.43	246667.56	144225.37	32719.30	7.46	4.77	244085.98	156071.06
DROP HG FWD	-245.25	1.79	1.90	-439.00	-465.97	.00	.00	.00	.00	.00
DROP HG AFT	-245.25	17.50	3.92	-4291.87	-951.38	.00	.00	.00	.00	.00
DROP FWD BATTERY	-1495.00	8.68	2.80	-12976.60	-4186.00	-929.00	8.68	2.80	-8063.72	-2601.20
DROP MID BATTERY	-1495.00	10.00	2.80	-14950.00	-4186.00	-929.00	10.00	2.80	-9290.00	-2601.20
DROP AFT BATTERY	-1495.00	11.40	2.80	-17043.00	-4186.00	-929.00	11.40	2.80	-10590.60	-2601.20

EMERGENCY CONDITIONS (6)

SUMMARY	NO. ITEMS	SUM W	S MXW	S MYW	SUM MX	SUM MY	SUM D	S MXP	S MYP	SUM MXP	SUM MYP
	6	27739.03	7.10	4.72	196967.08	130940.01	29332.30	7.22	4.95	216141.66	148267.46
SG LONGITUDINAL			.12		BG VERTICAL	.23

Emergency Conditions (6)

ALVIN WEIGHT AND STABILITY COMPUTATIONS

EMERGENCY CONDITIONS (7)

IDENTIFICATION	W	X	Y	MX	MY	D	XP	YP	MXP	MYP
IN NORMAL CONDITION	32714.53	7.54	4.43	246667.56	144925.37	32719.30	7.46	4.77	244085.98	156071.06
DR8P HG FWD	-245.25	1.79	1.90	-439.00	-465.97	.00	.00	.00	.00	.00
DR8P HG AFT	-245.25	17.50	3.92	-4291.87	-961.38	.00	.00	.00	.00	.00
DR8P FWD BATTERY	-1495.00	8.68	2.80	-12976.60	-4186.00	-929.00	8.68	2.80	-8063.72	-2601.20
DR8P MID BATTERY	-1495.00	10.00	2.80	-14950.00	-4186.00	-929.00	10.00	2.80	-9290.00	-2601.20
DR8P AFT BATTERY	-1495.00	11.40	2.80	-17043.00	-4186.00	-929.00	11.40	2.80	-10590.60	-2601.20
DR8P ARM	-438.55	-0.30	2.70	131.56	-1184.08	-143.00	.00	2.70	.00	-386.10

EMERGENCY CONDITIONS (7)

SUMMARY	NO. ITEMS	SUM W	S	MXW	S	MYW	SUM MX	SUM MY	SUM D	S	MXPD	S	MYPD	SUM MXP	SUM MYP
	7	27300.48		7.22		4.75	197098.65	129755.93	29789.30		7.26		4.96	216141.66	147881.36

BG LONGITUDINAL 04

BG VERTICAL 21

Emergency Conditions (7)

ALVIN WEIGHT AND STABILITY COMPUTATIONS

EMERGENCY CONDITIONS (8)

IDENTIFICATION	W	X	Y	MX	MY	D	XP	YP	MXP	MYP
IN NORMAL CONDITION	32714.53	7.54	4.43	246667.56	144925.37	32719.30	7.46	4.77	244085.98	156071.06
V/B GIL TO BAGS	.00	.00	.00	.00	.00	290.00	10.10	3.67	2929.00	1064.30
FL880 V/B SPHERES	1416.00	9.43	4.75	13352.88	6726.00	.00	.00	.00	.00	.00
DR8P HG FWD	-245.25	1.79	1.90	-439.00	-455.97	.00	.00	.00	.00	.00
DR8P HG AFT	-245.25	17.50	3.92	-4291.87	-961.38	.00	.00	.00	.00	.00
DR8P FWD BATTERY	-1495.00	8.68	2.80	-12976.60	-4186.00	-929.00	8.68	2.80	-8063.72	-2601.20
DR8P MID BATTERY	-1495.00	10.00	2.80	-14950.00	-4186.00	-929.00	10.00	2.80	-9290.00	-2601.20
DR8P AFT BATTERY	-1495.00	11.40	2.80	-17043.00	-4186.00	-929.00	11.40	2.80	-10590.60	-2601.20
DR8P ARM	-438.55	-1.30	2.70	131.56	-1184.08	-143.00	.00	2.70	.00	-385.10

EMERGENCY CONDITIONS (8)

SUMMARY	NO. ITEMS	SUM W	S MXW	S MYW	SUM MX	SUM MY	SUM D	S MXPD	S MYPD	SUM MXP	SUM MYP
9		28716.48	7.33	4.75	210451.53	136431.33	30079.30	7.28	4.95	219070.66	148945.66
BG LONGITUDINAL		-0.05			BG VERTICAL	.20

Emergency Conditions (8)

III. Inclining Experiments and Trim Dive

- A. Description of Tests For purposes of certification of the submarine by the U.S. Naval Ship Systems Command, a series of post-refit dockside trials was held in Woods Hole on May 18, 1971. Those tests concerned with stability were the surface inclining experiment, the submerged inclining experiment, and the trim dive. Surface and submerged inclining data were obtained by moving known weights, already aboard, through a known distance perpendicular to a vertical plane through the vehicle's longitudinal axis. After each movement of weights the submarine was allowed to settle in an equilibrium position, and the angle of inclination was measured. The weights were distributed so that three different angles of inclination were obtained, both port and starboard. From the test data, the inclining moments were calculated and these, together with the inclinometer readings, were used to prepare the plot of tangents for each of the tests. The slope of the plot of tangents was then used in determining the GM or BG value. Along with each inclining experiment the method of induced rolling or "sallying" was employed as a check on the inclining data. The observed roll period and the estimated value of radius of gyration of the vehicle together were used to calculate GM and BG.

The trim dive is essentially a test to determine the "load to submerge", or the load which must be added to the normal surfaced submarine to achieve submerged neutral buoyancy. The flooding of main ballast is included in this load as well as (for large submarines) normal fuel oil and fuel ballast tanks. Variable ballast is intended to serve as a fine adjustment of the load to submerge. In the case of ALVIN, only additional lead weights, plus an adjustment of variable ballast, were used after flooding main ballast.

The data, calculations, and results obtained in the certification trials are presented in this section. The plots of tangents are shown in Figures 4 and 5.

B. Experimental Data and Results

Surface Inclining Experiment

The following information is taken from the original data sheets for this experiment, which was performed in Woods Hole on May 18, 1971.

1. Preliminary Data

- a. Inclining weights: 10 lead blocks weighing each 21.3 pounds in air, 19.6 pounds in water. Total weight in air 213 pounds, in water 196 pounds.
- b. Three persons aboard-weight 500 pounds
- c. Inclinator mounted inside pressure hull (Electric Boat Co. Inclinator No. EB43008).
- d. Arm compensator weight: 20 weights @ 21.3 pounds or 426 pounds air weight.
- e. Ascent weights: 213 pounds port and 213 pounds starboard suspended from weight droppers, 6.55 ft. aft of forward perpendicular.
- f. Main ballast blown.
- g. Variable ballast oil: all in hard tanks.
- h. Mercury trim: 50 percent fwd., 50 percent aft
- i. Water sample: temperature 53°F
density 63.39 pounds per cu. ft.
- j. Moment arm for inclining weights: 3.5 ft.
- k. Vehicle displacement: 31,008 pounds.
- l. Vehicle draft: 7'5" port fwd.
7'6" port aft
7'4" stbd. fwd.
7'5" stbd. aft
- m. Location of inclining weights: 3 ft. 8 in. aft of forward perpendicular.

2. Moments and Angles

Net wt. pounds	Moment ft.-lbs.	Tan of angle θ
213 P	745	.0400, .0409
127.8 P	448	.0250, .0223
42.6 P	149	.0117 *
0	0	.0080, .0028*
42.6 S	149	.0090, .0088
127.8 S	448	.0242, .0238
213 S	745	.0400

3. Calculation of GM from Inclining Data

$$\begin{aligned}
 GM &= \frac{wxd}{Wx \tan \theta} \\
 &= \frac{1}{W} \times (\text{Slope of plot of tangents}) \\
 &= \frac{18650}{31008} = 0.60 \text{ ft.}
 \end{aligned}$$

* Deleted

DSRV ALVIN Surface Inclining Experiment

May 18, 1971

Figure 4. Plot of Tangents for Surface Inclining Experiment

4. Calculation of GM from Roll Period

Trial No.	Period T (sec.)
1	4.5
2	4.2
3	4.4
4	4.8
<hr/>	
	17.9 Total

$$\text{Average T} = 4.48$$

$$T^2 = 20.1$$

$$\text{Estimated radius of gyration, K} = 3$$

$$K^2 = 9$$

Then

$$GM = \frac{1.23 K^2}{T^2}$$

$$= \frac{1.23(9)}{20.1} = 0.55 \text{ ft.}$$

Trim Dive

The trim dive was conducted immediately following the surface inclining experiment, and began with the vehicle in the condition it had been in for that test. To cause the vehicle to submerge it was necessary to flood the main ballast tanks and add 10 additional lead weights of the type used for inclining weights. These were added aft of the conning tower, port and starboard, 9 feet aft of the forward perpendicular. The following is a weight summary for the trim dive:

Light ship - with lead	31,008 lbs.
MBT flooded	1,494 lbs.
Ten added lead weights	<u>213 lbs.</u>
Total displacement	32,715 lbs.

To achieve submerged equilibrium about 10 percent of variable ballast oil was pumped to the V/B bags

The load to submerge is then:

$$1494 + 213 = 1707 \text{ lbs.}$$

Water Sample: temperature 53°F
density 63.39 pounds per cu. ft.

Submerged Inclining Experiment

The following information was taken from the original data sheets for this experiment, which was performed in Woods Hole on May 18, 1971.

1. Preliminary Data - preliminary data for this test were the same as those for the surface inclining experiment except for the following:
 - a. Vehicle displacement: 32,715 pounds
 - b. Main ballast: flooded

- c. Draft: Vehicle was completely submerged with the top of the conning tower just under the surface.
- d. Vehicle was neutrally buoyant. To achieve this, an additional 213 pounds (air weight) of lead were placed aboard the vehicle, equally divided, port and starboard, aft of the inclining weights (about 9 ft. aft of forward perpendicular).

2. Moments and Angles

Net wt. pounds	Moment ft.-lbs.	Tan of angle θ
0	0	0
78.4 S	274	.0215
156.8 S	549	.0465
196 S	686	.0580
156.8 S	549	.0470
78.4 S	274	.0245
0	0	.0005
78.4 P	274	.0240
156.8 P	549	.0460
196 P	686	.0570

3. Calculation of BG from Inclining Data

$$\begin{aligned}
 BG &= \frac{wxd}{Wx \tan \theta} \\
 &= \frac{1}{W} \times (\text{slope of plot of tangents}) \\
 &= \frac{11830}{32715} = 0.36 \text{ ft.}
 \end{aligned}$$

DSRV ALVIN
Submerged Inclining
Experiment
May 18, 1971

Figure 5. Plot of Tangents for Submerged Inclining Experiment

4. Calculation of BG from Roll Period

<u>Trial No.</u>	<u>Period T (sec.)</u>
1	8
2	8
3	7.5
4	7
	<hr/>
	30.5 Total
	Average T = 7.63
	$T^2 = 58.2$

Estimated radius of gyration, $K = 4.4$

$$K^2 = 19.4$$

Then

$$\begin{aligned} BG &= \frac{1.23 K^2}{T^2} \\ &= \frac{1.23 (19.4)}{58.2} = 0.41 \text{ ft.} \end{aligned}$$

IV. Discussion

Table 1 presents calculated and experimental values of stability figures for ALVIN at this time. Results show that ALVIN's stability while on the surface has been reduced about 25 percent below the 1967 value (Ref. 1). However, submerged stability is essentially unchanged. Probable reasons for this are a) the addition of new syntactic foam buoyancy material on the upper part of the vehicle aft of the conning tower, and b) the presence of the newly designed lift propulsion box on the upper skin just aft of the conning tower. Both of these items are at least partly out of water when the vehicle is on the surface, and their weight tends to decrease stability. When the vehicle is submerged, the syntactic material provides positive buoyancy, and the propulsion box weighs somewhat less. Both effects would be favorable to submerged stability.

During early trials of the newly assembled ALVIN, but after the inclining experiments had been performed, it became apparent that a portion of the new syntactic foam (upper skin, aft of conning tower) was interfering with the efficient performance of the lift propellers and would have to be removed. Approximately 25 percent of these buoyancy blocks was cut away to provide a more natural flow of water through and past the lift propeller ducts. The weight and stability calculations reflect this modification but the inclining experiment results do not.

Because the inclining experiments were performed before the complete list of all small items aboard ALVIN (especially those inside the personnel sphere) had been obtained, the final calculated weight of the submarine was found to be some 300 pounds heavier than the estimated value used at the time of the tests. For purposes of this report, the inclining experiment and trim dive data have been reworked using the later, more correct value of vehicle displacement.

The stability of the released forebody is seen to be positive although the vertical component of the BG value is quite small. Also, the negative value of the longitudinal component of BG causes a significant nose-up angle (see diagram for released forebody). While the foregoing describes a static equilibrium condition, the forebody actually would move upward through the water after release. It is likely that hydrodynamic drag on the sail structure would cause the forebody to overturn during the ascent.

Table I

ALVIN Stability: Computed and Experimental Values

	Entire Vehicle		Released Forebody
	BG ¹ vertical, feet	GM ² transverse, feet	BG vertical, feet
Computed	0.34		0.06
Experimental (Inclining Data)	0.36	0.60	
Experimental (Roll Period)	0.41	0.55	

(1) Vehicle in "normal submerged" condition

(2) Vehicle in "normal surfaced" condition

V. References

1. "Weight, Buoyancy and Stability of DSRV ALVIN, 1967," by Arnold G. Sharp and Clifford L. Winget, W.H.O.I. Technical Memorandum DS-26, January 1968.
2. "ALVIN Inclining Experiments, Preliminary Report," by Arnold G. Sharp and Clifford L. Winget, Woods Hole Oceanographic Institution, Woods Hole, Mass., May 25, 1971.

VI. Appendix

Computer Program

NAME: ALVINSTA

TYPE: Main Program

PURPOSE: To compute total weight and total displacement of the DSV ALVIN in its normal and various emergency conditions; weight and displacement of various subassemblies (sphere, forebody, etc.); location of center of gravity and center of buoyancy for the vehicle and for subassemblies; BG distance for the vehicle and for subassemblies expressed in longitudinal and vertical components. The program has an optional plot tape output to give graphic representation of submersibles attitude under the various conditions.

MACHINE: XDS Sigma 7

SOURCE LANGUAGE: XDS Fortran IV

PROGRAM CATEGORY: Data Processing

DESCRIPTION:

A full description and an example of the input/output data may be found in W.H.O.I. Technical Memorandum DS-26, WEIGHT, BUOYANCY AND STABILITY OF DSRV ALVIN, 1967, Arnold G. Sharp, January 1968.

INPUT: Punched cards. For each section of data there is one set of data cards of the following form:

Card 1 28 character alphanumeric title

Succeeding Data cards of the following format:
cards (up
to 500) Columns

1-20	20	Char. Alphanumeric Identifier
22-29	W	Item air weight
31-35	X	CG X Distance
37-41	Y	CG Y Distance
43-50	D	Displacement of Item

52-56	XP	B X Distance
58-62	YP	B Y Distance
64	C	Control Integer

Last Card !EOD (After each data section)

OUTPUT: On the line printer. Please see Technical Memorandum DS-26 for format and example program output. On calcomp plotter. Graphic representation of ALVIN in the attitude calculated by the program for a given data section.

USAGE: The deck is set up

```
!JOB ----, ----
!MESSAGE PLOT TAPE (if needed)
!ASSIGN F:PLOT,(DEVICE,7T), (BIN), (OUTSN,
      PLT1), (OUT), (UNPACK)
!FORTRAN LS,GO,X*
      (Fortran deck of ALVINSTA)
!DATA
      (Permanent data deck)
      (Data cards as described above)
      *Use "X" option only if plot is desired
```

RESTRICTIONS:

1. Column 64 contains 0 (zero) on all but the last data card in each section (before !EOD card)
2. A (2) in column 64 of the last data card causes plot output for that section.
3. A (3) in column 64 of the last data card indicates last section and terminates program. Plot will be output for last section unless "X" option was not specified on !FORTRAN card.

STORAGE REQUIREMENTS: About 5000₁₀ words

SUBPROGRAMS REQUIRED: AXDRAW, PLOT, SYMBOL

OPERATIONAL ENVIRONMENT:

<u>Device</u>	<u>Function</u>	<u>Special requirements</u>
card reader	input	F:105 DCB
line printer	output	F:108 DCB
7 track tape	output	F:PLOT DCB

OPERATIONAL CHARACTERISTICS:

Reads a data section then prints and writes tape (if called for).

TIMING: About 2 1/2 min. for typical large job w/plot

PROGRAMMER: Andy Eliason

ORIGINATOR: Arnold Sharp

DATE: July, 1971

REFERENCE: Technical Memorandum DS-26

```

1: C      ALVIN WEIGHT AND STABILITY PROGRAM
2: C      JUNE 1971
3: C      PROGRAMMER: ANDREW H. ELIASON
4: C
5: C      USE X OPTION FOR CALCULATION WITH PLOT
6: C
7:      IMPLICIT DOUBLE PRECISION (A-H, O-Z)
8:      REAL X2, Y2
9: X      COMMON      IBUF(1000)
10:      COMMON      ARRAY1(500)
11:      COMMON      ARRAY2(500)
12: X      COMMON      ARRAY3(500)
13: X      COMMON      ARRAY4(500)
14: X      SCALE= 500.0
15:      COMMON      IDEN(300,5), ID(7)
16:      DIMENSION X(300), Y(300), W(300), D(300), XP(300), YP(300), C(300)
17:      100 FORMAT(5A4, 1X, F8.2, 2(1X, F5.2), 1X, F8.2, 2(1X, F5.2), 1X, I1)
18:      200 FORMAT(46X, 'ALVIN WEIGHT AND STABILITY COMPUTATIONS', 35X, 'PAGE ', I
19:      11/)
20:      250 FORMAT(46X, 7A4/)
21:      260 FORMAT(46X, 7A4, ' (CONTINUED)', /)
22:      300 FORMAT(3X, 'IDENTIFICATION', 11X, 'W', 9X, 'X', 8X, 'Y', 9X, 'MX', 10X, 'MY',
23:      11X, 'D', 9X, 'XP', 7X, 'YP', 8X, 'MXP', 9X, 'MYP', /)
24:      400 FORMAT(1X, 5A4, 4X, F8.2, 2(4X, F5.2), 3(3X, F9.2), 2(4X, F5.2), 2(3X, F9.2))
25:      500 FORMAT(/, 'SUMMARY   NO. ITEMS', 6X, 'SUM W', 4X, 'S MXW', 4X, 'S MYW',
26:      16X, 'SUM MX', 6X, 'SUM MY', 7X, 'SUM D', 5X, 'S MXP', 3X, 'S MYP', 4X, 'SUM
27:      1 MXP', 5X, 'SUM MYP')
28:      600 FORMAT(14X, I3, 8X, F8.2, 2(4X, F5.2), 3(3X, F9.2), 2(4X, F5.2), 2(3X, F9.2))
29:      700 FORMAT(/, 10X, 'BG LONGITUDINAL', 5X, F5.2, 20X, 'BG VERTICAL', 5X, F5.2)
30:      800 FORMAT('1')
31:      900 FORMAT(7A4)
32:      950 FORMAT(/, 1X, 7A4)
33: C*****
34: C      READ ALVIN PICTURE DATA
35:      M=1
36:      15 M1=M+3
37:      READ(105, 105, END=55) (ARRAY1(I), ARRAY2(I), I=M, M1)
38:      105 FORMAT(4(5X, I6, 2X, I6, 1X))
39:      M=M+4
40:      GO TO 15
41:      55 CONTINUE
42:      M=M-4
43: C*****
44: C      READ SECTION TITLE AND DATA
45:      IPAGE = 1
46:      5 N=1
47:      READ(105, 900) ID
48:      10 READ(105, 100, END=20) (IDEN(N, J), J=1, 5), W(N), X(N), Y(N), D(N), XP(N),
49:      1 YP(N), C(N)
50:      N=N+1
51:      GO TO 10
52:      20 N=N-1, WRITE(108, 200) IPAGE, WRITE(108, 250) ID, WRITE(108, 300)

```

```

53:      ITEM = 1
54:      SW=0.0,SRXW=0.0,SRYW=0.0,SRX=0.0,SRY=0.0,SD=0.0,SRXPD=0.0,SRYPD=0.0,
55:      SRXP=0.0,SRYP=0.0
56: C      CALCULATE RESULTS
57:      DO 30 I=1,N
58:      RX=W(I)*X(I),RY=W(I)*Y(I)
59:      RXP=D(I)*XP(I),RYP=D(I)*YP(I)
60:      SW=W(I)+SW,SD=D(I)+SD
61:      SRX=SRX+RX,SRY=SRY+RY,SRXP=SRXP+RXP,SRYP=SRYP+RYP
62:      SRXW=SRX/SW,SRYW=SRY/SW
63:      SRXPD=SRXP/SD,SRYPD=SRYP/SD
64:      BGL=SRXPD-SRXW,BGV=SRYPD-SRYW
65:      WRITE(108,400)(IDEN(I,J),J=1,5),W(I),X(I),Y(I),RX,RY,D(I),XP(I),
66:      1 YP(I),RXP,RYP
67:      IF(ITEM.EQ.40.0R,ITEM.EQ.80.0R,ITEM.EQ.120)IPAGE=IPAGE+1,WRITE(108
68:      1,800),WRITE(108,200)IPAGE,WRITE(108,260)ID,WRITE(108,300)
69:      ITEM=ITEM+1
70: 30 CONTINUE
71: C      PRINT RESULTS
72:      WRITE(108,950)ID
73:      WRITE(108,500)
74:      WRITE(108,600)N,SW,SRXW,SRYW,SRX,SRY,SD,SRXPD,SRYPD,SRXP,
75:      1SRYP,WRITE(108,700)BGL,BGV,WRITE(108,800),IPAGE=IPAGE+1
76: C*****
77: C      CALCULATE PICTURE ROTATION DATA
78: X      IF(C(N).LT.2) GO TO 80
79: X      THETA =DATAN2(SRXPD-SRXW,SRYPD-SRYW)
80: X      DO 25 I=1,M
81: X      IF(ARRAY2(I).GT.3000) ARRAY4(I)= 10500, GO TO 25
82: X      X1= ARRAY1(I)
83: X      Y1= ARRAY2(I)
84: X      GAMMA=DATAN2(Y1,X1)
85: X      R =DSQRT(X1**2+Y1**2)
86: X      A = GAMMA + THETA
87: X      X1= R*DCOS(A)
88: X      Y1= R*DSIN(A)
89: X      ARRAY3(I)=X1
90: X      ARRAY4(I)=Y1
91: X 25 CONTINUE
92: C*****
93: C      PLOT ALVIN PICTURE
94: X      CALL PLOTS(IBUF,-1000)
95: X      CALL PLOT(10.0,10.0,-3)
96: X      CALL AXDRAW(-6.0,0.0,'X',1,16.0,0.0,6.0,1.0,1.0,-1)
97: X      CALL AXDRAW(0.0,-4.0,'Y',-1,10.0,90.0,4.0,1.0,1.0,-1)
98: X      CALL SYMBOL(-7.0,-9.0,21,1,0,28)
99: X      DO 75 I=1,M
100: X      IPEN=2
101: X      IF(I.EQ.1.0R,IFLAG.EQ.1) IPEN=3,GO TO 65
102: X      IF(ARRAY4(I).GT.10000)IFLAG=1,GO TO 75
103: X 65 X2= ARRAY3(I)/SCALE
104: X      Y2= ARRAY4(I)/SCALE
105: X      CALL PLOT(X2,Y2,IPEN)
106: X      IFLAG=0
107: X 75 CONTINUE
108: X      CALL PLOT(20.0,-10.0,999)
109: C*****
110: 80 CONTINUE
111: C      CHECK FOR LAST CARD
112:      IF(C(N).EQ.3)GO TO 40
113:      GO TO 5
114: 40 CALL EXIT
115:      END

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