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TECHNICAL MEMORANDUM NO. 6-73

DSRV ALVIN WEIGHT REPORT, 1973

Arnold G. Sharp and
Kenneth W. Doherty

December 1973

Office of Naval Research Contract
N00014-73-C-0097; NR 265-107.

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Memo. 6-73
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WOODS HOLE OCEANOGRAPHIC INSTITUTION
Woods Hole, Massachusetts 02543

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DSRV ALVIN WEIGHT REPORT, 1973

prepared by

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ABSTRACT

Weight and stability computations are presented for the research submarine ALVIN following the installation, early in 1973, of the new titanium alloy pressure hull built by the U.S. Navy under "Project Titanes." Longitudinal and vertical components of the BG distance are shown for the vehicle in its normal submerged condition, and for a number of emergency conditions. Calculations for pounds per inch immersion and moment to heel one degree also are included. Results of the post-refit dockside trials are presented and discussed.

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I. Introduction

The following pages contain the weight and stability report for the research submarine ALVIN for the year 1973. While the emphasis mainly is on the computed weight and stability figures, the report also contains a discussion of the post refit trials which were performed at dockside in Woods Hole.

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.

The major change to the submarine prior to the 1973 operating season was the installation of the new titanium alloy pressure hull. This sphere, fabricated from titanium alloy 6Al-2Cb-1Ta-0.8Mo, was built by the U.S. Navy under the Deep Ocean Technology Program's, "Project Titanes." Outside

dimensions of the unit were made the same as those of the original steel sphere, to minimize installation difficulties. The wall thickness of the new hull is 1.93 in., about 45 percent greater than that of the steel sphere. The design operating depth for the new hull is 12,000 ft. and yet its weight is some 1400 pounds less than the 6,000 ft. steel sphere. It is expected that this weight difference will result in a significant increase in ALVIN's payload.

A second modification to the vehicle was the replacement of the old after fixed buoyancy packages (a combination of titanium spheres and syntactic foam) by a new single package made entirely of syntactic foam. The new unit weighs 2310 pounds, 165 pounds less than the original, and provides additional buoyancy to the after part of the boat to help solve the trim problem created by the rather large added buoyancy forward.

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

1. Pressure hull plus contents
2. Other forebody
3. Afterbody
4. Variable load
5. Entire vehicle

6. Released forebody
7. 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 tanks are three-quarters flooded, and the trim mercury is divided 50 percent forward and 50 percent aft.

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.

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

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

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

D - displacement of item, lbs. of seawater

XP - distance of center of buoyancy of item from forward perpendicular, feet (positive XP means aft of F.P.)

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 bow-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.)

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

7. BG longitudinal = XPD - XW

8. BG vertical = YPD - YW

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 INSRIS	5081.54	4.97	4.89	25255.25	24848.73	10604.08	4.50	4.75	47718.36	50369.38
HULL INSERT FWD	383.78	1.14	4.75	437.51	1822.95	14.77	1.14	4.75	16.84	70.16
HULL INSERT BBT	386.28	3.72	1.42	1436.96	548.52	14.77	3.72	1.42	54.94	20.97
HULL INSERT PORT	337.29	2.39	3.46	925.62	1340.02	14.77	2.39	3.46	35.30	51.10
HULL INSERT STBD	385.54	2.39	3.46	921.44	1333.97	14.77	2.39	3.46	35.30	51.10
HATCH INSERT	261.53	4.50	8.11	1176.88	2121.01	19.28	4.50	8.11	41.76	75.26
WINDSW FWD	9.02	1.14	4.75	10.28	42.84	3.48	1.14	4.75	3.97	16.53
WINDSW BBT	9.02	3.72	1.44	33.55	12.99	3.48	3.72	1.44	12.95	5.01
WINDSW P'S	13.04	2.39	3.46	43.12	62.42	6.96	2.39	3.46	16.63	24.08
WINDSW RET RING FWD	4.80	1.14	4.75	5.47	22.80	1.09	1.14	4.75	1.24	5.18
WINDSW RET RING BBT	4.80	3.72	1.30	17.86	6.24	1.09	3.72	1.30	4.05	1.42
WIND RET RINGS P'S	9.60	2.39	3.46	22.94	33.22	2.18	2.39	3.46	5.21	7.54
SPHERE REL UPPER	48.50	4.50	1.33	218.25	64.50	5.49	4.50	1.21	24.70	6.64
HATCH	199.34	4.50	8.11	897.03	1616.65	11.37	4.50	8.11	51.16	92.21
HINGE ARMS	4.57	4.21	8.28	19.24	37.84	1.05	4.21	8.28	4.42	8.69
HINGE SHAFT	3.25	4.00	8.28	13.00	26.91	.75	4.00	8.28	3.00	6.21
INSIDE HANDLE	2.57	4.91	7.94	20.41	20.41	.00	.00	.00	.00	.00
OUTSIDE HANDLE	5.14	4.91	8.28	25.24	42.56	1.18	4.91	8.28	5.79	9.77
SPRING RETAINER	2.67	4.14	8.28	11.05	22.11	.61	4.14	8.28	2.53	5.05
INT SWING CLAMP	1.52	4.60	7.94	6.99	12.07	.00	.00	.00	.00	.00
HINGE SPRINGS	12.05	4.00	8.28	48.20	99.77	1.45	4.00	8.28	5.80	12.01
HATCH WINDEN	2.02	4.50	8.19	9.09	16.54	.94	4.50	8.19	4.23	7.70
HATCH WIND RET RING	2.16	4.50	8.10	9.72	17.50	.50	4.50	8.10	2.25	4.05
HINGE BLOCKS	6.53	3.92	8.05	25.79	52.97	1.51	3.92	8.05	5.92	12.16
PENETRATORS (7) FWD	36.63	1.06	4.75	38.88	174.23	4.48	1.06	4.75	4.75	21.28
PENETRATORS (5) BBT	26.20	4.29	1.42	112.40	37.20	3.20	4.29	1.42	13.73	4.54
PENETRATORS (2) S	10.48	2.75	4.25	28.82	44.54	1.28	2.75	4.25	3.52	5.44
PENETRATORS (2) P	8.80	2.21	3.52	23.16	36.89	1.28	2.21	3.52	2.83	4.51
CABLE 24 COND 220 FT	18.00	2.97	2.70	214.50	231.66	42.24	2.97	2.70	105.60	114.05
BLANKING PLUGS (3) P	18.00	2.97	3.26	53.46	58.68	1.23	2.97	3.26	3.65	4.01
BLANKING PLUGS (4) S	24.00	3.04	3.52	72.34	84.48	1.64	3.04	3.52	4.99	5.77
LIFT PADS	10.20	4.50	8.17	45.90	83.33	2.35	4.50	8.17	10.57	19.20
CONN HALVES UPPER	52.50	4.50	1.09	236.25	57.22	5.25	4.50	1.09	23.63	5.72
MISC OUTSIDE	10.00	4.50	8.10	45.00	81.00	2.30	4.50	8.10	10.35	18.63
STRATA M8D 100	30.00	3.13	5.13	93.90	165.90	.00	.00	.00	.00	.00
STRATA M8D 200	32.00	4.04	5.95	129.28	190.72	.00	.00	.00	.00	.00
STRATA M8D 300	40.00	4.37	6.67	174.80	266.80	.00	.00	.00	.00	.00
TAPE RECORDER	2.00	4.13	6.50	8.26	9.00	.00	.00	.00	.00	.00
02 ANALYZER	3.50	5.38	6.70	18.83	23.45	.00	.00	.00	.00	.00
02 BOTTLES (3)	105.00	6.71	3.79	704.55	397.95	.00	.00	.00	.00	.00

ALVIN WEIGHT AND STABILITY COMPUTATIONS

SPHERE ONLY (CONTINUED)

IDENTIFICATION	W	X	Y	FX	MY	D	XP	YP	MXP	MYP
LIGH CANISTERS (3)	24.00	6.29	5.00	150.96	120.00	.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
EMERG BREATH APPAR 3	45.00	5.33	5.88	239.85	264.60	.00	.00	.00	.00	.00
VESTS (3)	6.00	5.33	5.88	31.98	35.28	.00	.00	.00	.00	.00
PILOTS CHAIR	9.31	2.88	3.88	26.81	26.81	.00	.00	.00	.00	.00
TRIM INDICATOR	.30	1.63	5.50	.49	1.65	.00	.00	.00	.00	.00
CABIN LIGHTS,P,S(2)	2.00	3.57	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	2.00	4.58	2.12	36.64	16.96	.00	.00	.00	.00	.00
MISC WIRING,PWR	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)	1.00	5.50	2.50	5.50	2.50	.00	.00	.00	.00	.00
CAMERAS	6.00	5.80	5.20	34.80	31.20	.00	.00	.00	.00	.00
TOOL KIT	4.00	5.50	2.40	22.00	9.60	.00	.00	.00	.00	.00
FLASHLIGHTS(6)	4.20	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
STBD DISTR PANEL	42.00	2.90	6.25	121.80	262.50	.00	2.90	6.25	.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
U G 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
GYR9	10.00	5.91	5.46	59.10	54.60	.00	.00	.00	.00	.00
POWER SUPPLY 6V.	17.00	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
POWER PANEL STBD	20.00	6.00	3.75	120.00	75.00	.00	6.00	3.75	.00	.00
SHELF UPPER PORT	2.00	4.35	6.75	8.70	13.50	.00	.00	.00	.00	.00
SHELF UPPER IND PANEL	3.50	4.35	6.75	15.22	23.63	.00	.00	.00	.00	.00
SHELF OVER LEAK DET.	1.50	1.70	6.60	2.55	9.90	.00	.00	.00	.00	.00
SHELF OVER LEAK DET.	2.00	2.88	7.04	5.76	14.08	.00	.00	.00	.00	.00
FATHOMETER SCOPE	7.00	3.83	6.29	26.81	44.03	.00	.00	.00	.00	.00
FATHOMETER XMTR (2)	14.00	3.00	5.50	42.00	77.00	.00	.00	.00	.00	.00
ALTIMETER	5.00	2.25	7.00	11.25	35.00	.00	.00	.00	.00	.00
22 BOTTLE BRK (3)	8.00	6.71	3.75	53.68	30.32	.00	.00	.00	.00	.00
AIR REGEN UNIT	13.50	6.38	4.50	86.13	60.75	.00	.00	.00	.00	.00

ALVIN WEIGHT AND STABILITY COMPUTATIONS

(CONTINUED)

SPHERE ONLY

IDENTIFICATION	W	X	Y	MX	MY	D	XP	YP	MXP	MYP
SPHERE STEP HDR	6.00	5.00	6.50	30.00	39.00	.00	.00	.00	.00	.00
BATTERY SHELF	3.00	5.62	7.33	16.89	21.99	.00	.00	.00	.00	.00
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	2.00	4.50	4.50	22.50	22.50	.00	.00	.00	.00	.00
GYRO 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
PILOTS 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 (3)	27.00	4.50	6.00	121.50	162.00	.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
	91	8322.11	4.37	4.72	36344.35	39245.46	10780.82	4.47	4.74	48239.98	51065.38

BG LONGITUDINAL .11 BG VERTICAL .02

ALVIN WEIGHT AND STABILITY COMPUTATIONS

OTHER FOREBODY

IDENTIFICATION	K	X	Y	MX	MY	D	XP	YP	MXP	MYP
SAIL, ETC	221.55	4.64	7.02	1029.38	1557.39	135.00	4.64	7.02	626.40	947.70
SPLASH GUARD	20.00	4.50	8.50	90.00	170.00	12.06	4.50	8.50	54.27	102.51
LITTON UP FBODY SYNT	1904.50	4.64	7.00	8836.88	13331.50	2201.65	4.64	7.00	10215.66	15411.55
3M UPPER FOREBODY	263.00	.38	7.00	327.94	6041.00	1434.60	.38	7.00	545.15	10042.20
LOWER SYNT RING	1052.00	4.42	3.43	4649.84	3608.36	1212.98	4.42	3.43	5361.37	4160.52
FRT WINDRW CANE	36.00	.75	4.75	27.00	171.00	21.70	.75	4.75	16.27	103.07
MAIN BALLAST WATER	1346.00	4.50	6.00	6057.00	8076.00	1346.00	4.50	6.00	6057.00	8076.00
MAIN BALLAST TANKS	178.00	4.50	6.00	801.00	1068.00	107.50	4.50	6.00	483.75	645.00
VELOCIMETER	20.00	2.20	9.50	44.00	190.00	10.00	2.20	9.50	22.00	95.00
SAIL CONTROL BRX	30.00	3.40	12.00	102.00	360.00	20.00	3.40	12.00	68.00	240.00
SAIL V BOX	107.00	7.00	9.00	749.00	963.00	72.00	7.00	9.00	504.00	648.00
FIBERGLASS CLAMP	4.00	2.39	3.46	9.56	13.84	2.22	2.39	3.46	5.31	7.68
SONAR UNIT	92.00	.50	8.00	46.00	736.00	30.00	.50	8.00	15.00	240.00
MAGNETIC COMPASS	9.07	7.00	10.13	63.49	91.88	8.33	7.00	10.13	58.31	84.38
EXTERIOR LIGHTS	24.00	2.50	5.40	60.00	129.60	8.00	2.50	5.40	20.00	43.20
CURRENT METER, ETC	18.08	3.50	13.20	63.28	238.66	4.00	3.50	13.20	14.00	52.80
PREC DEPTH XDCR	3.50	5.75	10.00	20.12	35.00	1.25	5.75	10.00	7.19	12.50
LGC XDCR	27.00	6.50	12.50	175.50	337.50	4.00	6.50	12.50	26.00	50.00
EGG CAMERAS (2)	104.00	.00	7.00	.00	734.24	30.00	.00	7.00	.00	211.80
STROBE PAR UNITS	45.00	7.50	7.25	360.00	348.00	32.00	7.50	7.25	240.00	232.00
FWD STRIKE	54.00	.00	6.50	.00	351.00	16.00	.00	6.50	.00	104.00

OTHER FOREBODY

SUMMARY	NO. ITEMS	SUM W	S MXW	S MYW	SUM MX	SUM MY	SUM D	S MXP	S MYP	SUM MXP	SUM MYP
21		6162.00	3.82	6.26	23512.00	38551.96	6709.29	3.63	6.19	24339.67	41509.92
BG LONGITUDINAL		--.19			BG VERTICAL	--.07					

4710128

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ALVIN WEIGHT AND STABILITY COMPUTATIONS

AFTERBBDY

IDENTIFICATION	W	X	Y	MX	MY	D	XP	YP	MXP	MYP
FRAME	447.50	9.12	2.77	4108.05	1239.57	169.00	9.18	2.77	1551.42	468.13
ADDN TB FRAME P	12.00	10.25	1.65	123.00	19.80	4.42	10.25	1.65	45.30	7.29
ADDN TB FRAME S	8.50	10.25	1.65	87.13	14.02	3.12	10.25	1.65	32.08	5.16
ADDN TB FRAME S	.50	6.00	2.75	3.60	1.65	.22	6.00	2.75	1.32	.60
LG BUOY PKG AFT	2310.00	14.16	5.05	32709.60	11665.50	4082.56	14.16	5.05	57809.05	20616.93
PINGER	87.00	14.00	6.75	1213.00	587.25	55.00	14.00	6.75	770.00	371.25
SM BUOYACY PK CTR	516.00	10.25	6.33	5239.00	3266.28	946.00	10.25	6.33	9696.50	5988.18
SIDE BUOY PKG (2)	433.00	10.40	6.75	4503.20	2922.75	692.00	10.40	6.75	7196.80	4671.00
V/B PKG UPPER P	1062.88	10.18	5.70	10820.12	6058.42	1314.00	10.18	5.70	13376.52	7489.80
V/B PKG LOWER S	1062.88	10.18	5.70	10820.12	6058.42	1314.00	10.18	5.70	13376.52	7489.80
V/B SPHERE LOWER S	300.80	6.78	1.42	2039.42	427.14	265.00	6.78	1.42	1796.70	376.30
V/B SPHERE LOWER S	300.80	6.78	1.42	2039.42	427.14	265.00	6.78	1.42	1796.70	376.30
V/B SPHERES PLUMBING	25.00	9.15	4.31	229.00	107.75	3.24	9.16	4.31	29.68	13.96
V/B PUMP	86.00	5.15	1.00	442.90	86.00	14.72	5.15	1.00	75.31	14.72
V/B PUMP MOTOR	150.00	5.15	1.00	772.50	150.00	88.96	5.15	1.00	458.14	88.96
SHUT OFF VALVE	11.70	9.00	1.75	105.30	20.47	2.18	9.00	1.75	19.62	3.81
FLOAT SWITCH	14.00	5.15	1.00	92.70	18.00	1.92	5.15	1.00	9.89	1.92
TANK RELIEF VALVE	1.50	9.00	1.75	13.50	2.63	.00	.00	.00	.00	.00
VALVE-FRAME, PIPING	20.00	9.83	3.38	196.60	67.60	.00	.00	.00	.00	.00
4-WAY VALVE	5.00	11.33	4.42	56.65	22.10	.00	.00	.00	.00	.00
BY-PASS VALVE	11.70	10.17	3.04	118.99	35.57	2.18	10.17	3.04	22.17	6.63
PB VALVE	15.40	10.13	4.46	54.70	24.08	.00	10.13	4.46	.00	.00
FLOW METER	21.00	10.96	2.88	230.16	60.48	2.96	10.96	2.88	32.44	8.52
PUMP RELIEF VALVE	1.50	10.25	3.36	15.37	5.94	.00	.00	.00	.00	.00
CHECK VALVE	1.30	10.58	4.44	20.10	8.44	.00	.00	.00	.00	.00
HYDR CONTROL B9X	193.00	9.04	4.52	1762.80	881.40	142.22	9.04	4.52	1285.67	642.83
MOTOR PUMP FRAME	15.00	5.15	1.00	77.25	15.00	.00	.00	.00	.00	.00
HG SPHERES F&D (2)	26.00	1.73	1.90	46.54	49.40	41.70	1.73	1.90	74.64	79.23
HG FRAME F&D	12.00	1.79	1.90	21.48	22.80	4.54	1.79	1.90	8.13	8.63
HG FRAME SYNT F&D	3.00	1.79	1.90	8.35	9.50	8.00	1.79	1.90	14.32	15.20
HG SPHERES AFT (2)	26.00	17.50	3.92	455.00	101.92	41.70	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 F&D	246.25	1.73	1.90	439.00	465.97	.00	1.73	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 & BOLTS (2 STS)	45.50	8.67	.25	403.15	11.62	17.60	8.67	.25	152.59	4.40
CONTROL CENTER	262.00	10.21	4.63	2675.02	1213.06	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. OGS, 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

ALVIN WEIGHT AND STABILITY COMPUTATIONS

(CONTINUED)

AFTERBODY

IDENTIFICATION	W	X	Y	MX	MY	D	XP	YP	MXP	MYP
SPHERE RELEASE SHIPS	2.50	4.50	.50	11.25	1.25	.95	4.50	.50	4.27	.47
PROPULSION BOX & OIL	349.00	13.50	2.30	11461.50	1922.70	510.00	13.50	2.30	6885.00	1173.00
PROP BOX SUPPORTS	3.00	13.50	2.30	108.00	18.40	2.00	13.50	2.30	27.00	4.60
PROP BOX 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
CANN HALVES LOWER	35.00	4.50	2.00	157.50	70.00	14.22	4.50	2.00	63.99	28.44
LIFT PROP UNITS, BOX	382.00	9.00	7.75	3438.00	290.50	232.00	9.00	7.75	2088.00	1798.00
LIFT PROP BOX OIL	127.00	9.00	7.75	1143.00	984.25	.00	.00	.00	.00	.00
STERN PROP ASSEMBLY	950.00	20.20	4.63	19190.00	4398.50	458.00	20.20	4.63	9251.60	2120.54
STERN PROP OIL	82.68	20.20	4.63	1670.14	382.81	.00	20.20	4.63	.00	.00
BATTERY & BOX FWD	1470.00	8.68	2.80	12759.60	4116.00	929.00	8.68	2.80	8063.72	2601.20
BATTERY & BOX AFT	1470.00	10.00	2.80	1700.00	4116.00	929.00	10.00	2.80	9290.00	2601.20
BATTERY DROPS(2) FWD	56.00	11.40	2.80	16758.00	4116.00	929.00	11.40	2.80	10590.60	2601.20
BATTERY DROPS(2) MID	56.00	8.68	3.03	486.08	169.68	7.15	8.68	3.25	62.06	23.24
BATTERY DROPS(2) AFT	56.00	10.00	3.03	560.00	169.68	7.15	10.00	3.25	71.50	23.24
SPHERE SUP SYNTAC(2)	3.00	11.40	3.03	638.40	169.68	7.15	11.40	3.25	81.51	23.24
FRAME SYNTACTIC(9)	17.00	9.00	2.00	12.90	6.00	4.80	4.30	2.00	20.64	9.60
V/B BOX BRKT	1.50	17.50	5.00	153.00	59.50	27.20	9.00	3.50	244.80	95.20
LWR BASKET HINGE (2)	4.50	4.00	.30	26.25	7.50	.56	17.50	5.00	9.80	2.80
WT & BSKT REL BRKT 3	2.00	4.62	2.75	18.00	1.35	1.70	4.00	.30	6.80	.51
V/B SPHERE BRAC (2)	2.00	6.78	1.42	19.24	5.50	.76	4.62	2.75	3.51	2.09
CTR V/B PKG BRAC 2	4.00	10.50	5.00	13.56	2.84	.95	6.78	1.42	5.15	1.08
BURY PKG HLDOWNS 6	3.00	15.00	5.00	42.00	20.00	1.33	10.50	5.00	15.96	5.65
POISTING PIN	2.50	12.50	7.44	31.25	18.60	.95	15.00	5.00	16.95	5.65
FWD FRAME SIDE BDS(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	19.35	4.67	584.37	291.87	31.25	19.35	4.67	292.19	145.94
INSTRUMENT CASE	17.00	6.30	.83	107.10	14.11	3.34	6.30	.83	21.04	2.77
BOTTOM WINDW CONE	12.50	3.50	1.00	43.75	12.50	6.95	3.50	1.00	24.32	6.95
FWD WT DROP, SBL	10.50	-25	3.00	-2.63	31.50	3.50	-25	3.00	-87	10.50
PBRT WT DROP, SBL FWD	10.10	-25	3.00	45.45	30.30	3.40	4.50	3.00	15.30	10.20
STBD WT DROP, SBL FWD	10.10	4.50	3.00	45.45	30.30	3.40	4.50	3.00	15.30	10.20
PBRT WT DROP, SBL AFT	10.10	6.00	3.00	60.60	30.30	3.40	6.00	3.00	20.40	10.20
STBD WT DROP, SBL AFT	10.10	6.00	3.00	60.60	30.30	3.40	6.00	3.00	20.40	10.20
BATTERY RESERVIR B0	182.00	7.00	1.40	1274.00	254.80	215.10	7.00	1.40	1505.70	301.14

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ALVIN WEIGHT AND STABILITY COMPUTATIONS

(CONTINUED)

AFTERBODY

IDENTIFICATION	W	X	Y	MX	MY	D	XP	YP	MXP	MYP
BATTERY RES RESX PAK	32.00	7.00	1.40	224.00	44.80	17.80	7.00	1.40	124.60	24.92
BATTERY RES RESX PAKT	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
FATHOMETER	31.50	5.50	2.25	173.25	70.87	15.50	5.50	2.25	85.25	34.87
SYNT FWC SKIDS	22.00	6.50	.25	143.00	5.50	39.00	6.50	.25	253.50	9.75
VE BAG SYN	234.00	10.40	3.70	2433.60	865.80	394.00	10.40	3.70	4097.60	1457.80
AFT SYN TACTIC	192.00	17.75	5.40	2098.00	820.80	256.00	17.75	5.40	4544.00	1382.40
SYNT AFT SKIDS	21.93	10.50	.25	230.26	5.48	38.98	10.50	.25	409.29	9.74

AFTERBODY

SUMMARY	N6. ITEMS	SUM W	S MXW	S MYW	SUM MX	SUM MY	SUM D	S MXP	S MYP	SUM MXP	SUM MYP
89		1611.657	11.19	3.96	180375.41	64148.90	14875.18	11.53	4.48	171546.59	66705.56

BG LONGITUDINAL .34 BG VERTICAL .50

ALVIN WEIGHT AND STABILITY COMPUTATIONS

VARIABLE LOAD(NORMAL)

IDENTIFICATION	W	X	Y	MX	MY	D	XP	YP	MXP	MYP
MECHANICAL ARM	438.55	-2.30	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 BRX	10.00	1.00	7.00	10.00	70.00	.00	1.00	7.00	.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, T68LS	159.00	-2.50	1.40	-375.00	210.00	45.00	-2.50	1.40	-112.50	63.00
PERSONNEL (3)	200.00	5.86	4.13	2930.00	2065.00	.00	.00	.00	.00	.00
ASCENT WEIGHT	500.00	4.50	2.60	2290.00	1300.00	45.00	4.50	2.60	202.50	117.00
ADD LEAD 6R PAYLOAD	210.00	4.00	3.00	840.00	630.00	.00	.00	.00	.00	.00

VARIABLE LOAD(NORMAL)

SUMMARY	NO. ITEMS	SUM W	S MAX	S MYW	SUM MX	SUM MY	SUM D	S MXP	S MYP	SUM MXP	SUM MYP
	8	1918.05	2.93	3.02	5613.63	5787.58	266.50	.44	2.50	117.40	666.60
BG LONGITUDINAL		-2.49			BG VERTICAL	-.52					

ALVIN WEIGHT AND STABILITY COMPUTATIONS

IDENTIFICATION	X	Y	MA	MY	D	XP	YP	MXP	MYP
SPHERE ONLY	4.37	4.72	36367.62	39280.36	1780.82	4.47		48190.27	51101.09
OTHER FOREBODY	3.82	6.25	23538.84	38574.12	6709.29	3.63	4.19	24354.72	41530.51
AFTERBODY	1.19	3.98	10366.80	64151.91	14875.18	11.53	4.48	171510.83	66640.81
VARIABLE LEAD	2.93	3.02	5613.89	5792.51	2666.50	.44	2.50	117.26	666.25

ENTIRE VEHICLE (NORMAL)										
SUMMARY	NO.	ITEMS	SUM W	S MAX	S MYW	SUM MX	SUM MY	SUM D	S MXP	SUM MYP
	4		32520.73	7.56	4.54	245893.15	147798.90	32631.79	244173.07	159938.65
BG LONGITUDINAL			-0.08			BG VERTICAL		.36		

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ALVIN WEIGHT AND STABILITY COMPUTATIONS

RELEASED FOREBODY

IDENTIFICATION	W	X	Y	MX	MY	D	XP	YP	MXP	MYP
SPHERE ONLY	8322.11	4.37	4.72	36367.62	39280.36	10780.82	4.47	4.74	48190.27	51101.09
OTHER FOREBODY	6162.00	3.82	6.26	23538.84	38574.12	6709.29	3.63	6.19	24354.72	41530.51
PERSONNEL (3)	500.00	5.86	4.13	2930.00	2065.00	.00	.00	.00	.00	.00
VECH ARY CNTR BOX	10.00	1.00	7.00	10.00	70.00	.00	.00	.00	.00	.00

RELEASED FOREBODY

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
4			14994.11		4.19		5.33		62846.46	79989.48	17490.11		4.15		5.30		72544.99	92631.59

BG LONGITUDINAL

--04

BG VERTICAL

--04

ALVIN WEIGHT AND STABILITY COMPUTATIONS

EMERGENCY CONDITIONS (1)

IDENTIFICATION	W	X	Y	MX	MY	D	XP	YP	MXP	MYP
IN NORMAL CONDITION	32520.73	7.55	4.54	245856.72	147644.11	32631.79	7.48	4.90	244085.79	159895.77
BLW MAIN BALLAST	-1346.00	4.50	6.00	-6057.00	-8076.00	.00	.00	.00	.00	.00

EMERGENCY CONDITIONS (1)

SUMMARY	NB. ITEMS	SUM W	S ^{MXW}	S ^{MYW}	SUM MX	SUM MY	SUM D	S ^{MXPD}	S ^{MYPD}	SUM MXP	SUM MYP
2		31174.73	7.69	4.48	239799.72	139568.11	32631.79	7.48	4.90	244085.79	159895.77

BG LONGITUDINAL -0.21

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	32520.73	7.56	4.54	245856.72	147644.11	32631.79	7.48	4.90	244085.79	159895.77
CRSP PG FAD	-245.25	1.79	1.90	-439.00	-465.97	.00	.00	.00	.00	.00
CRSP PG AFT	-245.25	17.50	3.92	-4291.87	-961.38	.00	.00	.00	.00	.00

EMERGENCY CONDITIONS (2)

SUMMARY	NO. ITEMS	SUM W	S MXW	S MYW	SUM MX	SUM MY	SUM D	S MXP	S MYP	SUM MXP	SUM MYP
3		32030.23	7.53	4.56	24125.85	146216.76	32631.79	7.48	4.90	244085.79	159895.77
BG LONGITUDINAL		-0.05		BG VERTICAL		.34					

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ALVIN WEIGHT AND STABILITY COMPUTATIONS

EMERGENCY CONDITIONS (3)

IDENTIFICATION	A	X	Y	MX	MY	D	XP	YP	MXP	MYP
IN NORMAL CONDITION	32520.73	7.56	4.54	245856.72	147644.11	32631.79	7.48	4.90	244085.79	159895.77
CROP MID BATTERY	-1470.00	10.00	2.80	-14700.00	-4116.00	-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	31050.73	7.44	4.52	231156.72	143528.11	31702.79	7.41	4.96	234795.79	157294.57

BG LONGITUDINAL -0.04

BG VERTICAL 0.34

ALVIN WEIGHT AND STABILITY COMPUTATIONS

EMERGENCY CONDITIONS (4)

IDENTIFICATION	W	X	Y	MX	MY	D	XP	YP	MXP	MYP
IN NORMAL CONDITION	32520.73	7.56	4.54	245856.72	147644.11	32631.79	7.48	4.90	244085.79	159895.77
CRBP FAC BATTERY	-1470.00	8.68	2.80	-12759.60	-4116.00	-929.00	8.68	2.80	-8063.72	-2601.20
CRBP AFT BATTERY	-1470.00	11.40	2.80	-16758.00	-4116.00	-929.00	11.40	2.80	-10590.60	-2601.20

EMERGENCY CONDITIONS (4)

SUMMARY	NB. ITEMS	SUM W	S MXH	S MYW	SUM MX	SUM MY	SUM D	S MXP	S MYP	SUM MXP	SUM MYP
3		29580.73	7.31	4.71	216339.12	139412.11	30773.79	7.33	5.03	225431.47	154693.37

EG LENGTHUDINAL	•01	BG VERTICAL	•31

ALVIN WEIGHT AND STABILITY COMPUTATIONS

EMERGENCY CONDITIONS (5)

IDENTIFICATION	W	X	Y	MX	MY	D	XP	YP	MXP	MYP
IN NORMAL CONDITION	32520.73	7.56	4.54	245556.72	147644.11	32631.79	7.48	4.90	244085.79	159895.77
DRBP FWD BATTERY	-1470.00	8.68	2.30	-12759.60	-4116.00	-929.00	8.68	2.80	-8063.72	-2601.20
DRBP MID BATTERY	-1470.00	10.00	2.30	-14700.00	-4116.00	-929.00	10.00	2.80	-9290.00	-2601.20
DRBP AFT BATTERY	-1470.00	11.40	2.30	-16758.00	-4116.00	-929.00	11.40	2.80	-10590.60	-2601.20

EMERGENCY CONDITIONS (5)

SUMMARY	N6. ITEMS	SUM W	S	MXW	S	MYW	SUM MX	SUM MY	SUM D	S	MXPD	S	MYPD	SUM MXP	SUM MYP
4		28110.73		7.17		4.21	201639.12	135296.11	29844.79		7.24		5.10	216141.47	152092.17

BG LONGITUDINAL .07

BG VERTICAL .28

ALVIN WEIGHT AND STABILITY COMPUTATIONS

EMERGENCY CONDITIONS (6)

IDENTIFICATION	W	X	Y	MX	MY	D	XP	YP	MXP	MYP
IN NERVAL CONDITION	3252.73	7.56	4.34	245556.72	147644.11	32631.79	7.48	4.90	244085.79	159895.77
CR9P PG FWD	-245.25	1.79	1.30	-439.00	-465.97	.00	.00	.00	.00	.00
CR9P PG AFT	-245.25	17.50	3.92	-4291.87	-961.38	.00	.00	.00	.00	.00
CR9P PG BATTERY	-1473.00	8.68	2.80	-12759.60	-4116.00	-929.00	8.68	2.80	-3063.72	-2601.20
CR9P MID BATTERY	-1473.00	10.00	2.80	-14700.00	-4116.00	-929.00	10.00	2.80	-9290.00	-2601.20
CR9P AFT BATTERY	-1473.00	11.40	2.80	-16758.00	-4116.00	-929.00	11.40	2.80	-10590.60	-2601.20

EMERGENCY CONDITIONS (6)

SUMMARY	NO. ITEMS	SUM W	S MAX	S MYW	SUM MX	SUM MY	SUM D	S MXP	S MYP	SUM MXP	SUM MYP
6	6	27620.23	7.13	4.85	196903.25	133863.76	29844.79	7.24	5.10	216141.47	152092.17
BG LONGITUDINAL			.11		BG VERTICAL	.25					

ALVIN WEIGHT AND STABILITY COMPUTATIONS

EMERGENCY CONDITIONS (7)

IDENTIFICATION	W	X	Y	MX	MY	D	XP	YP	MXP	MYP
IN NORMAL CONDITION	32520.73	7.56	4.54	245856.72	147644.11	32631.79	7.48	4.90	244085.79	159895.77
DRBP HG FWD	-245.25	1.79	1.90	-439.00	-465.97	.00	.00	.00	.00	.00
DRBP HG AFT	-245.25	17.50	3.92	-4291.87	-961.38	.00	.00	.00	.00	.00
DRBP FWD BATTERY	-1470.00	8.68	2.80	-12759.60	-4116.00	-929.00	8.68	2.80	-8063.72	-2601.20
DRBP MID BATTERY	-1470.00	10.00	2.80	-14700.00	-4116.00	-929.00	10.00	2.80	-9290.00	-2601.20
DRBP AFT BATTERY	-1470.00	11.40	2.80	-16758.00	-4116.00	-929.00	11.40	2.80	-10590.60	-2601.20
DRBP 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 MXP	S MYP	SUM MXP	SUM MYP
	7	27181.68	7.25	4.88	197039.81	132684.67	29701.79	7.28	5.11	216141.47	151706.07

BG VERTICAL .03

.03

BG LONGITUDINAL

ALVIN WEIGHT AND STABILITY COMPUTATIONS

EMERGENCY CONDITIONS (8)

IDENTIFICATION	W	X	Y	MX	MY	D	XP	YP	MXP	MYP
IN NORMAL CONDITION	32520.73	7.56	4.54	245856.72	147644.11	32631.79	7.48	4.30	244085.79	159895.77
FLOOD V/B SPHERES	1062.00	9.05	4.27	9611.10	4534.74	.00	.00	.00	.00	.00
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	-961.38	.00	.00	.00	.00	.00
DROP FWD BATTERY	-1470.00	8.58	2.80	-12759.60	-4116.00	-923.00	8.68	2.80	-8063.72	-2601.20
DROP MID BATTERY	-1470.00	10.00	2.80	-14700.00	-4116.00	-929.00	10.00	2.80	-9290.00	-2601.20
DROP AFT BATTERY	-1470.00	11.40	2.80	-16758.00	-4116.00	-929.00	11.40	2.80	-10590.60	-2601.20
DROP ARM	-438.55	-3.30	2.70	131.56	-1184.08	-143.00	.00	2.70	.00	-386.10

EMERGENCY CONDITIONS (8)

SUMMARY	NO. ITEMS	SUM W	S MXW	S MYW	SUM MX	SUM MY	SUM D	S MXP	S MYP	SUM MXP	SUM MYP
		28243.68	7.32	4.86	206650.91	137219.41	29701.79	7.23	5.11	216141.47	151706.07
BG LONGITUDINAL		-0.04			BG VERTICAL	.25					

E. Other Calculations

1. Pounds per Inch Immersion - This is the weight of a layer of sea water one inch thick at the vehicle's waterplane, and is used to obtain the change in draft for a given change in weight. The increase or decrease in draft is equal to the vehicle weight change divided by the pounds per inch immersion. The waterplane area used is based on draft readings taken at the time of the 1973 surface inclining experiment. Thus, the pounds per inch immersion

$$\begin{aligned} \text{PPI} &= A_{wp} \times \frac{1}{12} \times 64 \\ &= 73.96 \times \frac{1}{12} \times 64 \\ &= 394 \text{ lbs. per inch} \end{aligned}$$

2. Moment to Heel One Degree (submerged) - This is the moment required to produce an inclination of 1 degree about the vehicle's longitudinal axis. It is found for the submerged vehicle by

$$\begin{aligned} \text{MHD} &= W(\text{BG}) \sin 1^\circ \\ &= 32,520(.36) (.0175) \\ &= 205 \text{ ft.-lbs.} \end{aligned}$$

3. Moment to Heel One Degree (on surface) - This is the moment required to produce an inclination of 1 degree

about the longitudinal axis of the vehicle on the surface. It is given by

$$\begin{aligned} \text{MHD} &= W(\text{GM}) \sin 1^\circ \\ &= 31,136(.47) (.0175) \\ &= 256 \text{ ft.-lbs.} \end{aligned}$$

III. Dockside Trials

A. Procedures

1. Inclining Experiment Known weights were placed aboard the submarine and their total added to the total displacement. During the test the weights were shifted in increments from port to starboard and vice-versa to positions a known distance from the longitudinal centerline. After each movement of weights, the vehicle's list angle was obtained using a sensitive inclinometer. Data thus obtained were used to construct a curve called the plot of tangents. This plot in turn led to the determination of the vertical component of a.) the BG distance (submerged vehicle) and b.) the GM distance (vehicle on surface). These tests were performed for the entire submarine, both submerged and surfaced; and for the forebody alone, on the surface.
2. Induced Rolling The submarine was caused to roll at its natural frequency of oscillation, about its longitudinal axis. In ALVIN's case a line was attached to the top of the sail and several men hauled on it, then released it, repeating this a number of times.

The total elapsed time was recorded. This was divided by the number of rolls to give the average roll period. This value was used in the appropriate vibrations equation, and the vertical BG or GM distance was obtained. This test was done also for the forebody alone, on the surface.

B. ALVIN Surface Inclining Experiment

1. Test Conditions

- a. Inclining weights: 6 lead plates weighing each 21.0 pounds in air, 19.0 pounds in water. Total weight in air 126 pounds, in water 114 pounds.
- b. Three persons aboard-weight 490 pounds.
- c. Inclinator mounted inside pressure hull-weight 32 pounds.
- d. Ascent weights: 441 pounds
- e. Main ballast blown
- f. Variable ballast - 375 pounds of water in VB spheres
- g. Mercury trim: 30 percent fwd., 70 percent aft
- h. Weight changes from normal operating conditions.
 1. CTFM cables removed - weight 5.25 pounds
 2. CTFM analyzer removed - weight 42.2 pounds
 3. Sonar unit removed - weight 67.0 pounds
 4. Fathometer can removed - weight 31.5 pounds
 5. One emergency battery removed - weight 9.00 pounds

6. Two O₂ bottles removed - weight 70.00 pounds
7. One lithium hydroxide removed - weight 8.00 pounds
8. Fathometer removed - weight 17.0 pounds
9. Variable ballast skin removed - weight 15.0 pounds
10. Gyro removed - weight 10.0 pounds
11. Velocimeter removed - weight 20.0 pounds
12. Steel weight added - 124 pounds

i. Water sample: temperature 70.5°F
density 63.8 pounds per cubic foot

j. Simulated payload

1. 220.5 pounds at fwd. weight dropper
2. 242.5 pounds on forebody at x = 6.00 feet

k. Moment arm for inclining weights = 3.5 feet

l. Vehicle draft and angles

Draft Port 7'6" fwd
Stbd 7'5" fwd

Roll 3 1/4° port

Pitch 0°

m. Vehicle displacement 31,136 pounds

2. Moments and Angles

<u>Net Weight Pounds</u>	<u>Moment Ft.-Lbs.</u>	<u>Tan θ</u>
0	0	.000
38S	133	.010
76S	266	.017
114S	399	.027
0	0	.000
38P	133	.009
76P	266	.015
114P	399	.027
0	0	.000

PLOT OF TANGENTS SURFACE INCLINING EXPERIMENT

August 30, 1973

Figure 4. Plot of Tangents for Surface Inclining Experiment

3. Calculation of GM from Inclining Data

$$GM = \frac{Wxd}{W \times \tan \Theta} = \frac{1}{W} \times (\text{slope of plot of tangents})$$

$$GM = \frac{14670}{31,136} = 0.47 \text{ ft.}$$

4. Calculation of GM from roll period

<u>Trial No.</u>	<u>Period T (sec.)</u>
1	5.12
2	4.90
3	4.95
4	5.05
	<u>20.02 total</u>

$$\text{Average } T = 5.005$$

$$T^2 = 25.05$$

$$\begin{aligned} \text{Estimated Radius of Gyration } K &= 3 \\ K^2 &= 9 \end{aligned}$$

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

$$GM = \frac{1.23 (9)}{25.05} = 0.44 \text{ ft.}$$

C. ALVIN Submerged Inclining Experiment

1. Test Conditions

- a. Test conditions were the same as those for the surface inclining experiment except for the following:

1. Main ballast flooded
2. Mercury Trim: 45 percent fwd., 55 percent aft
3. Inclining weights: 8 lead plates weighing each 21.0 pounds in air, 19.0 pounds in water
Total weight in air 168 pounds, in water 152 pounds

4. Draft: WL 6 inches below top of conning tower

5. Vehicle displacement 32,520 pounds

2. Moments and Angles

<u>Net Wt. Pounds</u>	<u>Moment Ft.-Lbs.</u>	<u>Tan θ</u>
0	0	.000
76	266	.020
152	532	.048
0	0	.000
76	266	.022
152	532	.047
0	0	.000

3. Calculation of BG from Inclining Data

$$BG = \frac{Wxd}{W \tan \theta} = \frac{1}{W} \times (\text{slope of plot of tangents})$$

$$BG = \frac{11,000}{32,520} = 0.34 \text{ ft.}$$

4. Calculation of BG From Roll Period

<u>Trail No.</u>	<u>Period T (Sec.)</u>
1	7.90
2	8.05
3	7.80
4	7.90
	<u>31.65 total</u>

$$\begin{aligned} \text{Average } T &= 7.913 \\ T^2 &= 62.61 \end{aligned}$$

$$\begin{aligned} \text{Estimated Radius of Gyration } K &= 4.21 \\ K^2 &= 17.72 \end{aligned}$$

then

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

$$BG = \frac{21.8}{62.61} = \frac{21.8}{62.61} = 0.35 \text{ ft.}$$

PLOT OF TANGENTS SUBMERGED INCLINING EXPERIMENT

August 30, 1973

Figure 5. Plot of Tangents for Submerged Inclining Experiment

D. ALVIN Forebody Surface Inclining Experiment

1. Test Conditions

- a. Inclining weights: 6 lead plates weighing each 21.0 pounds in air. Total weight in air 126 pounds.
- b. Inclinator mounted inside pressure hull - weight 32 pounds.
- c. One person aboard, weight 175 pounds, and personnel compensating weights 302 pounds.
- d. Other changes from normal operating conditions.
 - 1. AMF transponder removed - weight 87 pounds
 - 2. Velocimeter removed - weight 20 pounds
 - 3. Sonar display unit removed - weight 27.25 pounds
 - 4. Two O₂ bottles removed - weight 70.00 pounds
- e. Main ballast flooded.
- f. Water Sample: Temperature 70.5°F
Density 63.8 pounds/ft.³
- g. Moment arm for inclining weights 3.5 feet
- h. Forebody draft and angles
 - Draft Port 7'4.5"
 - Stbd 7'5"
 - Pitch 10° down
 - Roll 2° port
- i. Weight (at time of inclining test and including inclining weights) 15,065 pounds.

2. Moments and Angles

<u>Net Weight Pounds</u>	<u>Moment Ft.-Lbs.</u>	<u>Tan θ</u>
0	0	.000
126S	441	.040
84S	294	.025
42S	147	.012
0	0	.000
42P	147	.015
84P	294	.030
126P	441	.048
0	0	.000

3. Calculation of GM from Inclining Data

$$GM = \frac{Wxd}{W \tan \theta} = \frac{1}{W} \times (\text{slope of plot of tangents})$$

$$GM = \frac{10,000}{15,065} = 0.66 \text{ ft.}$$

4. Calculation of GM from Roll Period

<u>Trial No.</u>	<u>Period T (Sec.)</u>
1	7.5
2	6.2
3	8.1
4	8.1
	<u>29.90 total</u>

$$\begin{aligned} \text{Average } T &= 7.48 \\ T^2 &= 55.9 \end{aligned}$$

$$\begin{aligned} \text{Estimated Radius of Gyration } K &= 5.3 \\ K^2 &= 28.1 \end{aligned}$$

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

$$GM = \frac{1.23 (28.1)}{55.9} = 0.62 \text{ ft.}$$

PLOT OF TANGENTS ALVIN FOREBODY INCLINING EXPERIMENT

August 28, 1973

Figure 6. Plot of Tangents for Forebody Surface Inclining Experiment

IV. Discussion of Results

The following table presents the results of the computations, and the experiments, done in 1973 for ALVIN with the titanium hull:

	Entire Vehicle (Submerged)	Entire Vehicle (Surfaced)	Forebody (Surfaced)
BG Vertical, ft. (computed)	.36		
BG Vertical, ft. (inclining)	.34		
BG Vertical, ft. (roll period)	.35		
GM Vertical, ft. (inclining)		.47	.66
GM Vertical, ft. (roll period)		.44	.62

For the submerged submarine, the center of buoyancy B must lie above the center of gravity G, for vertical stability. This was found to be true for ALVIN in all determinations made. The computed value of BG is about 5 percent greater than that for the 1972 steel-hull ALVIN (Ref. 1).

For the submarine on the surface the metacenter M must lie above the center of gravity G even if the center of buoyancy B does not. This was found to be true in all the tests done, on the evidence that a righting moment was present in each case.

The computer output also yields a value for the horizontal component of BG, a measure of longitudinal trim. Ideally this value should be zero, but in practise it almost never is. The value obtained in the present computation, 0.08 ft., is considered small enough to be readily corrected for by the mercury trim system.

For the released forebody the computed value of vertical BG is a small negative number so that a slight instability is indicated. This, taken together with the fact that the sail would be subject to hydrodynamic drag, indicates that the released forebody would almost certainly travel to the surface in the inverted condition. Further study is being conducted relative to the stability of the released forebody on the surface. There are indications that surface stability exists in both upright and inverted positions. If this proves to be true, measures will be taken to insure that the forebody can be righted; or that safe egress from the inverted hull can be accomplished.

The latest computer output shows a slight discrepancy between the total weight and total displacement of ALVIN, the latter being about 100 pounds greater. It is felt that this is due to the difficulty in determining accurate displacements

of the individual components. Past experience has shown that discrepancies of this magnitude have little or no effect on the final stability figures.

Early in the operating season the net buoyancy of the forebody alone was determined by actual test (Ref. 2). The value obtained, 3006 pounds, differed somewhat from the computed value, and was considered to be the more reliable of the two. Accordingly, some adjustments were made to the displacement values of certain portions of the syntactic foam on the forebody, to bring the computed and measured values of forebody net buoyancy into agreement.

At the time of this writing the submarine has had several months of diving experience during the 1973 season. Discussions with the pilots of ALVIN reveal that the quantities of scientific payload and/or additional lead actually carried on most dives, agree well with those values reported in the computation.

V. References

1. "DSRV ALVIN Weight Report, 1972", by Arnold G. Sharp and Andrew H. Eliason, WHOI Technical Memorandum No. 5-72, December, 1972.
2. "Documentation of Forebody Reserve Buoyancy Test and Calculations," WHOI Office Memorandum From David Hosom, Dated August 29, 1973.

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,
      PLTL), (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
3. C JUNE 1971
4. C PROGRAMMER: ANDREW H. ELIASON
5. C USE X OPTION FOR CALCULATION WITH PLOT
6. C
7. C IMPLICIT DOUBLE PRECISION (A-H, Z-Z)
8. C REAL X2,Y2
9. C COMPN IROF(1000)
10. C COMPN ARRAY1(500)
11. C COMPN ARRAY2(500)
12. C COMPN ARRAY3(500)
13. C COMPN ARRAY4(500)
14. C SCALE= 500.C
15. C COMPN IDEN(300,5),ID(7)
16. C DIMENSION X(300),Y(300),W(300),D(300),XP(300),YP(300),C(300)
17. C 100 FORMAT(5A4,1X,F5.2,2(1X,F5.2),1X,F8.2,2(1X,F5.2),1X,I1)
18. C 200 FORMAT(16X,ALVIN WEIGHT AND STABILITY COMPUTATIONS,35X,IPAGE,1,I
19. C 11)
20. C 250 FORMAT(46X,7A4/)
21. C 260 FORMAT(46X,7A4,1 (CONTINUED),/)
22. C 300 FORMAT(3X,IDENTIFICATION,11X,I1,9X,I1,8X,I1,9X,10X,1MY,
23. C 11X,I1,5X,1XP,17X,1YPI,8X,1MXP,9X,1MYP,/)
24. C 400 FORMAT(1X,5A4,4X,F8.2,2(4X,F5.2),3(3X,F5.2),2(4X,F5.2),2(3X,F9.2))
25. C 500 FORMAT(// SUMMARY N8, ITEMS,6X,ISUM X,1X,IS MYW,1X,IS MYW,
26. C 16X,ISUM MX,6X,ISUM MY,7X,ISUM D,5X,IS MYPD,4X,ISUM
27. C 1 XPI,5X,ISUM MYP,1)
28. C 600 FORMAT(14X,I3,8X,F8.2,2(4X,F5.2),3(3X,F9.2),2(4X,F5.2),2(3X,F9.2))
29. C 700 FORMAT(10X,166 LONGITUDINAL,5X,F5.2,20X,186 VERTICAL,5X,F5.2)
30. C 800 FORMAT(11)
31. C 900 FORMAT(7A4)
32. C 950 CALL PLTS(1BUF,-1000)
33. C *****
34. C READ ALVIN PICTURE DATA
35. C *****
36. C N=1
37. C 15 M1=M+3
38. C READ(105,105,END=55)(ARRAY1(I),ARRAY2(I),I=M,M+1)
39. C 105 FORMAT(4(5X,16,2X,16,1))
40. C N=M+4
41. C 59 TO 13
42. C 55 CONTINUE
43. C N=M+4
44. C *****
45. C READ SECTION TITLE AND DATA
46. C IPAGE = 1
47. C N=1
48. C READ(105,900)ID
49. C 10 READ(105,100,END=20)(IDEN(N,J),J=1,5),W(N),X(N),Y(N),D(N),XP(N),
50. C 1YF(N),C(N)
51. C N=N+1
52. C 59 TO 13

```


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-60-

```
106. X IFLIG=0
107. X 73 CONTINUE
108. X CALL FLAT (0.0,0.0,995)
109. C *****
110. X 73 CONTINUE
111. C CHECK FOR LAST CARD
112. IF (C(1).EQ.3) GO TO 40
113. GO TO 3
114. 40 CALL EXIT
115. END
```