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TORQUE TESTS OF A FULL SIZE MODEL OF THE ALVIN/AUTECH EMERGENCY SPHERE RELEASE

Arnold G. Sharp and James R. Sullivan

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TORQUE TESTS OF A FULL SIZE MODEL OF THE ALVIN AUTEC EMERGENCY SPHERE RELEASE

by

Arnold G. Sharp and James R. Sullivan

November 1970

TECHNICAL REPORT

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Scott C. Daubin, Chairman
Department of Ocean Engineering
Laboratory torque tests were performed using an actual emergency sphere release shaft of the type used in the research submarines ALVIN, SEA CLIFF and TURTLE. A test fixture was constructed which permitted laboratory simulation of the side (squeezing) forces applied to the release shaft cam as a result of forebody buoyancy. Estimated full-scale side forces were applied to the cam by a laboratory compression testing machine, and the torque required to rotate the shaft was measured. Tests were run with contacting surfaces (a) clean and dry, (b) greased, and (c) immersed in sea water. From the test results, values of release torque were calculated for the submarines in question. Coefficient of friction values for the contacting materials (Monel K-500 on phosphor bronze) also are reported.
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I INTRODUCTION

In 1965 the original emergency forebody release device of the research submarine ALVIN was replaced with one of improved design (Ref. 1). Subsequently, two new submarines, SEA CLIFF and TURTLE, have been built, and both vehicles use a release device patterned after the improved ALVIN release. The titanium pressure hull now being built by the U.S. Navy under Project Titanes is to be used interchangeably with the existing pressure hulls of the three aforementioned submarines, and it therefore will require release device components compatible with those vehicles.

In the event that use of the emergency sphere release ever should be necessary, it would be required that the release shaft be rotated manually one-quarter turn from within the sphere. The torque or turning effort needed to accomplish this rotation would depend on three major factors:

a. Possible squeeze of the contracted spherical hull wall around shaft bushing and shaft (a function of depth).

b. Axial thrust of release shaft cam against its thrust washer, caused by external hydrostatic pressure (a function of depth).

c. Frictional drag on release shaft cam due to side forces applied by release dogs (a function of forebody net buoyancy).

In addition to the foregoing factors, resistance to turning motion of the shaft could be caused by frictional drag of O-rings or other seals, possible misalignment of parts during assembly, and possible galling of contacting metal surfaces. These latter points are considered minor in the light of accumulated experience with the submarine ALVIN. Of the three major factors listed above, the effect of factor (a) should be negligible with a properly designed through-hull shaft bushing. Factors (b) and (c) will be present as factors inherent in the basic design of the release. It is therefore considered important to evaluate these effects as fully as possible for all anticipated operating conditions.
Full scale in-service tests of the release devices installed in their respective submarines, have proven to be less than completely satisfactory. Certain in-air tests have been performed but these have served primarily as a check on assembly procedures. The resisting torque would not have been comparable to that encountered in a submerged vehicle. Pressure vessel tests of the release shaft mounted in the sphere alone, such as those performed with the SEA CLIFF and TURTLE spheres at Naval Ship Research and Development Center (Ref. 2 and 3) yielded only partial information. Since the release dogs (part of the vehicle afterbody) were not present in these tests, the resisting torque on the release shaft due to the buoyancy of the forebody was missing. Only the axial thrust effect could be determined. Open water tests involving the complete submarine are difficult, expensive, and hazardous. Only in water of depth comparable to the operating depth of the submarine, would such a test provide full information. The shallow water tests which have been performed on a number of occasions have been until now the best source of information on the performance of the release. In these tests, however, the full effect of axial thrust due to hydrostatic pressure is absent.

Because of these difficulties in obtaining complete data in the field, the attempt has been made to provide full information by means of carefully controlled laboratory tests.

Pressure vessel tests of the newly designed ALVIN release shaft and bushing were performed at Woods Hole in April 1965. While these tests were primarily for the purpose of checking the effectiveness of the O-ring seals and gaskets, torque measurements were taken at that time also. Since the shaft and bushing alone were tested, measured torque was that due to axial thrust only. The test results were reported briefly at that time (Ref. 1).

In an earlier phase of the work reported herein, an accurately machined laboratory model of the release device was assembled and instrumented with electric resistance strain gages. Tests performed with this equipment led to the determination of forces on sphere release components under various conditions of loading. The results of these tests were reported in 1969 (Ref. 4).

The work outlined in this report was primarily concerned with applying the results of the 1969 model tests (Ref. 4) in an effort to predict release torques for ALVIN and the AUTEC
vehicles. A test fixture was constructed which permitted laboratory simulation of the side (squeezing) forces applied to the release shaft cam by the release dogs. Estimated full-scale side forces (for ALVIN) were applied to the cam portion of the shaft using a laboratory compression testing machine, and the torque required to rotate the shaft was measured. Tests were run with the contacting surfaces (a) clean and dry, (b) greased, and (c) immersed in sea water.

From the results obtained, values of the coefficient of friction were calculated for the contacting materials (Monel K-500 on phosphor bronze) under the given test conditions.

It is felt that if the pressure vessel test results of 1965 and the results of the present investigation are superposed, a reasonably accurate prediction of release operating torques is possible. This has been done for ALVIN and the two AUTEC vehicles SEA CLIFF and TURTLE, and the results are presented in this report.

As the Project Titanes pressure hull nears completion and its weight and displacement figures become established, torque predictions can be made for it by extrapolation of the present results.
II DESCRIPTION OF TESTS

Equipment

The torque test fixture was designed around an actual sphere release shaft obtained from Electric Boat Division of General Dynamics Corporation during the construction of the submarines SEA CLIFF and TURTLE. This shaft was mounted in self aligning ball bearings which were fastened to a length of steel channel (Fig. 1). A steel base plate was attached at right angles to the channel and shaft, and served to support the load rod guide cylinders. During testing, the base plate was held in a vertical position so that the load rods were aligned with the axis of the compression testing machine. The load push rods were cylindrical, but were keyed to prevent their rotation during testing. At the inner end of each push rod a small bronze insert was fastened which had the same face dimensions and thickness as the bronze inserts on the ALVIN release dogs (Ref. 1). Material was Grade A phosphor bronze (copper alloy No. 510) and pieces for these tests were made from a bar of the material remaining after the manufacture of the ALVIN release in 1965. The bronze inserts of the fixture were designed to contact the cam surface in the same way that the release dog inserts contact the cam in the actual release device. The test fixture was fitted with 3 levelling screws so that it could be adjusted to its correct position in the testing machine. After a small initial load had been set on the testing machine the levelling screws could be backed off so that the compressive load would be taken entirely by the push rods.

For the in-salt water tests a watertight sheet metal box was constructed (Fig. 3). This box was open at the top so that the test model could be placed in the box, and the assembly mounted in the testing machine as a unit. The box was filled with salt water to a level where the friction surfaces were submerged. A watertight rotating seal was built into one side of the box so that the release shaft could extend through the wall, and the torque wrench could be used outside the box.

Compressive loads were applied to the test fixture using a Baldwin 60,000 pound capacity universal testing machine.

Torque measurements were made using a dial indicator type torque wrench made by Snap-On Tools Corp. of Kenosha, Wisconsin. This wrench was 12 in. long and had a range of 0-150 ft. lbs. (see Fig. 1).
Test Procedure

The first series of tests was performed with the contacting surfaces nominally clean and dry. Surfaces were prepared by first washing with liberal amounts of a degreasing compound called Megasol, and further, by wiping with a gauze pad soaked in trichloroethylene.

In the second test series the friction surfaces were coated with Lubriplate No. 130AA. This is a thin, light colored lubricating grease which has been used extensively by the operators of the submarine ALVIN in applications where both lubrication and corrosion protection have been required.

Finally a series of tests was run in which the contacting surfaces were immersed in sea water. The metal tank contained approximately 10 gallons of salt water taken from Woods Hole Harbor. The test fixture was placed in this box and the entire assembly mounted in the testing machine. The friction surfaces were cleaned, as in the first test series, so that they would be free of grease or oil before the sea water was added to the tank.

Test loads were applied in 100 or 200 pound increments over the range of the approximate full scale cam loading for the submarine ALVIN. Compressive loads were taken up to at least 1200 pounds, although higher loads were applied in some of the tests. At each value of load, the torque wrench was rotated through a small angle, first clockwise, then counterclockwise, and readings taken for both directions. The torque required to rotate the shaft was taken to be the torque wrench reading at the onset of shaft rotation.

The torque wrench was calibrated using dead weights. The head of the wrench was clamped firmly in a vise with the handle in a horizontal position, and a weight pan was suspended from the midpoint of the handgrip. Laboratory weights were added to the pan in 10 pound increments up to 60 pounds, and the wrench dial was read at each increment. Readings were found to be approximately 7 percent high (Fig. 7) and the torque values obtained during the tests were corrected accordingly.
Based on the data obtained in these tests, the coefficient of friction for the two mating materials was calculated for each of the test conditions imposed. These values are shown in Table 1. By using these results, and combining the results of the model tests (Ref. 4) and the pressure-torque tests done in April, 1965 (see Table A-1), predicted torque values required to release the forebody were determined as shown in Table 2. For the submarine inclined at 30 degrees, the torque was computed on the basis of a transverse cam force equal to 0.7 times the forebody net buoyancy, as determined in the model tests (Ref. 4). Torque values for the level vehicle are based on a calculated cam force of 0.43 times net buoyancy. An experimentally determined value of this force was found to be somewhat less than the calculated value, and so the more conservative figure was used for the present report. All of the torque values reported include the effect of axial thrust due to hydrostatic pressure at operating depth.

The forebody net buoyancy values used in the calculations are 1844 pounds for ALVIN (Ref. 5), and 3120 pounds for the AUTEC vehicles (Ref. 6).
TABLE 1

Coefficient of Static Friction
Monel K-500 on Phosphor Bronze

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<th>Surfaces</th>
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<tr>
<td>Dry</td>
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<td>In Sea Water</td>
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TABLE 2

Approximate Torque to Release Forebody - Ft.-Lbs. Vehicle in Sea Water at Operating Depth

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<td>42</td>
<td>60</td>
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<tr>
<td>SEA CLIFF/TURTLE</td>
<td>63</td>
<td>95</td>
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IV DISCUSSION

From a practical viewpoint the "clean and dry" test condition is the least interesting one since it is unlikely that the release device would be operated that way. If the device is actuated in air (for example, in a pre-dive test) this condition might be encountered, but there is a good chance that the surfaces would contain some quantity of oil or grease, either intentionally or otherwise. The operators of ALVIN follow a practice of applying a thin coating of grease to mechanical components such as those of the release mechanism, at the time of assembly.

With the submarine in sea water, any grease previously applied to the contact surfaces probably would be washed away in a short time. However, the test results show that sea water itself provides a fair degree of lubrication. In practice, it is possible that a thin film of grease might remain on the components in spite of the presence of sea water. If this should happen, torque values might be somewhat less than those reported here.

The axial thrust effect, i.e., the resisting torque attributable to external hydrostatic pressure forcing the release shaft cam against its thrust washer, appears to be difficult to predict accurately. The Woods Hole tests for this effect (Table A-1), indicated a torque of 12 foot-pounds at the 6000 foot depth, while the AUTEC tests at 7150 feet gave 9.2 foot-pounds for the SEA CLIFF hull (Ref. 2), and 3.3 foot-pounds for the TURTLE hull (Ref. 3). This discrepancy could be the result of slight differences in the O-ring seal arrangement in the two hull designs, or possibly because of the presence in one or more of the tests of a lubricant other than sea water. The pressure proof test of the AUTEC 2 (TURTLE) hull was done in two parts: a test in oil in which viewport deflections were measured, and a test in salt water, during which the hull release shaft was torque-tested (Ref. 3). It is possible that the low torque reading in that test was the result of a quantity of oil remaining on the release shaft after the completion of the first part of the test. The SEA CLIFF hull tests were done in salt water only, as were the Woods Hole tests of the ALVIN shaft-bushing assembly.
V CONCLUSIONS

Torque tests were performed with a full size laboratory model of the ALVIN/AUTEC sphere release, using estimated full scale frictional drag forces. The results were combined with est data, previously obtained, of torque as a function of xternal hydrostatic pressure. The combined results led to the calculation of predicted torque required to actuate the release device. Torque values are shown in Table 2 of this report. The maximum torque of 95 foot-pounds is that for the AUTEC vehicles, at operating depth, and having a 30 degree list.
VI REFERENCES


APPENDIX

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Figure 2. Close-up View of Test Model
Figure 3. Test Model in Tank for Sea Water Tests
Figure 4. Test Data - Surfaces Clean and Dry
Figure 5. Test Data - Surfaces Greased
Figure 6. Test Data - Surfaces in Sea Water
Figure 7. Torque Wrench Calibration
TABLE A-1

Pressure-Torque Test of ALVIN Sphere Release

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<tr>
<th>Pressure (psi)</th>
<th>Torque (inch-lbs.)</th>
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The above data were taken on April 22, 1965 during a test of the newly designed ALVIN sphere release shaft and bushing. The test was designed to detect possible leakage past the O-ring seals, and to measure rotational torque due to axial thrust of the shaft. See W.H.O.I. Technical Memorandum No. DS-20, "Design and Manufacture of New Emergency Hull Release for ALVIN" by James W. Mavor and Arnold G. Sharp, August, 1965.
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Laboratory torque tests were performed using an actual emergency sphere release shaft of the type used in the research submarines ALVIN, SEA CLIFF, and TURTLE. A test fixture was constructed which permitted laboratory simulation of the side (squeezing) forces applied to the release shaft cam as a result of forebody buoyancy. Estimated full-scale side forces were applied to the cam by a laboratory compression testing machine, and the torque required to rotate the shaft was measured. Tests were run with contacting surfaces (a) clean and dry, (b) greased, and (c) immersed in sea water. From the test results, values of release torque were calculated for the submarines in question. Coefficient of friction values of the contacting materials (Monel K-500 on phosphor bronze) also are reported.

1. Torque Test
2. Emergency sphere release
3. Research submarine


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1. Sharp, Arnold G.
2. Sullivan, James R.
3. Nonr-2484(00); NR 260-107

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