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S4607, Task 11896
Lab. Project 930-77
Progress Report 2

Development of Buoyancy Material for the Deep Submergence Search Vehicle

Evaluation of Sympathetic Implosion of Buoyancy Modules

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DEVELOPMENT OF BUOYANCY MATERIAL
FOR THE
DEEP SUBMERGENCE SEARCH VEHICLE

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S4607, Task 11896
7 June 1968
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U. S. NAVAL APPLIED SCIENCE LABORATORY
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SUMMARY

The U. S. Naval Applied Science Laboratory is conducting work directed toward the development of a 34 pcf density buoyancy material for the Deep Submergence Search Vehicle (DSSV). One of the approaches being followed by the Laboratory is the development of a buoyancy module. The module currently under consideration is in the shape of a right hexagonal prism and consists of a 3 in. O.D. hollow glass sphere centrally embedded in a matrix of syntactic foam.

This report presents the results of tests which demonstrate that sympathetic implosion at high hydrostatic pressure is a significant problem with regard to glass sphere modules. Tests were conducted on multiple module specimens wherein one module was "weakened" to cause premature failure with the result that remaining modules failed catastrophically by the phenomenon of sympathetic implosion. Sympathetic implosion was exhibited at hydrostatic pressures ranging from 5,600 to 14,800 psi.

The Laboratory is initiating work on several approaches which have merit for eliminating the sympathetic implosion problem.

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ADMINISTRATIVE INFORMATION

Ref: (a) NASL Program Summary, S4607, Task 11896 of 1 May 1968
(b) NASL Project 930-77, Progress Report 1 of 25 Jan 1968
(c) Proteus Report No. SP-651F of 1 Oct 1965

1. In accordance with reference (a), the Naval Applied Science Laboratory (NASL) has undertaken the development of a buoyancy material for the Deep Submergence Search Vehicle (DSSV). This report presents the results of recently acquired significant information regarding the phenomenon of sympathetic implosion on buoyancy modules at high hydrostatic pressures.

BACKGROUND

2. One of the Laboratory's approaches to provide supplementary buoyancy for the DSSV is the development of a right hexagonal buoyancy module consisting of a hollow sphere embedded in a matrix of syntactic foam.

3. Preliminary evaluation for this approach was reported in the Laboratory's last progress report, reference (b). In general, the work was concerned with the selection of the most promising module design. A 4 in. hexagonal module containing a 3 in. O.D. hollow sphere embedded in NASL-B18 syntactic foam was investigated in the initial phase. A number of modules were evaluated, each of which contained one of the following hollow spheres, namely, glass, alumina, titanium and aluminum. The NASL-B18 syntactic foam was considered to have the required properties for 20,000 ft. applications.

4. The glass sphere module was selected for further development; the decision was based on preliminary hydrostatic pressure, pressure cycling, and sympathetic implosion tests.

OBJECTIVE

5. The objective of this program is to develop a buoyancy material for the DSSV having a density of 34 pcf.

PROCEDURE AND RESULTS

PHASE I

6. In the early stages of the program, sympathetic implosion tests were conducted to determine whether failure of a module by implosion of its embedded sphere would cause destruction of an adjacent module and its sphere, as reported in reference (b). Additionally, the effect of varying the distance between embedded spheres in resisting sympathetic implosion was determined.

7. The specimen consisted of a pair of 4.0 in. hexagonal glass sphere modules bonded together at one of the hexagonal sides with a rigid epoxy resin. The separation between embedded spheres was varied from 0.5 to 1.0 inches. Three tests were conducted with this type of specimen. The method used to cause sympathetic implosion was to induce premature failure of one of the modules in each pair by either:

a. Reducing its syntactic foam wall thickness, or

b. Embedding an inherently weak sphere in the module (see reference (b)).

8. In the three tests, the "weakened" module imploded without causing sympathetic implosion of the adjacent module. However, the tests also showed that when the sphere imploded, thus causing massive destruction of its syntactic foam envelope, the syntactic foam of the rigidly-bonded adjacent module fractured by crack propagation from the imploded module. Subsequently, a test was conducted wherein the modules were not bonded but simply banded together with a metal strap. Results in this case showed that the crack propagation into the adjacent module was eliminated. Test results are as follows:

Module Size, in.	Sphere Separation in.	Sphere Coating	Type of Bond	Implosion Pressure, psi	Results of Test on Adjacent Module
		Pair of Modules			
4.0	0.50	None	Rigid epoxy	13,500	No sympathetic implosion; matrix cracked
4.0	0.75	None	Rigid epoxy	15,800	No sympathetic implosion; matrix cracked
4.0	1.00	None	Rigid epoxy	13,500	No sympathetic implosion; matrix cracked
4.0	1.00	None	Banded; unbonded	13,500	No sympathetic implosion nor cracking of matrix.

9. Although the above results appeared to indicate that sympathetic implosion would not be a problem, further work was undertaken under Phase II to determine whether sympathetic implosion could be induced in a cluster of modules. These modules, occupying a larger percentage of the pressure chamber volume than paired modules, simulate more closely actual service conditions in the DSSV.

PHASE II

10. Initial calculations, based on the glass manufacturer's published data showing a 0.080 inch wall thickness for a 3 in. glass sphere, indicated that the module target density of 34.0 pcf would be attainable. However, the glass spheres available from the manufacturer at the time Phase II was initiated had a wall thickness averaging 0.093 inches and resulted in a module having a 35.4 pcf density. In subsequent discussions, the manufacturer stated that a reduction of the wall thickness to 0.080 inches in the glass sphere would necessitate use of a different manufacturing process. This process would require development work to produce spheres of a quality comparable to that of the currently available spheres.

11. In the interim, it was necessary, therefore, to reduce the minimum wall thickness of the syntactic foam from 0.5 in. to 0.3 in. to attain the 34.0 pcf target density. Results of the tests described in paragraph (8), wherein the separation distance between spheres was varied, indicated that the 0.3 in. wall thickness would be sufficient to resist the effects of sympathetic implosion. Therefore, the next phase of the program was directed to the comprehensive evaluation of the 3.6 in. hexagonal module.

12. To that end, large quantities of the 3.6 in. hexagonal module were fabricated. One of the first tests performed was sympathetic implosion.

13. The test using an unbonded pair of modules was repeated. In this test one of the paired modules had been weakened by grinding flat a small surface on the glass sphere to reduce its thickness at that location. Failure of the "weakened" module did not cause sympathetic implosion nor cracking of the matrix in the adjacent module (see Figure 1) which has also been the case with the 4 in. module. The next test conducted utilized a specimen consisting of multiple modules (cluster). Two such tests were conducted in which failure of the "weakened" module resulted in catastrophic failure of all adjacent modules, as shown in Figure 2. Approximate positioning in the pressure chamber of both types of specimens, that is, paired and clustered modules, is shown in Figures 3(a) and 3(b), respectively. Data for the above tests are shown below:

Module Size, in.	Sphere Separation in.	Sphere Coating	Type of Bond	Implosion Pressure, psi	Results of Test on Adjacent Module
		Pair of Modules			
3.6	0.60	RTV Silicone (1)	Banded; Unbonded	15,000	No sympathetic implosion nor cracking of matrix.
		Multiple Modules (Cluster)			
3.6	0.60	RTV Silicone (1)	Banded; Unbonded	12,200	Sympathetic implosion causing catastrophic failure.
3.6	0.60	RTV Silicone (1)	Banded; Unbonded	14,800	Sympathetic implosion causing catastrophic failure.

NOTE: (1) Room temperature vulcanizing silicone rubber (Dow Corning Sylgard 182); 0.010 to 0.015 inches thick.

PHASE III

14. To determine whether sympathetic implosion is affected by the distance of modules from a rigid structural member, another test of an unbonded pair of modules was conducted. This specimen was placed in a steel pipe, 6 in. inside diameter and 9 in. long, which was in turn placed inside the pressure chamber, as shown in Figure 3(c). Sympathetic implosion was also obtained in this test. It is to be noted that sympathetic implosion for this test occurred at 5,600 psi whereas the implosion pressure for all other tests was in excess of 12,000 psi. Results are as follows:

Module Size, in.	Sphere Separation, in.	Sphere Coating	Type of Bond	Implosion Pressure, psi	Results of Test on Adjacent Module
		Pair of Modules			
3.6	0.60	RTV Silicone (1)	Banded; Unbonded	5,600	Sympathetic implosion causing catastrophic failure.

NOTE: (1) Room temperature vulcanizing silicone rubber (Dow Corning Sylgard 182); 0.010 to 0.015 inches thick.

15. Additional test specimens are being prepared in which syntactic foam will be poured around a pair of modules centrally located in a steel pipe. This syntactic foam will fill in the unoccupied volume between the modules and the inner wall of the pipe. It is presumed that this test specimen will more closely simulate actual service conditions than any previous specimen. The addition of this extra foam might be sufficient to provide additional energy absorption during implosion.

DISCUSSION

16. Figure 3 shows the positioning of the three types of specimens tested to date in the pressure chamber. In Position A, distance from the paired module to the chamber wall was approximately 2.7 inches. In Position B, which depicts the clustered module in the pressure chamber, and Position C, the paired module in the steel pipe, the distance from the constraining steel wall was approximately the same, namely 1.1 inches for Position B and 0.9 inches for Position C. In both of the latter cases, catastrophic failure from sympathetic implosion occurred.

17. It is theorized that, in the instances where sympathetic implosion occurred, the pressure wave emanating from the imploded "weakened" module was not dissipated but perhaps oscillated between modules and the chamber walls. This could result in increased pressures sufficient to implode the remaining modules. A second possibility is that the pressure wave created an unequal pressure loading on the modules which would result in premature failure.

CONCLUSIONS

18. Results of work presented in this report show that a sympathetic implosion problem exists with a composite material which consists of a 3 in. O.D. hollow glass sphere embedded in a matrix of syntactic foam. However, the Laboratory considers that there are several approaches available which can be developed that may eliminate this problem.

FUTURE WORK

19. The Laboratory is investigating two approaches in the development of a buoyancy material. Future work is as follows:

PHASE IV

a. Buoyancy Module Approach

(1) Obtain information regarding the mechanism which causes sympathetic implosion. This information may lead to a method by which the module can be redesigned or fabricated to eliminate the problem.

(2) Heat-treated 3 in. hollow glass spheres which may be more shock resistant than those currently available.

(3) Low density foams contained within bonded 3 in. hollow glass hemispheres to absorb energy.

(4) Tough, resilient elastomeric coating on the outside surface of the sphere to reduce the implosion energy.

(5) Smaller-size hollow glass macrospheres to reduce the implosion energy.

(6) Three inch hollow metal spheres, in lieu of glass spheres, since a report, reference (c), postulates that metal spheres implode with less energy release as compared to glass spheres.

PHASE V

B. Minispheres in Syntactic Foam Approach

(1) The Laboratory has also initiated work on the development of hollow glass minispheres. These spheres, when combined with smaller size hollow glass microspheres and a high-strength epoxy resin, have potential in producing a material of 34 pcf density (or less) with reliability at 10,000 psi. However, these minispheres are not presently available, even in small quantities, and extensive development work must be accomplished in order to obtain spheres having appropriate size, density, strength and sphericity. Work in this area has already been initiated by Corning Glass Works wherein they have demonstrated that spheres of this type can be manufactured.

(2) On 9 May 1968, at NASL, and again on 17 May 1968, at Corning representatives of both NASL and Corning discussed and outlined a tentative development program. As a first step, Corning will supply prototype minispheres to NASL in July 1968 for preliminary evaluation; these prototype spheres will have a high strength but also a high density. NASL will conduct packing studies and then formulate syntactic foam which will be evaluated for strength. Based on these results, NASL will provide guidance to Corning in their continuing development.

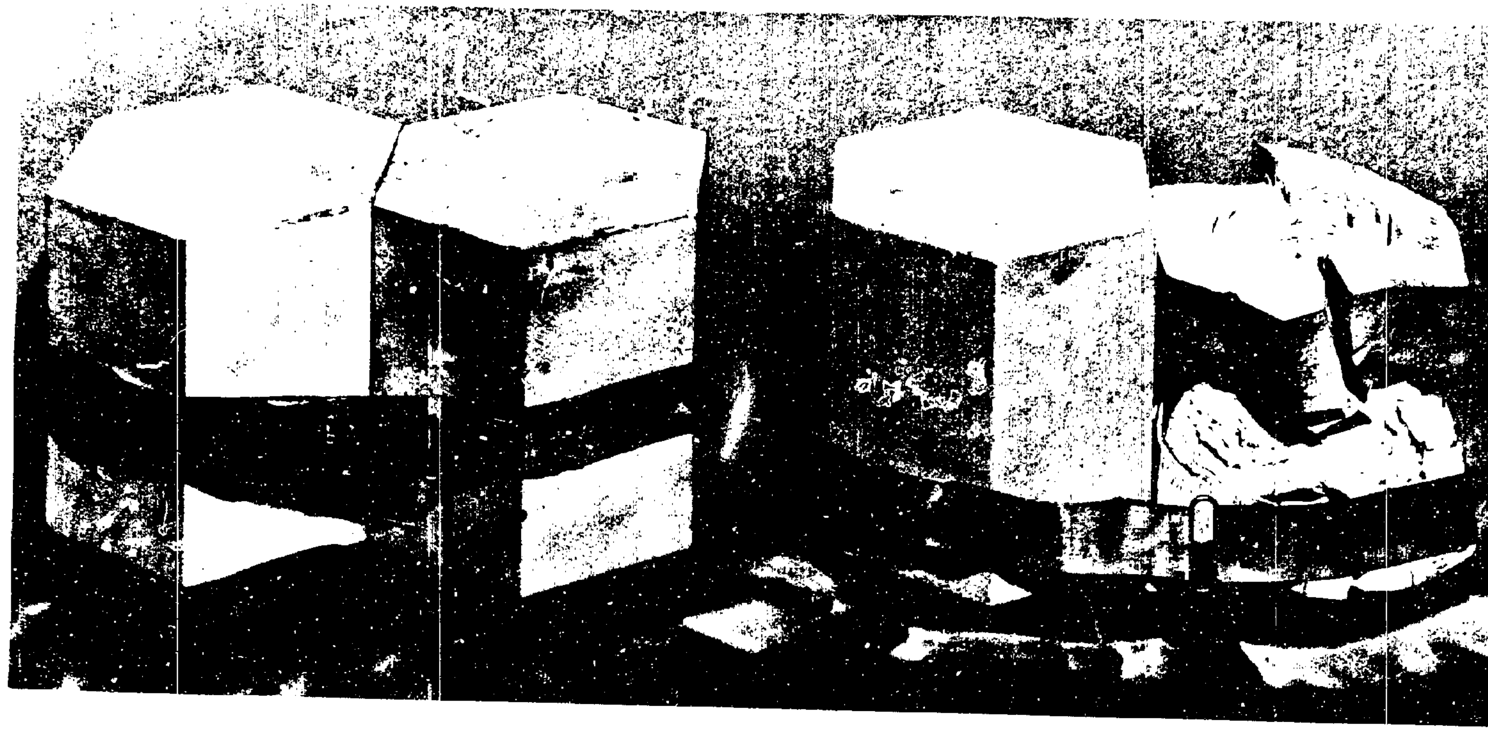

PHOTO L21559-1

Figure 1 - Sympathetic Implosion Test on a Pair of 3.6 in. Hexagonal Glass Sphere Modules

PHOTO L21559-2

Figure 2 - Sympathetic Implosion Test on a Cluster of 3.6 in. Hexagonal Glass Sphere Modules

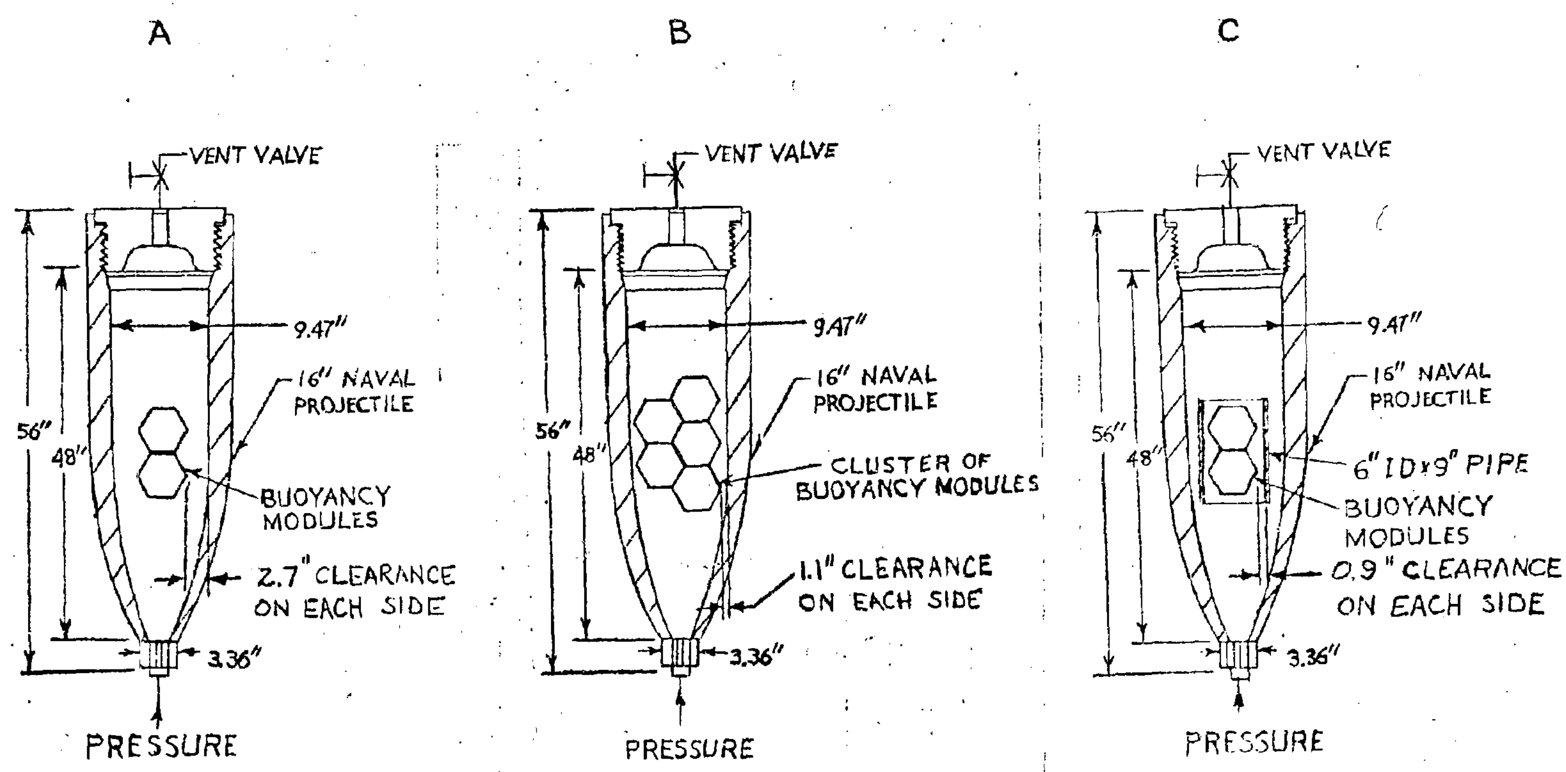

FIG. 3 - SKETCH OF NASL HIGH PRESSURE CHAMBER SHOWING POSITIONING OF MODULES DURING TEST

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