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| AUTHORITY                                                                                                                                                                                                             |              |
| 31 Oct 1964, DoDD 5200.10; ONR ltr, 26 Oct 1977                                                                                                                                                                       |              |

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Report No. L800-73

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~~Aerjet~~ **ENGINEERING CORPORATION**

AZUSA, CALIFORNIA

Code  
ONR: 429  
4007

**FORMAL REPORT OF PROGRESS**

Copy No. 11

17 October 1952

TO: Office of Naval Research  
Department of the Navy  
Washington 25, D. C.

VIA: Bureau of Aeronautics Representative  
15 South Raymond Avenue  
Pasadena 1, California

SUBJECT: Research, Development, and Testing  
of Underwater Propulsion Devices

CONTRACT: N6ori-10, Task Order I  
Project NR 220 003

PERIOD  
COVERED: 1 September through 30 September 1952

This informal monthly progress report is  
submitted in partial fulfillment of the  
contract.

**AEROJET ENGINEERING CORPORATION**

*C. A. Gongwer*  
C. A. Gongwer, Manager  
Underwater Engine Division

NOTE: The information contained herein is regarded as preliminary  
and subject to further checking, verification, and analysis.

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Report No. 1800-73

## SECURITY INFORMATION

### I. ALCLO MOTOR

#### A. DOUBLE-WALL MOTOR USING 3.75-IN.-DIA GRAIN

1. Testing was initiated on an injector of the whirl-chamber type, which is composed of 16 individual sprays. This injector has a larger pressure drop than the spinner-type injector. Test results indicate that the performance of the motor is unchanged.

2. A series of tests using grains containing 20 and 30% excess aluminum was initiated to determine what increase in performance could be expected as the result of the reaction of the excess aluminum with the steam.

#### B. DOUBLE-WALL MOTOR USING 4.75-IN.-DIA GRAIN

Fabrication of this motor was completed.

#### C. SINGLE-WALL MOTOR USING 4.75-IN.-DIA GRAIN

Design of this motor was completed, and fabrication of the major components was ordered.

#### D. TEST VEHICLE MOTOR USING 3.75-IN.-DIA GRAIN

1. A delayed-action blasting cap was installed in the static-test motor and wired to the ignition circuit. The cap functioned properly, firing after the specified time delay. This type of cap will be installed in the 4.5-in.-dia test vehicle in a similar manner to aid in locating the test vehicle at the end of its trajectory, the detonation of the cap being picked up by means of hydrophones.

2. In the hydroductor design it will be necessary to reduce the volume of the combustion chamber to accommodate the condensing section in the 4.5-in.-dia envelope. In order to determine the effect on the performance, a test motor with a short combustion chamber will be tested.

### II. STEAM-INJECTOR CONDENSER

A. Investigation has indicated that several factors influence the efficiency of the diffusion process at the exit of the condenser. It was found that the diffusion efficiency varied directly with the ratio of water inlet area to diffuser throat area. The mass mixture ratio of water to steam was also of great importance. Test results have shown that mixture ratios of about 40:1 made possible diffusion efficiencies of greater than 90%. The length of diffuser had an appreciable effect on the performance. Cutting the exit section off at the throat and depending on external diffusion proved to be unsatisfactory, because of decreased efficiency and instability of the jet. Further tests, however, will be conducted.

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B. The design parameters which determine the starting properties of the system are being studied. Tests have indicated that ease of starting is inversely proportional to both the ratio of water inlet area to diffuser throat area and the ratio of steam-nozzle throat area to diffuser throat area. In view of these results and those discussed in the previous paragraph, it can be seen that practical operation requires a compromise in the choice of design parameters.

### III. ALCLO-FIRED TEST STEAM GENERATOR FOR SUBMARINE

The new feeders for the Alclo-fired closed-cycle steam generator gave consistently good results during calibration. The flames obtained in preliminary firing in the open appear to be satisfactory. The test steam generator will be operated using Alclo in the near future.

### IV. ALCLO STUDIES

#### A. BURNING-RATE STUDIES

1. A total of 17 burning-rate tests were made using the vertical steam generator Mk II. The investigation of copper oxide as rate-increasing additive was continued. A mixture composed of 38.5% flake Al, 55.8%  $KClO_4$ , 1.6%  $CuO$ , and 4.1% Pb was found to burn 18% more slowly than the standard Alclo mixture throughout the range from 100 psia to 450 psia.

2. The investigation of potassium bromide as a rate-increasing additive was continued using two different proportions. The burning rate of a mixture containing 29.8% Al, 57.2%  $KClO_4$ , 4.3% Pb, and 8.7% KBr was found to be approximately 25% less than for the standard mixture in the pressure range from 200 to 500 psi. A mixture composed of 29.8% Al, 57.2%  $KClO_4$ , 8.7% Pb and 4.3% KBr was found to burn at a rate equal to or greater than that of the standard mixture at pressures up to 150 psia; but in the higher range of pressures (200 to 500 psia) the burning rate was 12% less than that of the standard mixture.

3. A series of tests were made in which the effect of prolonged storage (aging) on the performance of Alclo grains was determined. One group of grains was stored in a hot (180°F), dry, inert ( $N_2$ ) atmosphere for a period of 43 days, another group was stored in a cool (80°F), dry, inert atmosphere for 41 days, and a third group was tested immediately as a control. Test results indicated no measurable decrease in the heat of reaction or in the burning rate of the stored propellant.

4. As a general rule, a rise in temperature of 10°C doubles the speed of a chemical change. Therefore, the effect of high-temperature storage can be corrected to an equivalent storage time at ambient temperature by using the following relation:

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$$\frac{D_1}{D_2} = 2^{0.1(T_2 - T_1)}$$

$$\text{or } D_1 = D_2 \cdot 2^{0.1(T_2 - T_1)}$$

where

$D_1$  = duration of storage (or aging) at temperature  $T_1$

$D_2$  = duration of storage (or aging) at temperature  $T_2$

$T_1$  = ambient temperature, °C

$T_2$  = aging temperature, °C

Therefore, the grains which were aged for 43 days at 180°F (82°C) had an equivalent age at ambient temperature storage (80°F = 27°C) of

$$D_{27^\circ\text{C}} = 43 \times 2^{0.1(82-27)} = 43 \times 2^{5.5} = 43 \times 45 = 1935 \text{ days}$$

$$= 5.3 \text{ years}$$

5. The problem of storage will be studied further to determine the effect of moisture and oxygen on the aging of Alclo propellant.

#### B. 100-TON PRESS

1. Thirty-seven 3.75-in.-dia grains were pressed during the month of September. The grains averaged about 8.25 in. in length, and weighed about 9 lb each.

2. Several experimental grains were made; a pneumatic vibrator was used to agitate the loose powder of each increment in turn after it had been poured into the die cavity. This procedure causes the fluffy powder to settle, forcing out much of the entrapped air. It was believed that the occurrence of laminary fractures would be less likely if a reduction was made in the quantity of air that must be forced out of the grain while it is being formed under the high pressure of the hydraulic ram. The use of the vibrator improved the physical quality of the grain moderately, but its effect on performance in the motor has not yet been determined.

3. Mechanical failure of the main cylinder of the press resulted in a two-week shutdown for repair during this report period. The repair has been completed and the press is again in operation.

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V. GASOLINE—COMPRESSED AIR HYDROPULSE

A. Static operation of the motor on gasoline and air was continued throughout the month. Fairly consistent combustion was obtained with the two injectors, utilizing two No. 80 holes in each, with the jets pointed upstream against the incoming air blast. However, the explosions were not powerful, and only a part of the fuel injected each cycle was being burned.

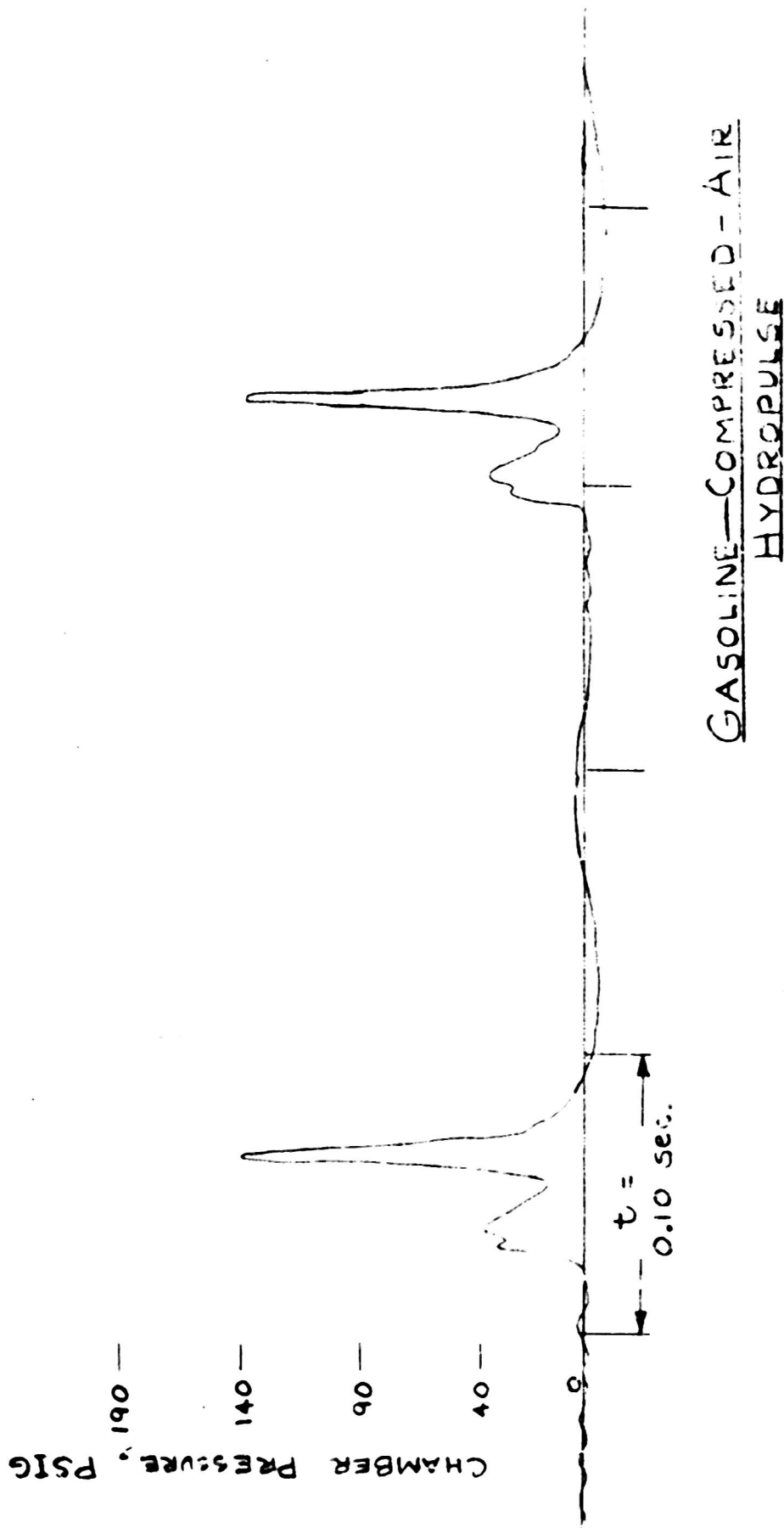
B. In order to improve combustion efficiency, a new type of injector was built and tested. In this design, a single jet of gasoline is atomized by means of a small jet of high pressure air which it intersects at a 45-degree angle. This device produces a very finely divided spray at the injector tip, and appears to give the best fuel atomization thus far obtained. Two injectors of this type were built and installed in the motor.

C. When the motor was operated, better combustion was obtained immediately. Figure 1 is a trace of an oscillograph record showing combustion-chamber pressure in the motor when this new type of injector is used. The first peak of each cycle is the pressure resulting from injecting compressed air into the chamber. The second peak is produced by combustion of the fuel. It will be observed that ignition of the charge did not take place until some time after air and fuel injection were completed, because the timing of the spark was retarded considerably. Advancing the spark slightly resulted in a lower combustion pressure and irregular firing, while slightly more advance stopped combustion completely. The spark should fire exactly at the end of the injection portion of the cycle. It was apparent that even with the spark retarded, only a part of the fuel injected in each cycle was being burned.

D. Several methods of improving the performance are under consideration and will be tested in the immediate future.

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CHAMBER PRESSURE  
WITH ATOMIZING NOZZLE - 9-17-52

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Figure 1

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