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DELAY ACTUATOR, SILICONE

SUMMARY REPORT

EB #3E

ON

TASK ORDER NO. LL

November 30, 1960

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Dear Sir:

This summary report describes the effort performed under Task Order No. LL, from October 14, 1959, through November 30, 1960. The objective of this program was to conduct additional research directed toward the development of a 12-month time-delay device utilizing silicone fluid that had been evolved previously, and to prepare and evaluate four timers.

Background Information

During the past several years, a search by many organizations for a cheap, reliable, and reasonably accurate time-delay mechanism has led to the consideration of silicone fluid as a timing medium. Under Task Order No. J, basic design criteria were established for an experimental time-delay unit which utilized silicone fluid. The effort under that Task Order was directed toward the development of an experimental unit for use in providing time-delay periods ranging from 15 minutes to 2 months, at temperatures varying from -20 to +120 F; the desired accuracy was such that the flow of silicone fluid could not vary more than ±10 per cent over this range of temperatures. In the research performed under Task Order No. J, it was found necessary to incorporate in the experimental unit a device designed to provide temperature compensation, so that changes in the viscosity of the fluid that were brought about by temperature variations would not cause the fluid-flow rate of the experimental unit to vary beyond the specified limits.

On March 27, 1959, an effort under Work Order No. IX, Task Order No. CC, was undertaken, to conduct research directed toward the

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and relatively small; and was to be self-contained, i.e., emit no silicone fluid to the ambient water. Since the service environment for the desired timer would minimize temperature fluctuation, it appeared likely that a study directed toward the development of a suitable device using silicone fluid would not have to include consideration of means for temperature compensation, with its associated complexities.

The Work Order No. IX effort resulted in an experimental device which showed satisfactory operating characteristics over a period of 3 months (the longest period possible within the time limit of the contract) at an ambient temperature of approximately 75 F. Because a major problem in the development of any time-delay device is reproducibility, Task Order No. LL was subsequently initiated to provide for minor modifications to the unit developed under Work Order No. IX, the preparation of four timers of that type, and an evaluation of the timers at temperatures of about 75 and 40 F. The research performed under Task Order No. LL is described in the following.

Summary

Under this program, the experimental time-delay unit which had been developed and evaluated cursorily under a previous research program was redesigned, and four timers were fabricated and assembled. The regulating or metering tubes for these timers were selected on the basis of the flow characteristics of the tubes; these characteristics were determined by metering the silicone fluid, Viscasil 500,000, through the tubes for approximately 21 days.

The timers were evaluated at about 75 and 40 F over a total period of about 9 months. The results obtained during the first 5 months of the evaluation period were partially invalidated by the presence of foreign particles in the fluid; lint-like particles generally restricted the flow of fluid in the timers, and in one unit, plugged the metering tube. Filtered silicone fluid was subsequently used in three of the units, in the evaluation at 40 F. The evaluation test on the fourth timer was continued through the temperature transition from about 75 F to 40 F; this unit had shown a reasonable flow rate at about 75 F, and it appeared desirable to observe the effect of the temperature change on the fluid, and consequently on the operation of the unit.

The 4-month evaluation at 40 F indicated appreciable variations in the flow rate obtained in the four timers. The reason for this variation was not completely apparent; however, it was believed that "dirt", i.e., foreign particles picked up during normally careful handling of the fluid and of the units, probably was the cause of the variations in flow rate.

It appeared that the next logical step in the development of an appropriate time-delay device of this type would be to investigate practical methods of cleaning the silicone fluid, preparatory to performing evaluation tests on the timers filled with cleaner fluid.

Engineering Activity

The engineering activity under this program included the redesign of the experimental time-delay device developed previously, the investigation and selection of timer metering tubes, the fabrication and assembly of four timers, and an evaluation of the timers at about 75 and 40 F.

Redesign of the Timer

The experimental timer* developed under Work Order No. IX, Task Order No. CC, was redesigned to utilize an O-ring seal at the flanges (between the end cap and the housing), castings for the major components, and threaded ends for connection of the unit to the workpiece and to the neutral-buoyancy chamber. A disassembly view of the modified experimental timer, without the main spring (and firing-pin mechanism), is shown in Figure 1.

The flange of the rubber Bellofram piston seal was bonded to an aluminum-alloy washer with an adhesive, so that this subassembly could be installed as a unit between the flanges of the end cap and of the housing. An O-ring seal was incorporated in a face groove provided in the end cap, to seal against the aluminum-alloy washer of the Bellofram subassembly. With this seal, the flange screws could be tightened to "bottom out" the flanges, and then the O-ring squeeze would produce an effective seal. A flat-gasket-type seal had been used previously between the flanges, and

* The design details were presented in the "Summary Letter Report on Work Order No. IX, Task Order No. CC" dated July 26, 1959.

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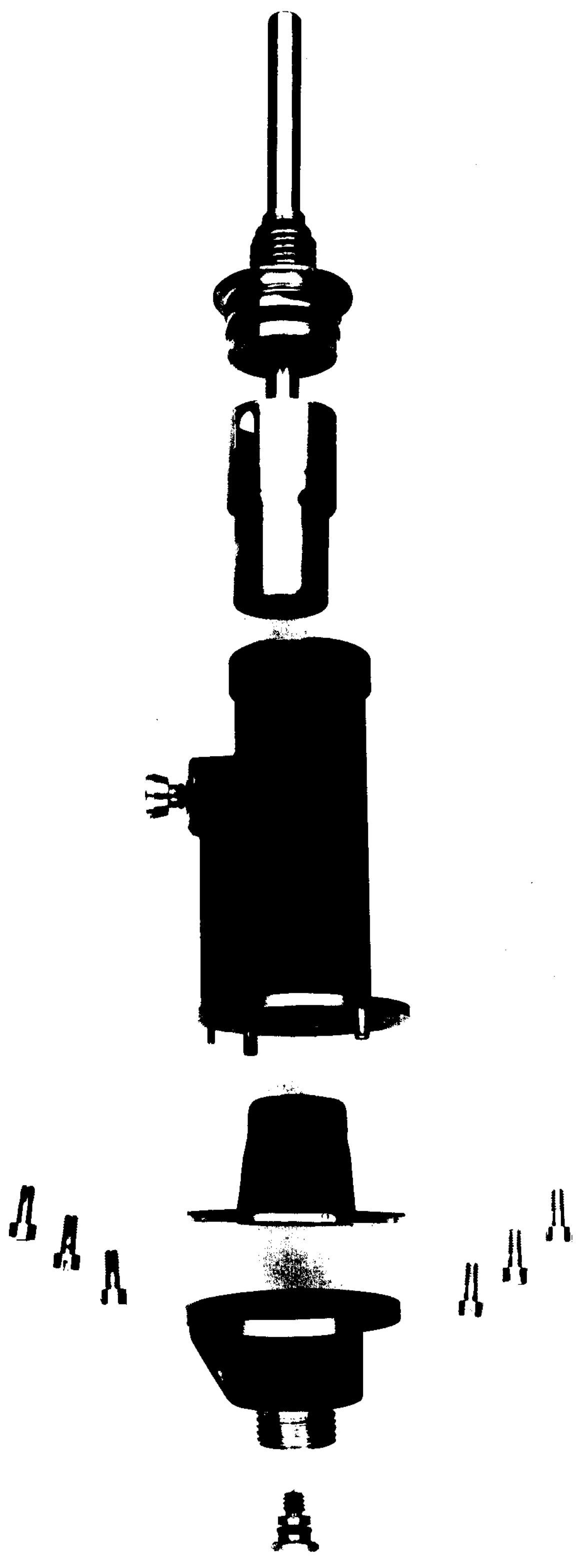

Figure 1. Disassembly View of Modified Experimental Timer (Without Main Spring and Firing-Pin Mechanism)

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gross extrusion of the seal had been encountered when the flange screws were tightened in an effort to insure a leak-tight joint.

A threaded extension was provided on the end cap to permit attachment of the timer to a neutral-buoyancy chamber, which could be added later; a plug was incorporated in the threaded extension to facilitate the filling of the unit with the silicone fluid. A threaded extension was also added at the firing-pin end of the timer to permit attachment of the unit to the "workpiece". For experimental purposes, a piston-rod extension was arranged [redacted], so that movement of 25X1 the piston could be measured with a dial indicator in contact with the end of the piston-rod extension.

Selection of Timer Metering Tubes

Eight metering tubes, each 0.075 inch in OD x 0.010 inch in ID x 2 inches in length, were cut from a common piece of Type 321 stainless steel seamless capillary tubing. The tubes were deburred, inspected, and placed on a manifold for flow measurements. Each tube was inserted in a manifold adapter and held by two O-rings; thus, the actual metering-tube seal installation was simulated. Silicone fluid (Viscasil 500,000) was extruded through these tubes for 21 days under a pressure of 70 psi and at an average ambient temperature of 77.5 F. The quantity of fluid extruded during each 24-hour period was collected in a covered container and weighed. The metering tubes and the manifold with related equipment are shown in Figure 2.

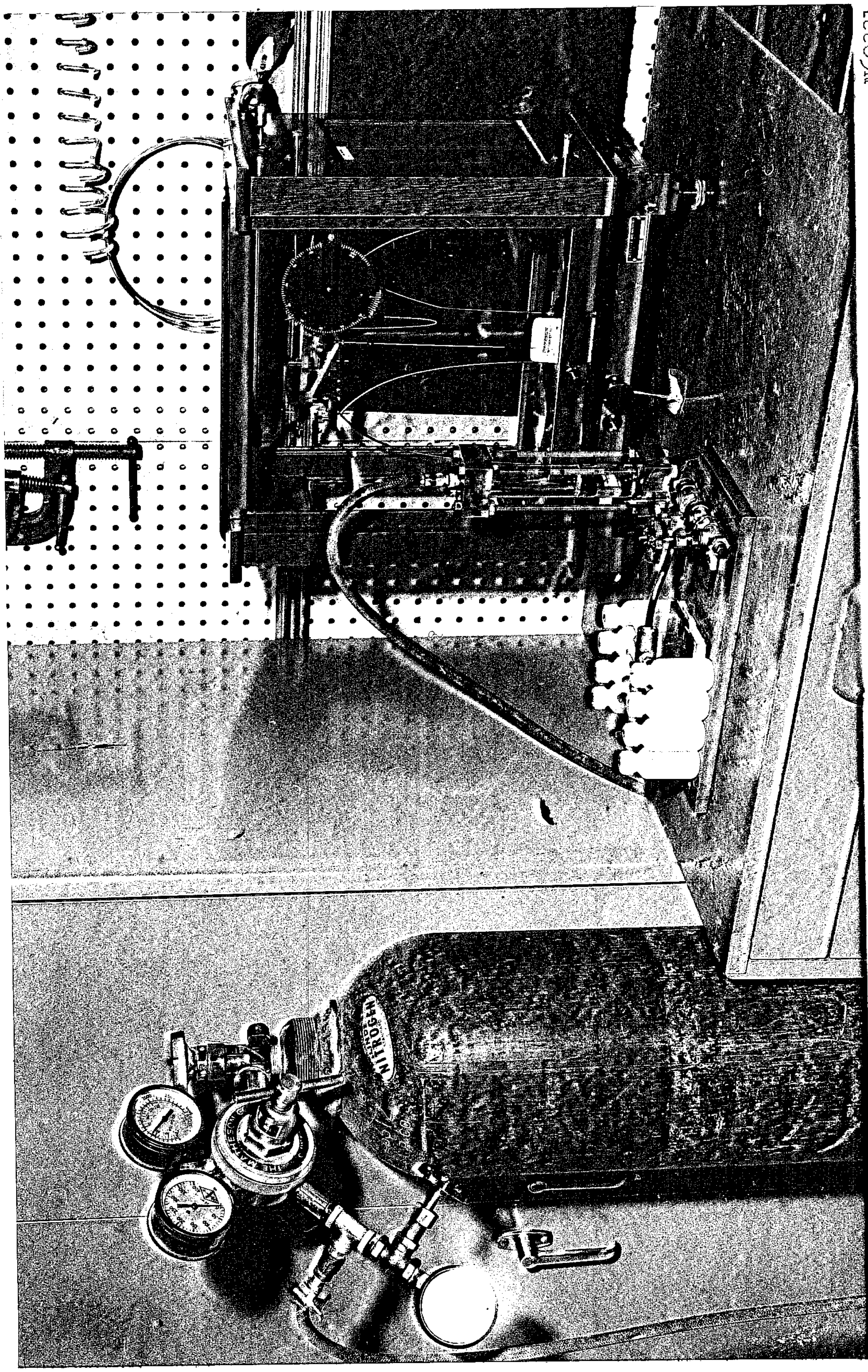

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Figure 2. Laboratory Set Up for Calibrating Metering Tubes

The total flow for each of seven of these metering tubes over a 21-day period varied from about 5.04 to 5.93 grams. A restriction in the eighth tube resulted in only 2.10 grams of fluid being extruded during the same period. Four metering tubes were then selected for assembly in the experimental time-delay units. The tubes chosen were those which had extruded the most similar amounts of fluid, namely, 5.315, 5.389, 5.533, and 5.534 grams. Also, based on these data, a spring was designed that would permit the timer units to provide for the desired delay period of one year at an average temperature of 75 F.

Fabrication and Assembly of the Timers

The housing, end cap, cap at the firing-pin end of the unit, and miscellaneous external parts were prepared from cast 356 aluminum alloy heat treated to the T6 condition; this material was used because of its good resistance to sea-water corrosion. The piston and Bellofram washer were fabricated from 2024-T4 aluminum alloy, and the piston-rod extension and dowel pins, from drill rod. All of the parts and fluid passages were cleaned and inspected before final assembly. Individual parts and subassemblies of the experimental timer (excluding the main spring) are shown in Figure 1 prior to assembly.

After the metering tube was installed in the housing and the O-rings were assembled to the various parts, final assembly of the timers was completed. (In the course of filling, to insure proper positioning of the Bellofram piston-seal subassembly, the spring was not inserted until the fluid chamber was filled with the Viscasil.) Each experimental timer was approximately 6-3/4 inches long (excluding the piston-rod extension); had an effective diameter of 2-1/2 inches and a 2-1/4-inch diameter at the flanges; and weighed about 1 pound (when filled with Viscasil 500,000). An assembled experimental timer is shown in Figure 3.

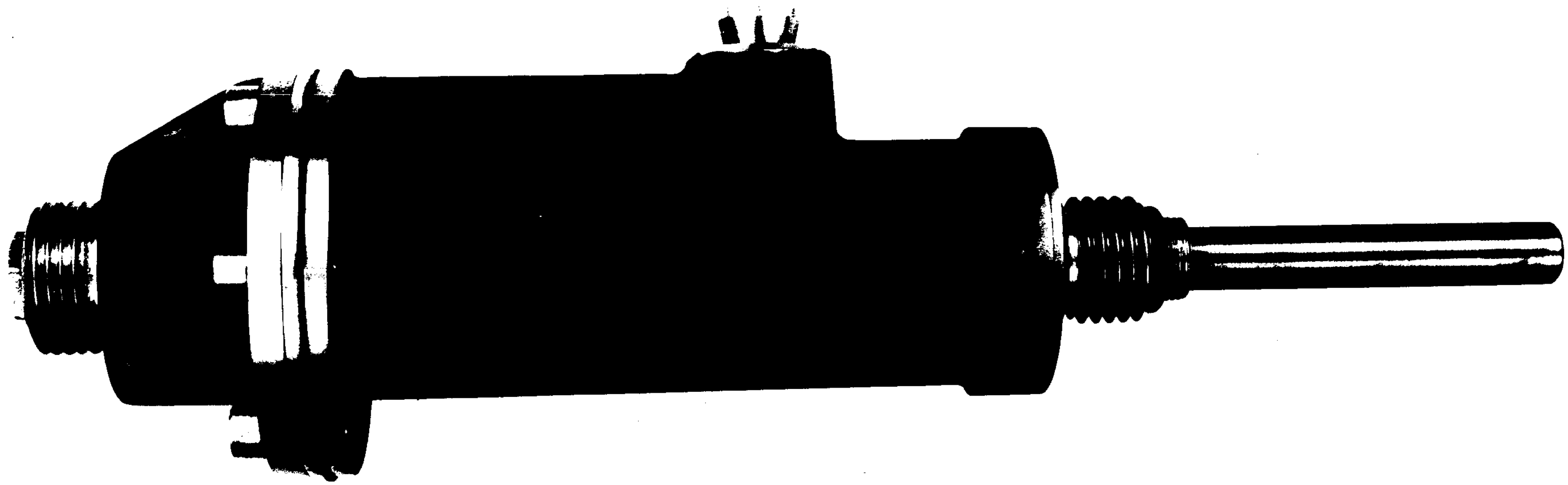
A special adapter was fabricated that duplicated the end-cap-plug thread and seal, and in addition had a center hole and a hose-attachment projection. This adapter was used in leak testing the units prior to filling them with the Viscasil; it permitted air to be introduced into the fluid chamber without disturbing or changing the assembly or the type of seals in the timers (as described below).

Timer Evaluation at 75 F

Following fabrication and assembly, the four experimental time-delay devices were set up for operational testing at 75 F. The tests were conducted, flow-characteristic data were recorded, and the performance of the experimental units was evaluated.

Preparation. To set up for the evaluation of performance, the end-cap plug was replaced by the special leak-test adapter described above, the fluid chamber was pressurized with air at 15 psi, and soapy fluid was spread over the outside surfaces of the units, in order to check for leaks. The end cap of one experimental timer leaked through the casting; this leak was plugged with an epoxy resin. The other units did not leak.

The spring and piston subassembly was removed, and the four experimental timers were filled simultaneously with Viscasil 500,000 from a manifold; the silicone fluid was forced into the fluid chamber and, to



Approximately actual size

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Figure 3. An Assembled Experimental Timer

the extent practical, into the metering tube of each timer. The fluid was pressurized in the manifold system, to minimize fill time. The experimental units were allowed to sit for one week, during which time they were visually inspected; this procedure was used to insure that air bubbles trapped in the fluid could escape, through the filler-plug opening. When the air bubbles in the fluid had dissipated, the filler plug was installed, and the metering-tube valve was moved to the open position. The piston and spring subassembly was then installed; the fluid which consequently became surplus was allowed to flow through the metering tube until the "keyhole" in the piston moved sufficiently to line up with the metering-tube valve; and the valve was closed. Under a constant-temperature condition and with the valve closed, no further movement of the piston was expected unless a leakage of fluid occurred.

The experimental units were subsequently installed in a previously converted refrigerator, which was adjusted to maintain a temperature of 75 ±2 F. For several days the units in a non-operating condition were observed and no leakage of silicone fluid was noted.

This experimental time-delay unit had been designed so that the silicone fluid would be forced through the metering tube by the spring acting on the piston, which was in contact with the Bellofram piston seal; therefore, by means of measurements of the rate of piston travel, the amount of fluid displaced per unit of time and, consequently, the time-delay characteristics of the unit could be evaluated. In the laboratory set up used, the piston travel was measured with dial indicators. Each experimental timer and a dial indicator were mounted on a test stand with the stem of the dial indicator in contact with the piston-rod extension of the timer. This arrangement is shown in Figure 4.

Following temperature stabilization of the experimental timers in the constant-temperature box (at about 75 F), the metering-tube valve was moved to the open position on each unit, and the timers were actuated for operation at about 75 F.

Results of Evaluation at 75 F. The flow characteristics of the four experimental timers, as observed during the 5-month evaluation period, are illustrated in Figure 5.

After the first 2 months of operation, three of the experimental timers (Nos. 1, 3, and 4) were within the tolerances of piston travel based on an allowable variation of 1-1/2 months per year. The values for total travel for the three units were 0.374, 0.382, and 0.404 inch. The fourth unit (No. 2) showed a reduced flow almost from the start; this indicated some restriction in the metering tube. During the third month, Timer No. 1 suddenly showed a reduced flow and then stoppage. In the fourth month of operation, movement of Timer No. 4 slowed down as a result of restricted flow. In the meantime, Timer No. 3 continued to operate with a slowly decreasing flow rate; at the end of 5 months, the amount of piston travel was just outside the allowable variation based on the calculated travel for 5 months.

After two of the experimental timers showed an appreciable reduction in flow rate, an investigation was made to locate the cause of the difficulty. During this investigation, an examination of the Viscasil 500,000 received from the manufacturer for use on this program

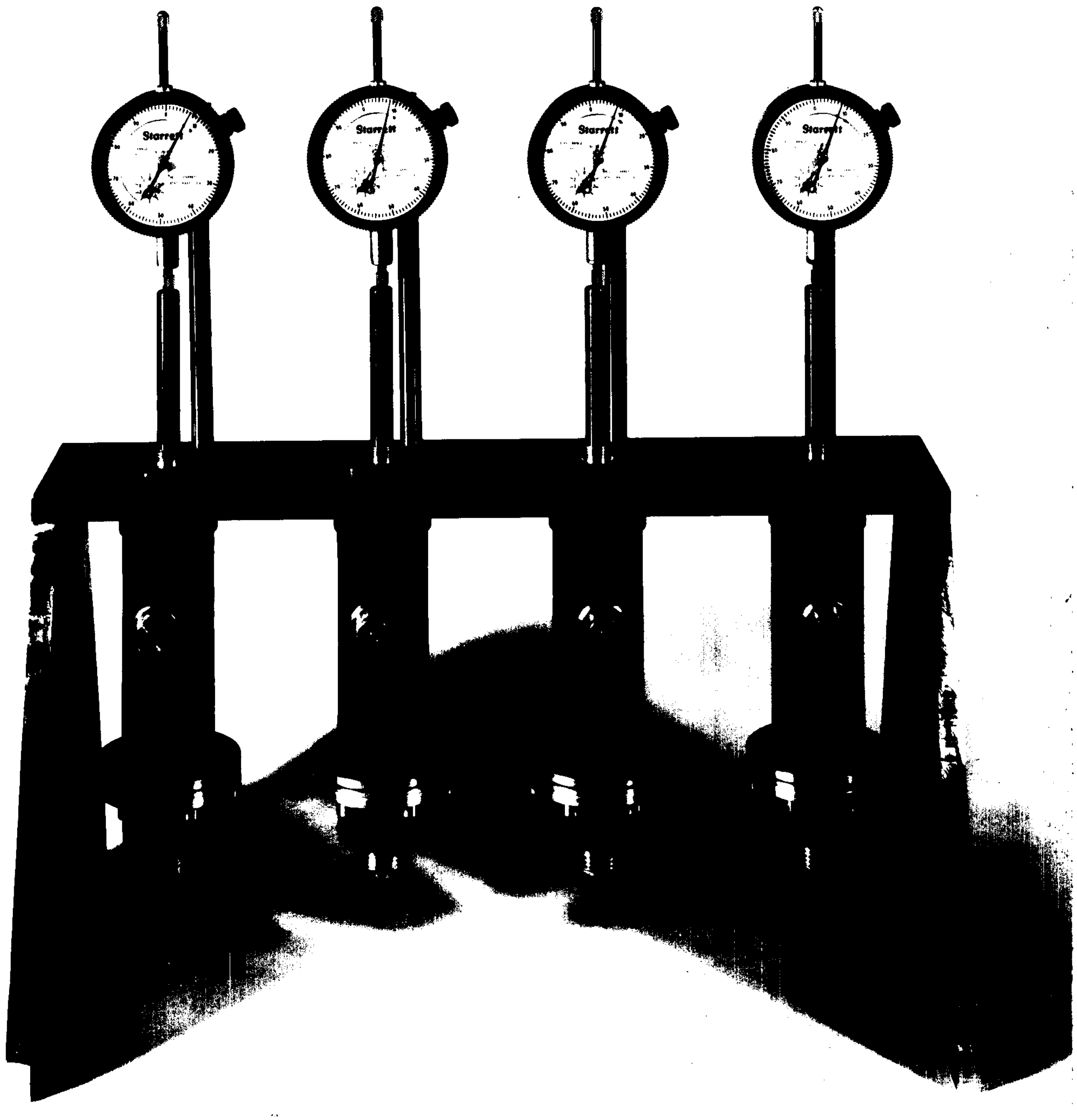

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Figure 4. Laboratory Set Up for Measuring Piston Travel in Experimental Timers

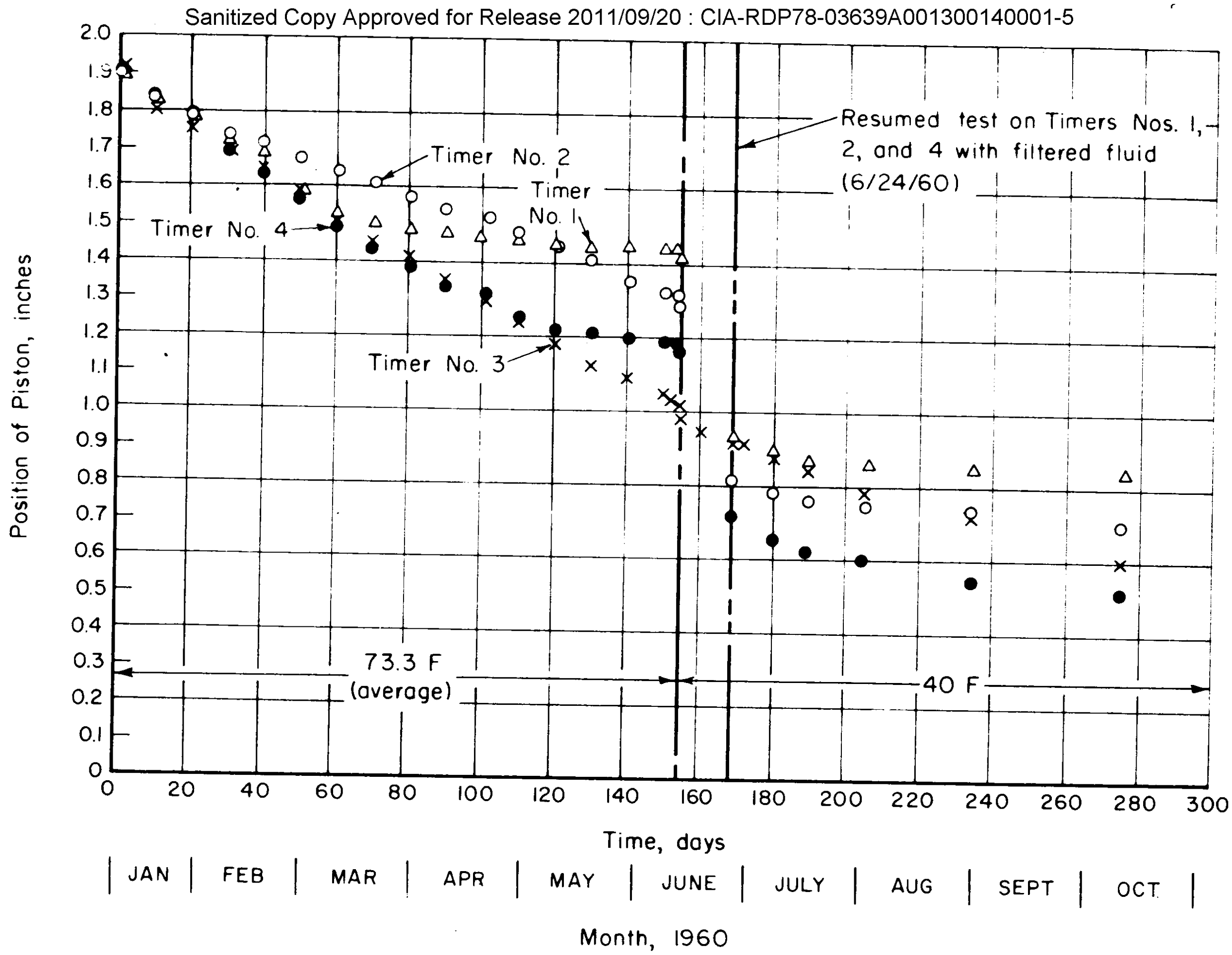

FIGURE 5. FLOW CHARACTERISTICS OF THE FOUR EXPERIMENTAL TIMERS AT ABOUT 75 F AND 40 F

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showed what appeared to be lint and chipped-paint-like particles in suspension in the silicone fluid. In a telephone conversation, the silicone-fluid-manufacturer's representative expressed the opinion that the condition of the fluid as described did not measure up to the quality-control standards of their product; at his request, the remaining fluid was returned to the manufacturer for examination.

Subsequently, the maufacturer sent us a new batch of Viscasil 500,000; this appeared to be as dirty as the fluid which had been shipped back. In answer to a further inquiry, the manufacturer's representative suggested that the visible foreign bodies were possibly lint particles which had entered the fluid during the filtering operations conducted in the course of manufacture; also, he indicated that the replacement fluid was representative of production lots of the high-viscosity series of silicone fluids. It appeared that the limit on the size of extraneous particles which could be tolerated in the silicone fluid used in the experimental timers was more stringent than that encountered previously by the manufacturer; in this connection, the manufacturer had no recommendations regarding a standard method of filtering the Viscasil 500,000 fluid.

In view of the relatively large size of the visible extraneous particles described above, it was logical to assume that the flow of the silicone fluid through the 0.010-inch-ID metering tube would be affected by these foreign bodies. Consequently, the three experimental timers (Nos. 1, 2, and 4) which had shown appreciable deviations from the calculated flow rate were disassembled and inspected.

Examination of the metering tubes from the three disassembled timers showed varying degrees of plugging as a result of the presence of foreign particles at the fluid-entrance end of each tube. One of these tubes was completely plugged with plainly visible lint and flaky-like particles.

Timer Evaluation at 40 F

It was decided that the three experimental timers which had been disassembled and inspected after 5 months of operation at 75 F would be prepared for further evaluation at 40 F using filtered silicone fluid. Since the flow rate of one of the timers had not decreased significantly during the 5-month evaluation period, this unit was continued in operation through the transition from 75 F to 40 F, and the effect of the temperature change on the total piston travel was observed.

Preparation. After the replacement batch of Viscasil 500,000 was received and was found to be dirty, an effort was made to clean the fluid by filtering. The silicone fluid was placed in a covered 325-mesh sieve and a vacuum was drawn on the lower container part of the sieve. The filtering apparatus is illustrated in Figure 6. It was found that the fluid was drawn through the sieve rather quickly, even though the system was relatively inefficient. About one pint of fluid was filtered in a 12-hour period, and it appeared clear and clean. This filtered fluid was then used to fill the three experimental timer units after they had been cleaned, inspected, reassembled, and leak tested.

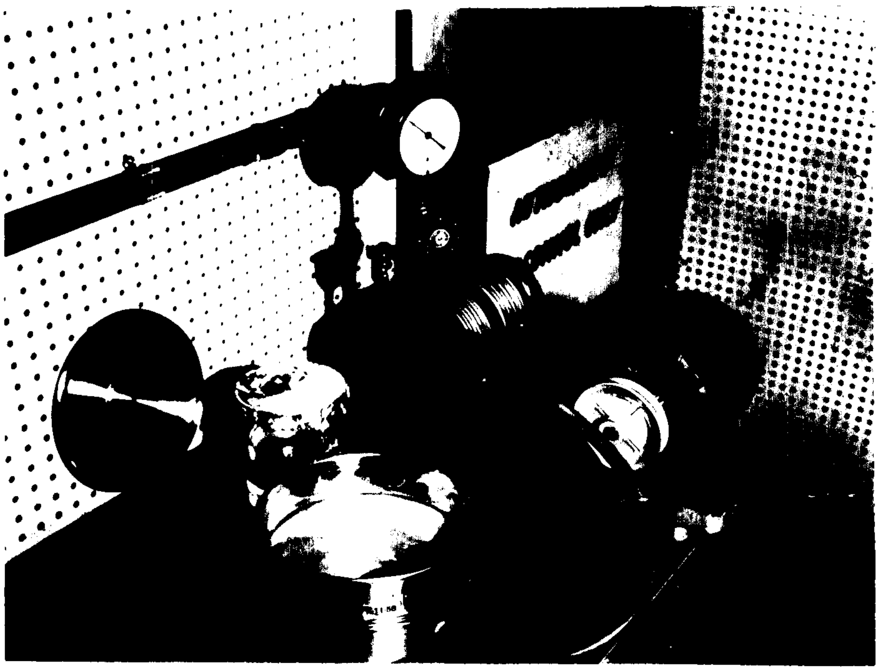

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Figure 6. Apparatus Used to Filter the Silicone Fluid

The constant-temperature box was set up to maintain a temperature of 40 ±2 F. Following temperature stabilization of the three refilled timers, the units were adjusted to approximately the same piston position as that held by the timer which had not been disassembled, and the evaluation at 40 F was started.

Results of Evaluation at 40 F. Contrary to our expectation, the experimental timers varied noticeably in flow characteristics within the first 2 months of operation at 40 F. The slope of the flow curves for 40 F was less than that for the 75 F curves, as was expected; however, two of the timers with the filtered fluid showed considerably less movement than the unit which had been operating continuously (at 75 F, through the transition from 75 F to 40 F, and then at 40 F). This is evident in Figure 5.

Due to the slowness of operation of these units, considerable time elapses before significant changes can be detected. Also, it is difficult to measure some of the minute factors which could affect the operation of such units; consequently, locating the trouble areas is frequently rigorous.

In view of the flow data obtained at 40 F, it was apparent that the units were not functioning properly. The units were disassembled; and examination of the metering tubes revealed that the flow was still being affected by foreign particles in the silicone fluid.

Future Work

Contamination of the silicone fluid with foreign particles was found to cause a semi- or complete-plugging problem. However, the procedures necessary to resolve this problem are considered to be straightforward and well within our laboratory practice as well as U. S. manufacturing practice. It is visualized that to eliminate partial or total blocking of the metering tubes, essentially a standard filter should be inserted in each experimental unit just upstream from the metering orifice; the various timer parts and the silicone fluid should be carefully cleaned before assembly; and the assembly of each unit should be conducted in a dust-free room. In connection with the handling of these components or the assembled experimental units, we apparently are concerned with particles which are 100 times larger than those which almost every day in the U. S. are being eliminated from aircraft and missile hydraulic systems by extremely clean handling and subsequent filtering. It is anticipated that with proper control of "cleanliness", the operating performance of these four experimental units would show satisfactory reproducibility and predictability.

Accordingly, after a discussion of the above-indicated data and pertinent considerations, the Sponsor requested that a program of additional research be prepared and submitted. Our letters dated November 15 and December 14, 1960, described such a proposed program, directed toward the investigation of selected modifications,as outlined above, in the design and in the procedure for handling these four experimental time-delay units; and toward an evaluation of their effects. (This program was subsequently set up under Work Order No. 6, Task Order No. TT.)

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We would appreciate any comments which you or your associates might care to make with regard to our efforts under Task Order No. LL.

Sincerely,

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ABW:sjm

In Triplicate

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