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#6

SUMMARY REPORT

ON

TASK ORDER NO. 13 #7

May 21, 1962

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SUMMARY REPORT

ON

TASK ORDER NO. 13

May 21, 1962

INTRODUCTION

Your technical representatives had an urgent need for a unit which could be used at night to generate enough hydrogen to provide about 45 lb of lift at sea level; this corresponded, in round numbers, to about 750 cu ft of dry hydrogen. An acceptable total generation time was thought to fall within the range of 15 to 40 minutes. A desirable total operating time, from the time that the operator started to set up the generating unit until the generation was concluded, was 2 to 3 hours. The generating unit was to be operated on dry land. Also, it was to be capable of operating with as small a volume of water as was practicable, with the temperature of the water available ranging from 70 to 80 F. The procedure to be followed in operating the unit was to be simple, so that a nontechnical operator, with no previous operating experience, could successfully perform the generation on the basis of oral and written instructions. Also, it was essential that the entire generation operation be such that it could be performed at as low a noise level as possible. Further, the unit and the necessary materials and accessory equipment were to be as small as possible in size and weight.

During previous research under Task Order No. C, a detailed investigation had been made of the aqueous sodium borohydride-cobalt chloride reaction for generating hydrogen, and a generator had been developed that utilized this reaction to provide 3,500 cu ft of hydrogen. In the course of that effort, an experimental "1/5 scale" unit had been designed and prepared, and generation tests had been performed in that unit. On the basis of the background of knowledge and experience with the above-mentioned chemical reaction and the "1/5 scale" unit, it was considered likely that, with minor modifications of that unit and of the operating procedure, experiments could be performed to demonstrate the applicability of the unit to the problem of interest.

To provide for this research, Work Order No. 3 under Task Order No. 9 was set up for the period February 7 through May 6, 1962, and subsequently Task Order No. 13 was set up for the period February 20 through May 21, 1962. Also, the Sponsor furnished us the 3,500-cu-ft and the experimental "1/5 scale" (700+ cu ft) hydrogen generators prepared previously under Task Order No. C. As a matter of convenience, this report summarizes the results of the over-all development effort performed under the two agreements.

OBJECTIVE

The objective of this effort was to investigate the feasibility of utilizing a previously developed experimental hydrogen generator (the "1/5 scale" unit from Task Order No. C) for a particular specialized application, as generally outlined above.

SUMMARY

The "1/5 scale" generator from Task Order No. C was repaired and modified, and then adapted to operate and to look like a water-purification and -storage unit. Leaks were patched and wooden stays were replaced with aluminum stays. The air mat, which had been used to float the original unit in water, was removed. Because the generator resembled typical portable water-purification and -storage containers, the disguise of the generator as an operating water purifier was completed rather simply by the provision of a hand pump to be inserted in the gas outlet of the generator. It was envisioned that stencilled lettering would be applied to the generator to label it as a Government-issue water-purification unit.

Prior to the beginning of this program, a combination of sodium borohydride and cobalt chloride for producing hydrogen had appeared on the market in pelletized form under the label of Hydripills®. Small-scale and half-scale experiments were conducted to determine the amount of these chemical pellets and the time required to generate 750 cu ft of hydrogen. It was determined that 22 pounds of Hydripills® would satisfactorily produce 750 cu ft of hydrogen in the modified "1/5 scale" generator with the pellets added in 3-pound batches; and that a batch of Hydripills® could be satisfactorily added to the generator from a polyethylene bag, which also served as a good packaging container. Bags containing 3 pounds of Hydripills® were then prepared and inserted in the cartons of various commercial food-staff and detergent packages. These packages were used to provide camouflage for the chemical pellets under anticipated service conditions.

A satisfactory operating procedure was developed. This consisted generally of adding water to the generator, attaching the balloon to the

generator, and then introducing the Hydripills® into the generator. The equipment and the operation were demonstrated successfully at our facilities and subsequently at a field site provided by the Sponsor.

RESEARCH ACTIVITY

The hydrogen-generation reaction used in the program was the catalyzed hydrolysis of sodium borohydride ($NaBH_4$), with cobalt chloride used to provide the catalyst. The information and experience underlying our exploitation of this reaction stemmed from previously performed research, described in three reports: (1) "Summary Report on Task Order No. C", dated January 28, 1957, (2) "Summary Report on Task Order No. C (Phase II)", dated December 31, 1958, and (3) "Summary Report on Task Order No. C (Phase III)", dated August 31, 1959.

The research effort performed consisted of the following three types of activities: (1) the modification and conversion of the "1/5 scale" generator fabricated previously under Task Order No. C, (2) the hydrogen-generation experimentation with Hydripills®*, and (3) the packaging and development of a technique for handling the Hydripills®. Also, an operating procedure was formulated to cover all of the steps involved in using this generator to obtain 750 cu ft of hydrogen under the anticipated service conditions.

Preparation of Generator

The experimental 1/5-scale hydrogen generator which had been developed during the Phase II study of Task Order No. C (and is shown in

*Commercially available pills which consisted of sodium borohydride and cobalt chloride; additional detail on these pills is given later.

Figure 1) was ideally suited to the requirements of the urgent application of interest. The original generator was a cylindrical, neoprene-coated nylon unit 33 inches high by 43 inches in diameter. An inflatable rubber mat approximately 3 inches in annular thickness and 15 inches high was cemented to the periphery at the upper part of the generator. When the generator was placed in water (the expected procedure for the original application), the inflated mat served to support the generator and to stabilize it in a cylindrical configuration. Wooden stays attached to the lower sides of the generator served to keep the sides essentially vertical. The generator was equipped with a 4-inch-diameter, neoprene-coated nylon water-inlet tube located at one point on the cylindrical surface close to the bottom. Also, there was a gas outlet consisting basically of a reinforced tube-shaped component with a brass ring at the top; this was attached at the top surface of the generator, along with another 4-inch-diameter tube with a larger bag attached to it.

In order to use this unit for the application of interest, two types of activities had to be performed: (1) the generator had to be repaired and modified to satisfy certain new requirements; and (2) it had to be modified and disguised so that it would look like, and could be used as, a water-purification unit. (This latter requirement was imposed after the effort was started and is described in more detail below.) The remodelled generator is shown in Figure 2. The drawing for the final design evolved is included in Appendix 1.

Generator Repair and Modification

Two types of repairs had to be made on the experimental 1/5-scale generator. The wooden stays had either broken or become warped from moisture. These were replaced with aluminum-rod stays (1/2 inch in diameter

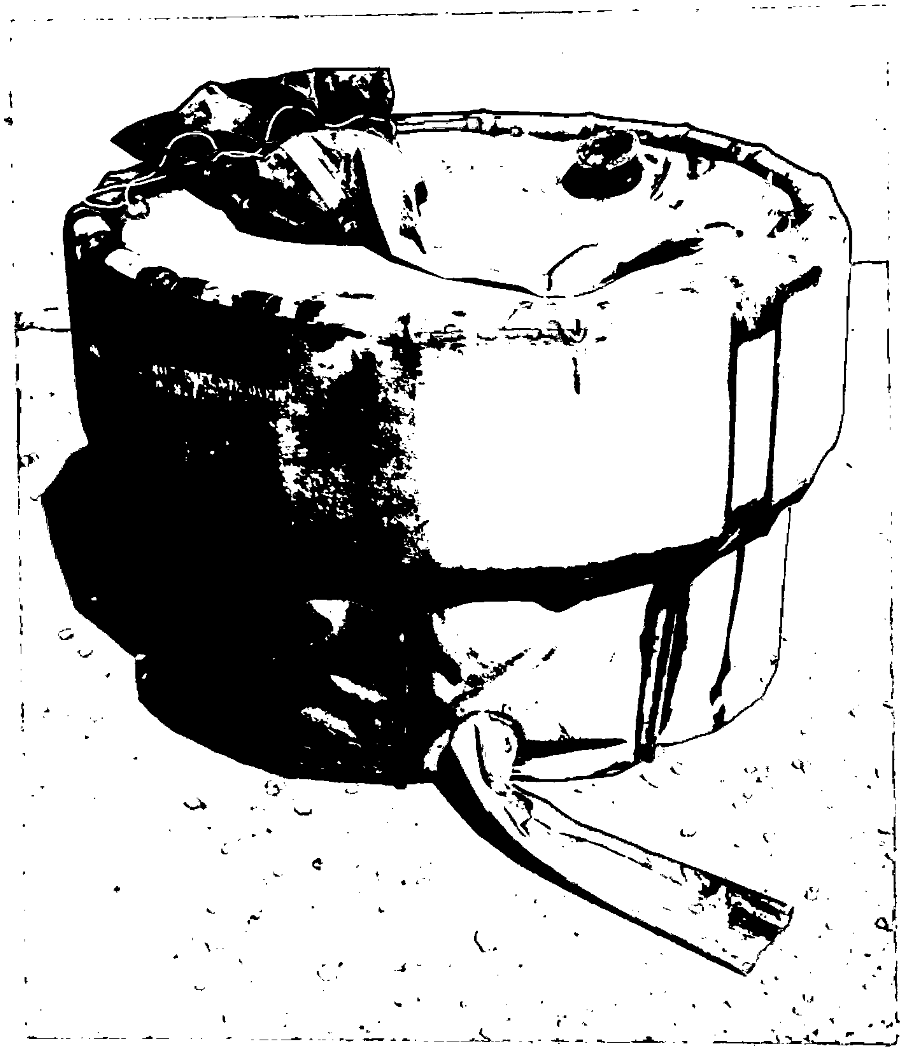

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Figure 1. Original Experimental 1/5-Scale Hydrogen Generator Developed Previously Under Task Order No. C

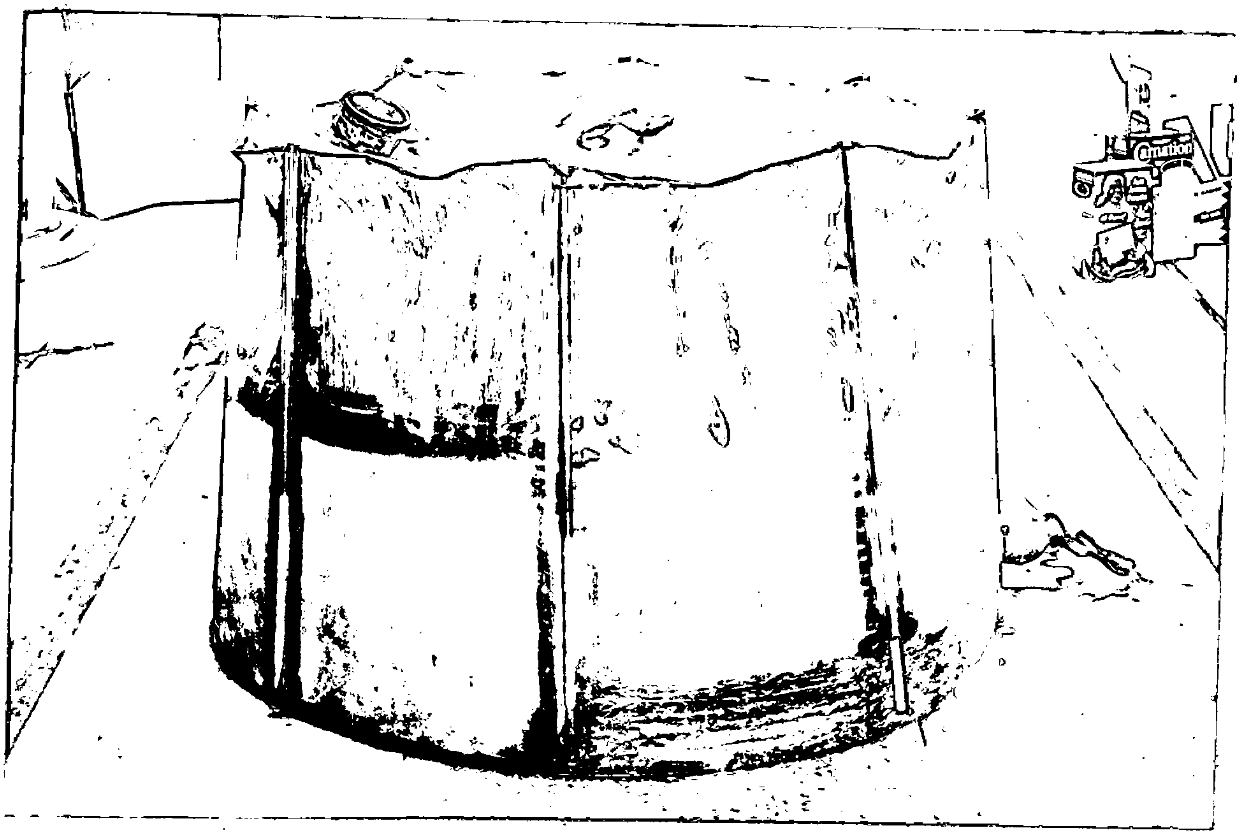

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Figure 2. Modified Generator Filled With 112 Gallons of Water

by 30 inches long). During the handling of the generator for the experimental work under Task Order No. C, holes and tears had developed in the bottom and lower sides of the generator. These were repaired as described below.

The formerly used repair method was improved by adopting a recently developed adhesive. This adhesive is used extensively in the manufacture of neoprene-rubber skin-diving gear and is available under the trade name of "Black Magic". It is a foam neoprene cement which is manufactured by the Lebec Chemical Corporation, Paramont, California.

To effect a repair, the damaged area was cleaned with coarse sand-paper and denatured alcohol. A repair patch was cut from the same neoprene-coated nylon fabric used to fabricate the generator. The repair patch and the area to be repaired were each coated with the special adhesive. The patch was then placed over the defect and pressure was applied to the patch with a rolling pin. Satisfactory repair was thus accomplished.

Under the requirements of the current application of interest, the generator was to be used on land instead of in water. In this situation, the air mat would not be needed to float the generator. Furthermore, with the air mat attached, the volume and weight of the generator in the packaged condition were approximately doubled. However, it was not evident that the generator would function properly on land without the air mat to help keep the generator sides in a cylindrical shape.

Tests were made in which the generator with the air mat attached but not inflated was filled with the required amount of water (112 gallons). It appeared that the generator could support the water and still remain substantially cylindrical in shape; the water tended to push the aluminum stays into a vertical position. The air mat was removed as shown in Figure 2, and the generator functioned satisfactorily. It was subsequently found that preparatory to adding water to the generator, it was particularly convenient to place the bottom of the generator flat on the ground and to arrange the aluminum stays in "teepee" fashion; as water was added, the aluminum stays assumed an upright position.

For the application of interest, there was no need for 4-inch-diameter tube and bag assembly attached to the top of the generator. This assembly was cut off leaving a stub, which was sealed.

Conversion to Water-Purification Unit

After the effort described herein was initiated, the Sponsor presented information which made it necessary, and convenient, to convert the generator into a unit which, prior to being used to generate hydrogen, would serve as a normal-looking water-purification and -storage unit.

It was expected that the generator would be used in an area where water was relatively scarce. The climate would be hot and dry, such that the presence of a water-purification and -storage unit would not be conspicuous. Because it would not be possible for much advance notice to be given relative to the specific time for the generation to be performed and because 112 gallons of water could not be easily obtained once the operator had learned the time for the generation, it appeared prudent for the generator to be disguised as a water-purification unit, and also to be usable as such.

The conversion of the generator to a water-purification unit was rather straightforward. The black neoprene-coated nylon material from which the generator was fabricated was similar to that often used for portable water-purification units and containers. The application of a stenciled label on the side of the generator, to call out selected identification words such as are frequently found on Government-issued items, would, it was believed, help convince indigenous observers that the unit was indeed a water-purification and -storage unit. It was decided that this would be done ultimately by the Sponsor's associates.

It was necessary to add a pump which would permit water to be drawn from the unit for drinking purposes. A satisfactory pump assembly, shown in Figure 3 (and later in Figure 5), consisted of an inexpensive, hand-operated bilge pump fitted with an adapter that permitted the pump to be attached to the generator by insertion into the gas outlet. The pump adapter was machined from black plastic pipe and sheet, and was assembled with an adhesive. The outside diameter was such that this adapter slipped into the gas outlet without too much difficulty, but the fit was tight enough to permit the pump to operate effectively. The pump itself was fitted through the center of this adapter. As a result of judicious selection of dimensions, it was also possible for the pump assembly to be fitted into a plastic T-adapter (Figure 5) which was fabricated for use in generating hydrogen and filling the balloon, although this combination was not considered necessary by the Sponsor.

The generator T-adapter was also prepared from black plastic pipe and consisted of several components glued together. The inside of the vertical part of the T was lined with rubber so as to minimize the noise generated by the chemical pellets as they were dropped into the generator through the T-adapter. In the area corresponding to the cross section of the horizontal or gas-outlet portion of the T-adapter, holes were cut in the rubber lining to permit flow of the hydrogen generated from the reaction

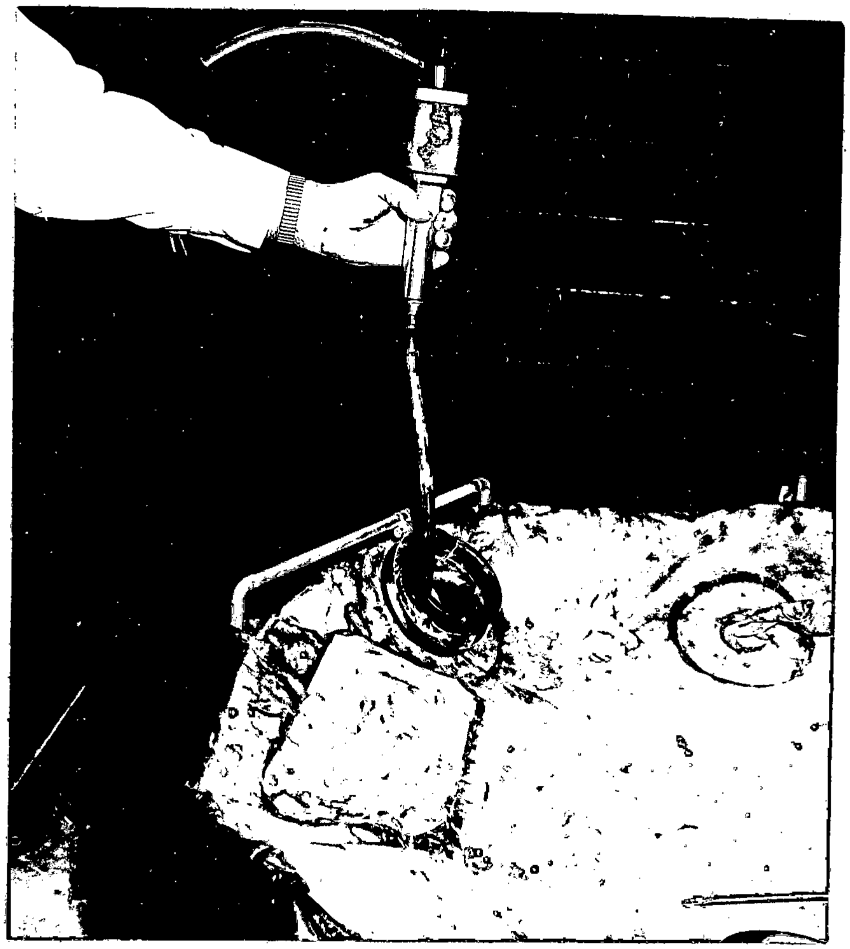

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Figure 3. Water-Pump Assembly Being Placed in the Generator

bath into the balloon (Figure 5). Also, the T-adapter was provided with a black plastic lid equipped with a handle on top; the lid fitted snugly into the top of the vertical portion of the T-adapter.

(These accessory components are described in detail in the report summarizing the effort under Work Order No. 2, Task Order No. 21.)

A purification chemical was needed that would make the indigenous water safe for drinking and at the same time would not interfere with the reaction of the chemicals in the generation of hydrogen. As described in the next section, chlorine in the form of NaOCl (Clorox) was finally selected as the water-purification chemical.

Hydrogen-Generation Experiments

Under Task Order No. C, considerable work had been done with the aqueous sodium borohydride-cobalt chloride reaction for generating hydrogen. Work with the 1/5-scale generator had shown that 750 cu ft of hydrogen could be generated from 20 lb of sodium borohydride and an appropriate amount of cobalt chloride. The rate of hydrogen generation was a function of the amount and temperature of the water, and the amount of catalyst (cobaltous chloride, $CoCl_2$). Under Task Order No. C, the use of 112 gallons of water in the 1/5-scale generator (corresponding to a water height of 18 inches) generally resulted in satisfactory generation conditions of foam level and elapsed time.

Subsequent to the completion of our Task Order No. C effort, Metal Hydrides, Incorporated, placed Hydripills® on the market. Hydripills® are cylindrical pellets normally containing 92.5 weight per cent of $NaBH_4$

and 7.5 weight per cent of $CoCl_2$ (anhydrous). The pellets are available in two sizes, 10/32- and 3/4-inch diameter. By special order, pellets with different percentages of the chemicals can be obtained. For the available pellets, assuming 98 per cent purity for the Hydripills®, it was calculated that about 22 lb of Hydripills® would be needed to generate 750 cu ft of hydrogen.

Because we had not previously worked with Hydripills®, and because our previous experience indicated that too rapid a reaction can produce excessive foaming and gas pressures, it was decided that three series of experiments should be run in the temperature range of 70 to 80 F, namely, (1) various small-scale experiments, (2) 1/2-scale experiments, and (3) full-scale experiments; and that the proportion of water used during the Task Order No. C experimentation would be utilized. The results of the experiments are summarized in Table 1, and discussed in the following.

<u>Small-Scale Experiments</u>

The first six runs were small-scale experiments. The first three showed that the generation of hydrogen at temperatures above 70 F might be too rapid for this application. Three experiments were then made with the Hydripills® being added in two batches. As a result of this work, it was believed that satisfactory generation could be achieved by adding the Hydripills® in batches. The letters next to the Run No. designations in the table identify discrete additions of the chemical pellets. In all instances, the relative total quantities of Hydripills® and water were those used in the full-scale generation.

TABLE 1. RESULTS OF DIFFERENT HYDROGEN-GENERATION EXPERIMENTS

Run No.	Weight of Pellets	Volume of Water	Temperature, F Initial	Temperature, F Final	Total Time min:sec	Vessel and Remarks
1	12.5 g	550 ml	73	112	13:50	1,500-ml beaker
2	12.9 g	570 ml	73	116	11:15	1,500-ml beaker
3	428. g	18.6 liters	72	120	10:10	6-gal tub; D/h (water) = 15.5 in/6.0 in.
4A	6.25 g	550 ml	72	90	24:00	1,500-ml beaker
B	6.25 g	--	90	111	6:30	
Total	12.5 g	550 ml	72	111	30:30	
5A	6.25 g	550 ml	80	100-1/2	12:20	1,500-ml beaker
B	6.25 g	--	100-1/2	121-1/2	3:30	
Total	12.5 g	550 ml	80	121-1/2	15:50	
6A	214 g	18.6 liters	80-1/2	104	12:20	
B	214 g	--	104	127	4:10	6-gal tub
Total	428 g	18.6 liters	80-1/2	127	16:30	
7A	5.5 lb	56 gal	81-1/2	116	3:30	Half-scale test:
B(b)	2.7 lb	--	-(a)	-(a)	3:30	(a) Temp. indeterminate
C(c)	2.8 lb	--	-(a)	136-1/2	2:00	(b) Added 28-1/2 min after t=0
Total	11.0 lb	56 gal	81-1/2	136-1/2	34:30(d)	(c) Added 32-1/2 min after t=0
						(d) Includes "wait periods"

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TABLE 1. (Continued)

Run No.	Weight of Pellets	Volume of Water	Temperature, F Initial	Temperature, F Final	Total Time min:sec	Vessel and Remarks
8A	6.0 lb	112 gal	77-1/2	-[a]	4:00	Full-scale test:
B	6.0 lb	--	-[a]	-[a]	3:30	(a) Temp. indeterminate
C	5.5 lb	--	-[a]	-[a]	2:30	(b) Includes time between
D	5.5 lb	--	-[a]	132-1/2	1:30	additions
Total	23 lb	112 gal	77-1/2	132-1/2	15:30[b]	
9A	6.25 g	550 ml[a]	80	95	18:	(a) 4 g of Pittabs® ($CaOCl_2$)
B	6.25 g	--	95	96	4:	in water
Total	12.50 g	550 ml	80	96	22:[b]	(b) Reaction was proceeding very slowly
10A	6.25 g	550 ml[a]	80	103	11:00	
B	6.25 g	--	103	124-1/2	4:00	(a) 5 ml of NaOCl in water
Total	12.50 g	550 ml	80	124-1/2	15:00	

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Runs Nos. 9 and 10 were made to determine what effect, if any, two selected water-purification chemicals would have on the generation time. The chemicals used for this purpose were Pittabs® ($CaOCl_2$ pills) (Run No. 9) and NaOCl (Run No. 10). These chemicals were added at about 100 times the recommended concentration for normal water-purification purposes, to obtain a better appreciation of the effect of the excess calcium or sodium ions on the hydrogen-generation reaction. As noted in the table, the excess calcium had a retarding effect on the generation time. Excess sodium had no noticeable effect. Thus, it is concluded that a water-purification chemical which is a sodium-bearing compound, such as Chlorox® (NaOCl), can be used without concern relative to unfavorable effects on the generation reaction.

Half- and Full-Scale Experiments

Half-scale Run No. 7 was originally intended to be a "two addition" test. The first batch of Hydripills® reacted so rapidly, however, that the second batch was added in two parts. It became evident from the temperature measurements made during this experiment that the Hydripills® were not mixing with the water in the large-scale experiment nearly as rapidly as they did in the small-scale experiments. As a result, the reaction was occurring primarily in the water layer at the top of the pool, the reaction temperatures were higher than before, and the reaction was proceeding very rapidly.

On the basis of the half-scale test results, a full-scale test (No. 8) was set up as a four-addition experiment. Although full-scale requirements called for only 22 lb of Hydripills® to generate 750 cu ft of hydrogen, 23 lb were used to provide a slight safety margin for our calculations.

The experiment was completed very smoothly in a total time of 15-1/2 minutes, including the time which elapsed between the end of each reaction period and the addition of another batch of Hydripills®.

On March 7, 1962, a full-scale field test was carried out at a special site arranged for by the Sponsor. For this test all items were packaged as they would be for actual field usage. The generator was set up and water was added to a predetermined level. The water temperature at the start of generation was 87 F; 3 oz of NaOCl was added to the water prior to the run to simulate "purified" water. A 750-cu-ft balloon was attached to the generator. A total of 24 lb of Hydripills®, packaged in eight 3-lb batches, were to be used. A chronology of events starting with the water in the generator is given in Table 2.

On the basis that 3 lb of Hydripills® yield approximately 100 cu ft of hydrogen, it appeared that approximately 550 cu ft of hydrogen had been loaded into the balloon because only 5-1/2 additions were needed. It could not be determined whether the balloon capacity was actually less than 750 cu ft (as was suspected), or whether the volume difference (between 750 and about 550 cu ft) represented water vapor trapped in the hydrogen.

During the week of April 9, 1962, another full-scale field test was conducted by the Sponsor and his associates to determine load-lifting capability and balloon-maneuverability factors under specialized conditions and within specific limitations as to available space; the time involved in the operation was not of immediate concern. In preparation for this full-scale operation, several simulated tests were conducted using helium as the lifting gas. These tests provided the experience necessary to determine the appropriate balloon filling, handling, loading, and release techniques to be used in the final

TABLE 2. CHRONOLOGY OF FULL-SCALE, FIELD, HYDROGEN-GENERATION TEST

Chronological Time, minutes	Operation
0	Proper amount of water in generator. Operator started carrying packages to the generator. Balloon unrolled.
8	Balloon staked down.
11	Last check of water temperature; T = 87 F.
17	Neck of balloon taped to generator.
22	1st addition of Hydripills® (generation time 3 minutes 2 seconds)
25	Balloon tied down in better position (operator assisted by others)
28	2nd addition (generation time 3 minutes 3 seconds)
34	Neck of balloon cut down and re-taped to generator
37	3rd addition (generation time 2 minutes 37 seconds)
40	4th addition (generation time 2 minutes 10 seconds)
43	5th addition (generation time 2 minutes 23 seconds)
46	6th addition (generation proceeded for 51 seconds and the balloon was filled; approximately half of the hydrogen generated from this addition was vented to the atmosphere)
49	Balloon tied off and moved around to test maneuverability. Hydrogen then "dumped".

application. Following these procedural tests, the full-scale generation test was completed satisfactorily. (Relative to this full-scale operation, one of our personnel provided technical advisory services, under Work Order No. 7, Task Order No. 9.)

Chemical Packaging and Handling

Because of the potential toxic hazards of the Hydripills®, there was a need for care to be used in the packaging and handling of the chemical. Although it had been shown that the Hydripills® could be added in 6-pound batches for a satisfactory reaction, experiments showed that one man could not easily and quietly put 6 pounds of the pellets into the generator in the dark. Further work showed that he could add the chemical satisfactorily in 3-pound quantities. Consequently, a package was designed to hold 3 pounds of pellets. The first packaging containers were made from ridged plastic pipe, 5 inches in diameter and 30 inches long. The diameter was determined by the size of the opening in the generator. Although this pipe provided a relatively substantial and moisture-proof package, it proved to be difficult to disguise and, in addition, was conducive to considerable noise when the Hydripills® were being emptied from it. The plastic pipe acted like a sounding-board as the solid Hydripills® bounced back and forth against the hard surface when the pellets were being poured from these containers.

Additional efforts resulted in the use of a plastic (polyethylene) bag. Various diameters and lengths of bags were investigated. The ultimate bag configuration was determined by the generator opening, by the amount of chemical needed, and by the ease with which the containers could be disguised. The final design of the plastic bags represented two sizes of bags. One bag was 4 inches in diameter and 26 inches long, and the other was 5 inches in diameter and 20 inches long (Figure 4). Each bag was fabricated with an extra 6-inch-long neck, so that this neck could be pushed through the gas-outlet tube and thus prevent spillage of the chemical pellets. Each package was sealed against moisture infiltration and placed in containers previously selected to provide suitable storage capacity and also appropriate camouflage. The containers used were taken from commercial food-stuff packages, such as cardboard boxes for crackers, cereals, cookies, etc., and also commercial detergent packages, as shown in Figure 4; the use of this type of camouflage reflected the strong recommendation of the Sponsor's associate.

After careful opening of the bottom flaps of the various boxes, the original contents were removed and replaced with a selected number of appropriate bags of pellets. Usually there was either one 4-inch-diameter bag or one 5-inch-diameter bag fitted into each selected food box. However, it was possible to pack as many as four of the filled plastic bags in one large home-laundry-size box of detergent such as AD® (Figure 4).

Operating Procedure

In accordance with the objectives of the program, an operating procedure was evolved for unpacking, setting up, and operating the generator. This procedure represented a two-step operation. One step involved the set up and operation of the generator as a water-purification and -storage unit, 50X1

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and the second step involved the use of the generator to generate hydrogen. The components, materials, and supplies needed for this procedure are listed in Table 3; most of them are shown in Figure 5.

TABLE 3. COMPONENTS, ETC., NEEDED FOR OPERATION OF THE GENERATOR AS A WATER-PURIFICATION AND -STORAGE UNIT AND ALSO AS A HYDROGEN-GENERATION UNIT

1.	Generator (neoprene-coated fabric cylindrical tank)
2.	Generator stays (eight 1/2"-diameter x 30"-long aluminum rods)
3.	Generator T-adapter (6"-diameter plastic T)
4.	Generator T-adapter lid
5.	Generator T-adapter support (1/2"-diameter pipe with attached 6"-diameter clamp)
6.	Packaged chemical pellets
7.	Black plastic tape (Scotch Brand No. 33 or equivalent)
8.	Scissors, 1 pair
9.	Measuring stick (wooden dowel)
10.	Thermometer (metal)
11.	Water pump, plus inlet and outlet hose
12.	Water-purification kit (chlorine solution and chlorine comparator kit)
13.	Fabric repair kit
14.	Rubber gloves

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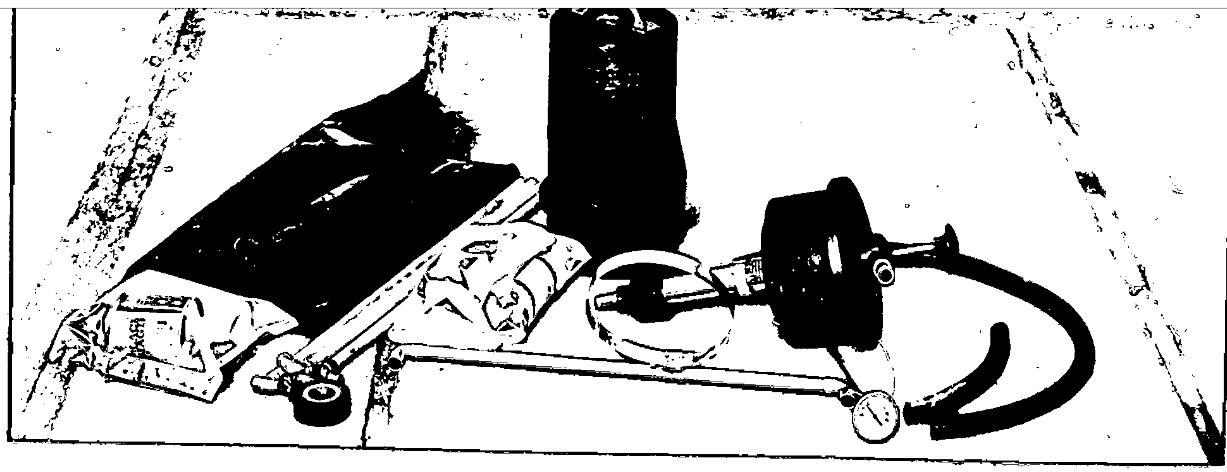

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Figure 5. Components Needed for Operation of the Generator as a Water-Purification and -Storage Unit and Also as a Hydrogen-Generation Unit

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Water-Purification Set Up

The procedure for setting up the generator as a water-purification and -storage unit is as follows:

(1) Remove the contents of the box which houses the generator, stays, ground cloth, and other related equipment (Figure 5).

(2) Place the ground cloth (6-mil polyethylene sheet or equivalent) on the ground in the area selected for the water-purification set up.

(3) Place the generator on the ground cloth; untie and unfold the generator.

(4) Place the generator, with the bottom flat on the ground, in the center of the ground cloth.

(5) "Tie off" the drain tube by tying two tight knots in the 4"-diameter tube which extends from the side of the generator close to the bottom.

(6) Arrange the aluminum stays and the side of the generator in tee-pee fashion, with the top of the stays pointed inward toward the center.

(7) Grasp the gas outlet (the tube on the top of the generator) and pull it upward and outward to make it easy to add water to the generator. If a hose is used, place the end of the hose on the bottom of the generator.

(8) Fill the generator with 112 gallons of water. To determine that the proper amount of water has been added, measure the height of the water within the generator in either of two ways: (1) use the 1/2"-diameter wooden dowel that is provided, and stop the flow of water when it reaches the black mark near the center of the dowel; or (2) measure the actual depth with an appropriate rule. The height of the water from the bottom of the generator should average 18".

(9) Arrange the aluminum stays and the generator so that it stands properly. (See Figure 2.)

(10) Install the T-adapter support by placing the support elbows on the two adjacent aluminum support stays which are located closest to the gas outlet as shown in Figure 6.

(11) Add the proper amount of water-purification chemical (chlorine-bearing liquid) and test for chlorine content by the method discussed under "Water-Purity Test Procedure".

(12) Place the intake and outlet hoses on the water pump - the long hose on the intake tube and the short hose on the outlet tube as shown in Figure 3.

(13) Insert the water-pump assembly through the clamp of the T-adapter support and into the gas outlet (Figure 2).

(14) Work the water-pump handle until the pump becomes primed. If the pump does not prime, check the intake hose to be certain that the hose end is under water, and work the pump handle again.

Water-Purity Test Procedure

After the chlorine-solution purification chemical (Chlorox®) is added to the water, a test should be run to be sure that the water, so treated, can be drunk with safety. Two methods for checking the water are described below; either of these methods can be used with confidence:

Procedure 1. Add approximately 10 drops of water-purification solution per one gallon of water to be treated. After at least 30 minutes, smell or taste a sample of the water. If the water has an odor or a taste

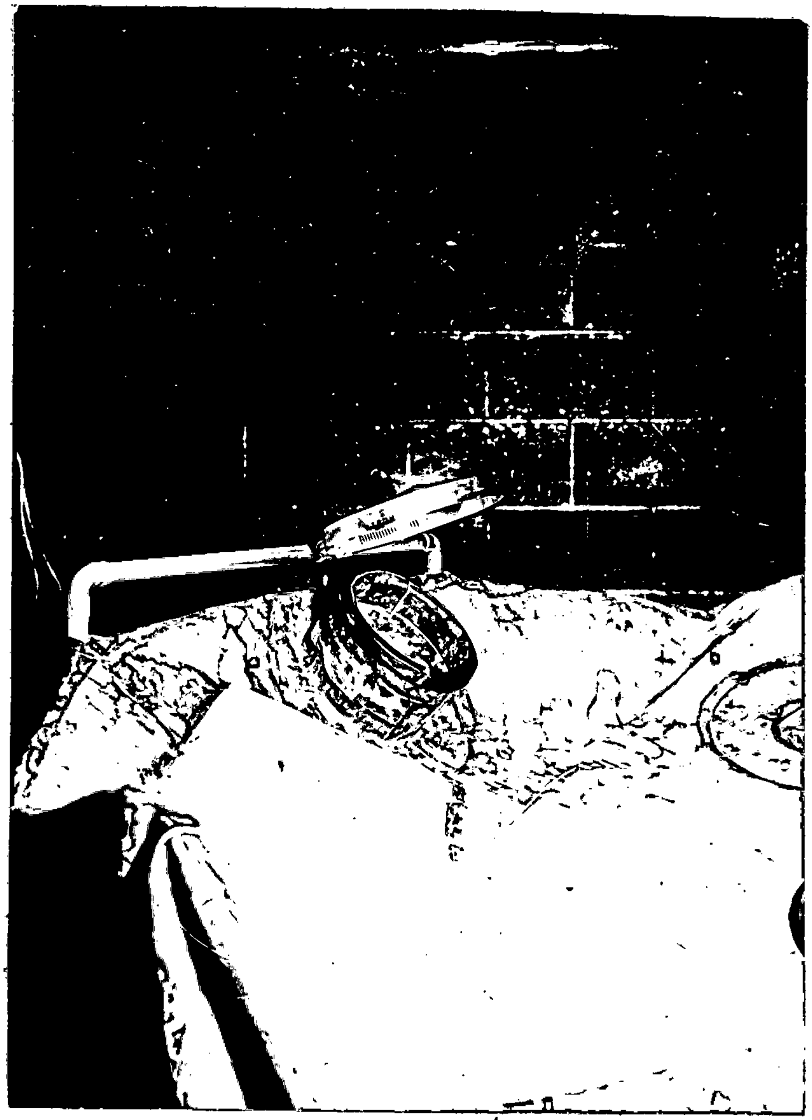

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Figure 6. T-Adapter Support With Elbows Attached to Two Aluminum Stays Near Generator Gas Outlet

of chlorine, then enough chlorine is present to render the water safe to drink. If the water is not relatively clear or if it contains a large amount of matter, then more than the above-indicated amount of water-purification liquid should be added. The water should always be tested before drinking, and sufficient chlorine should be added to provide a noticeable chlorine smell or taste after 30 minutes have elapsed from the time the addition is made.

Procedure 2. To test for safe water using the chlorine comparator kit furnished, the following procedure should be followed:

Add approximately 10 drops of water-purification liquid for each one gallon of water to be treated. After at least 30 minutes have elapsed, take a sample of the water and add five drops of ortho-tolidine reagent provided in the kit. After another 30 minutes, compare the color of the water sample with the comparator standard from the kit provided and note the reading. This reading indicates the amount of residual chlorine in the water. If the residual-chlorine content is in the range of 0.1 to 0.3 ppm (part per million) or higher, the water is safe for drinking. If the residual-chlorine content is lower than 0.1 ppm, add more chlorine solution and repeat the procedure.

Hydrogen-Generation Set Up

The procedure for generating hydrogen is presented in the following:

If the generator has not been set up as a water-purification and -storage unit, follow Steps 1 through 10 as described above under "Water-Purification Set Up". Then, proceed with the instructions presented below (Steps 1 through 11). If the generator has been set up as a water-purification and -storage unit, remove the water-pump assembly and then proceed as follows:

(1) Insert the bottom end of the vertical part of the T-adapter (the end with the flange) through the clamp of the T-adapter support and into the generator gas outlet as shown in Figure 7. Position the T-adapter so that the horizontal part of the T (the outlet) faces outward from the generator. Tighten the clamp screw so as to hold the T-adapter firmly. Tape the joint between the T-adapter and the gas outlet so that the joint is gas tight; use the black Scotch Brand No. 33 tape provided.

(2) Check the level of the water with the wooden dowel. Add water, if necessary. Insert T-adapter lid in the top of the T-adapter (Figure 8).

(3) Place all of the equipment necessary to generate and contain the hydrogen gas in the relative locations as follows:

(a) Place the bores containing the pellets, the gloves, the scissors, and the black tape within 3 or 4 steps of the generator near the T-adapter (Figure 5).

<u>NOTE</u>: There should be no smoking or fires from this step on.

(b) Unfold, lay out, arrange, and tie down the balloon as specified by the instructions accompanying the balloon. The balloon should be arranged in line with the T-adapter outlet (horizontal part of the T) and far enough away

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Figure 7. Installation of the T-Adapter on the Generator

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Figure 8. Removal of T-Adapter Lid

to permit the balloon transfer tube to be just long enough to reach the T-adapter without kinking or twisting).

(4) Open the "foodstuff" and "detergent" containers housing the bagged chemical pellets and take out the bags. Lay the bags on the ground cloth or the equivalent, to keep water or moisture away from the bagged chemical.

(5) Attach the balloon transfer tube to the T-adapter by sliding the transfer tube over the horizontal portion of the T-adapter and taping the transfer tube to the T-adapter with the black tape provided. This connection must be strong and gastight.

(6) Put on the rubber gloves provided. Remove the T-adapter lid. Pick up one of the bags of pellets and open it by cutting off the end seal with the scissors, as shown in Figure 9.

(7) Grasp the neck of the bag with one hand to prevent the chemical from spilling out, and lift the bottom of the bag with the other hand. Then, while inserting the neck of the bag into the top of the T-adapter (as shown in Figure 10), invert the bag to permit the pellets to drop from the bag into the generator.

(8) Quickly replace the T-adapter lid. Adjust the balloon transfer tube to permit a free flow of gas into the balloon at all times. Work the balloon so that the gas fills the nose section of the balloon first.

<u>Note</u>: The hydrogen generation slows down usually after about 3 minutes for each 3-lb batch of pellets, at a water temperature of 80+ F. When the generation slows down, the normal hissing sound within the generator gets more and more quiet, and the top of the generator, which bulges during active generation, relaxes and resumes its original fairly horizontal position.

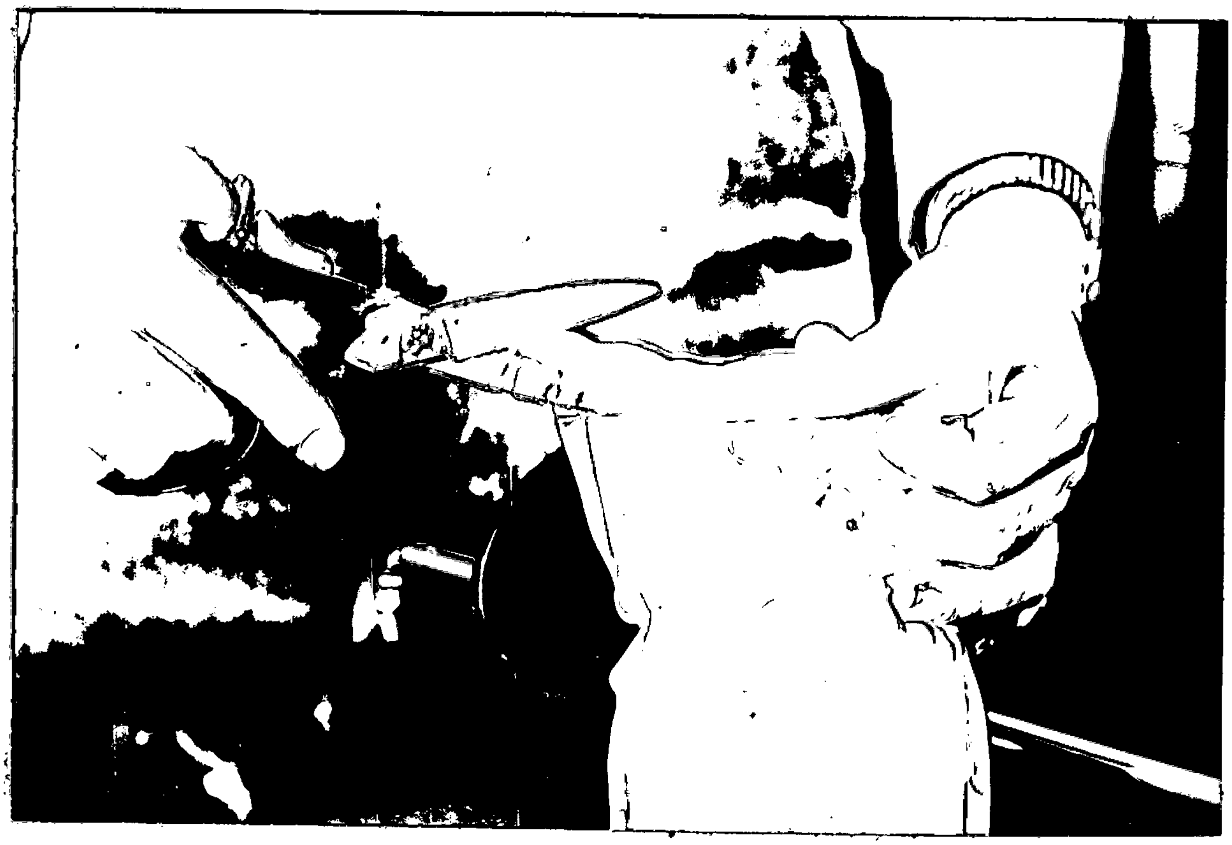

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Figure 9. Cutting of Sealed End of Plastic Bag Containing Pellets

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Figure 10. Pellets Being Dropped Into the Generator

(9) Take another bag of pellets, cut off the sealed end of the bag, and prepare to add the pellets. As soon as the generation slows down or stops, add this bag of pellets, by repeating Steps 7 and 8.

(10) Continue to add the batches of pellets in this manner until the balloon is properly filled with hydrogen, as indicated by the instructions accompanying the balloon. Then, seal off the balloon transfer tube with one hand, and cut the tube between the sealed-off section and the T-adapter with the scissors. Tie off the transfer tube as close to the balloon as possible with several (3 or 4) simple overhand knots.

(11) Attach the load and associated equipment, and release the balloon as directed in the balloon instructions.

(12) If the generator was to be repacked for future use, the following procedure should be followed:

(a) Untie the knots in the generator drain tube and permit the water and chemical to run out to a suitable drain.

(b) Untape and remove the T-adapter from the gas outlet and T-adapter support clamp. Remove the T-adapter support.

(c) If possible, flush the generator until the water running from the drain tube is clear and shows no discoloration. Drain all excess water from the generator and whenever possible, permit the generator to drain and dry for from 4 to 24 hours.

(d) Remove the aluminum stays. Fold and roll the generator into a package approximately 30" long and 12" in diameter.

(e) Pack all of the equipment in the original containers.

NOTES: 1. The hydrogen-generation process develops considerable heat within the generator and in the balloon transfer tube. Every attempt should be made not to touch these items with bare parts of the body. Gloves and clothing should be worn to protect the body from such contact.

2. The Hydripills® are slightly caustic as is the water plus chemicals which remains after hydrogen generation. The eyes and skin should be reasonably protected at all times from contact with this chemical.

FUTURE WORK

No further work is contemplated at this time in connection with the 750-cu-ft hydrogen generator.

Appendix 1

Drawing of Final Design of
750-cu-ft Generator

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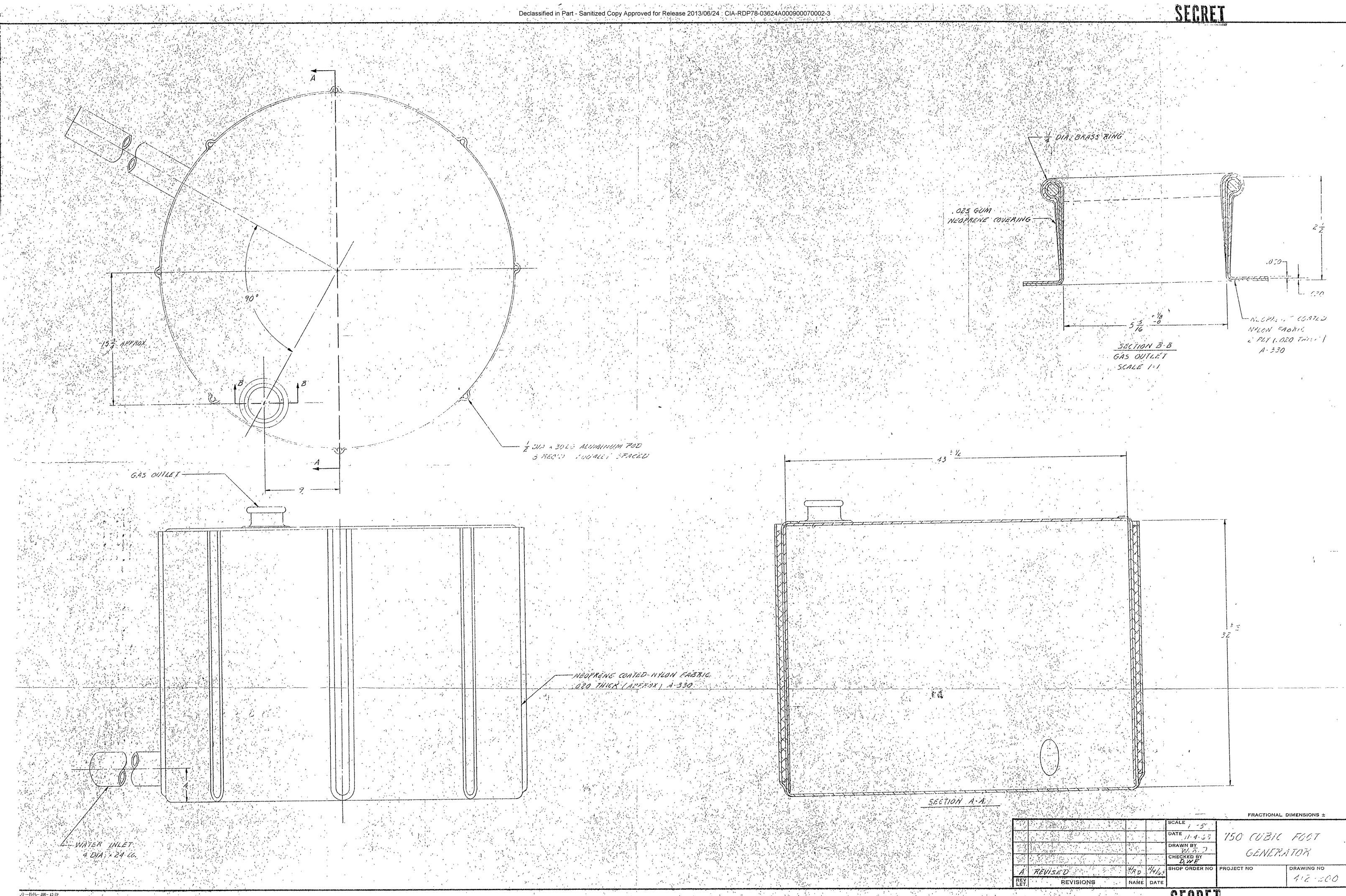

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