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A THIN-PLATE BATTERY

SUPPLEMENT TO

Twelfth Quarterly Report
on
Molecular Circuit Development

Contract NOw 60-0362-c

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SUPPLEMENT

TO

TWELFTH QUARTERLY REPORT

ON

MOLECULAR CIRCUIT DEVELOPMENT

Period of 15 February 1963 to 15 May 1963

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1. INTRODUCTION

This supplement describes the technical progress in the development of a special power source. The objective of this program is the realization of a practical, reserve-type primary battery based on the NOLC liquid-ammonia activated cell. A practical high-rate power source, as delineated by the Bureau of Naval Weapons, is a source that has:

a. High energy-to-weight ratio.

b. High energy-to-volume ratio.

c. High current-density drain-rate capabilities with voltage-output regulation of ± 10% for six to ten minutes.

d. Rapid activation.

e. Uniformity of characteristics over the military range of operating temperature.

f. Safety and reliability of operation.

g. Ease and economy of fabrication.

Theoretically, the active constituents of the NOLC liquid-ammonia activated cell have the capability of meeting the energy requirements. The solvent for the system, liquid ammonia, fulfills the temperature requirement. Further, the investigation of single-cell characteristics has demonstrated the practicability of utilizing the NOLC cell at high-drain rates. However, the transition from a single-cell unit to a multi-cell device is accompanied by many difficulties of a practical nature. It is the immediate goal of the program to accomplish this transition. During this report period, several encapsulated devices were fabricated and evaluated. Additionally, a new multi-cell test fixture was designed and constructed.

2. TECHNICAL EFFORT

2.1 Description of Technical Effort

Early in this reporting period, emphasis centered on the fabrication and testing of encapsulated 28-volt series battery packs. Prior to this, several fixture-held, 30 cm^2 plate 10-volt series units were activated. These units were tested to ascertain the effect on battery performance of inter-cell spacing and electrolytic solution activation.

Early in this report period, J. Smit and H. Titus engaged in technical discussions with NOLC personnel at Corona, California. At that time, five encapsulated 28-volt units were released to them for evaluation.

The latter portion of this report period was devoted mainly to the design and fabrication of a multi-cell test fixture. This fixture was designed to simulate conditions as they occur in an encapsulated unit. In addition, a new high-pressure test stand and shield was constructed to augment test work carried out with this new fixture. Details of this effort, as well as pertinent data, are given in subsequent sections.

2.2 Results of Technical Effort

2.2.1 Multiple-Cell Evaluation, Fixture Tested

Several laminate-series battery assemblies were activated at varied inter-cell spacings and drain rates. These units, as described in the eleventh quarterly report, consisted of electrodes formed by spot welding 0.006-inch thick magnesium discs to 0.0015-inch thick stainless steel discs. The magnesium is the anode side of the cell. Cathode matrix was applied to the stainless steel surface of this combination. Four of these combinations when placed between a standard cathode and a standard magnesium anode in the Mark II test fixture, formed a five-cell series battery. Unit F-B.16 when discharged across a 4.9-ohm load, attained a peak load of 9.4 volts and operated for 189 seconds to 80% of peak voltage. The initial current density for this run was 64 ma/cm^2. The cell spacing was 0.030 inches. All fixture-tested units of this type were center fed; i.e., the electrolyte was injected into a 0.25-inch diameter center hole in the plate assembly. The data for these runs are given in table 1.

2.2.2 Multiple-Cell Evaluation, Encapsulated

Two types of encapsulated 28-volt series battery packs were prepared from 12 cm^2 laminate electrodes. The units differed chiefly in the electrolyte fill-port geometry. All units contained 15 cells, stacked in series. Each cell plate contained 0.32 grams nominally of cathode matrix mix. The units were encased in an epoxy-glass cylindrical vessel, which was formed closed at one end. The cells were positioned in the vessel and locked into position at a proper depth, depending on the desired cell spacing, by a cover plate of epoxy-glass laminate. A second plate sealed the open end of the vessel. Feed-throughs were provided for electrical contact and electrolyte filling.

The first mode of construction involved setting the plates on a center mandrel in the container. A segment was cut from the plates to provide a free volume in one section along the periphery of the plate stack. The remainder of the plate circumference cleared the interior of the container by 1/32 inch. Filling was accomplished through a 1/4-inch

Table I

MARK II Fixture Tested Batteries

Electrolyte concentration 34% by weight NH_4SCN to NH_3. Reagent grade D.N.B. (undetermined particle size)

Battery No.	Type of Battery and Electrical Rating	External Load (ohms)	Peak Voltage (volts)	Cell Thickness (inch)	Current Density (ma/cm^2)	Time to 80% Peak Voltage (sec.)
F-B .11	10 Volt - 1 Amp: Series	10.2	9.51	0.040	31.0	321
F-B .12	10 Volt - 1 Amp: Series	10.2	9.58	0.035	32.0	371
F-B .13	10 Volt - 1 Amp: Series	10.2	9.70	0.030	31.7	504
F-B .14	10 Volt - 1 Amp: Series	10.2	9.65	0.030	31.5	384
F-B .15	10 Volt - 1 Amp: Series	10.2	9.56	0.030	31.2	270
F-B .16	10 Volt - 2 Amp: Series	4.9	9.18	0.039	62.1	97
F-B .17	10 Volt - 2 Amp: Series	4.9	9.40	0.030	64.0	189

stainless steel tube positioned over the free volume section of the stack assembly. Thus, the stack was fed peripherially with electrolyte.

The second mode of construction utilized an off-center stud upon which the cell plates were affixed. All plates used in this construction were cut with a 1/4-inch diameter center hole. A 1/4-inch stainless steel tube, fixed to the center of the upper cover plate, provided the fill port for the electrolyte. The circumference of the plates in this case also cleared the vessel interior by 1/32 inch. These stacks were then center fed with electrolyte. These devices are shown in figures 1 and 2.

Several encapsulated units were activated successfully; two units in the presence of Mr. R. M. McIntyre (BuWeps). Unit MC-5, an edge-fed unit, produced at peak 29.2 volts across a 50-ohm load. This represents an initial current density of 52 ma/cm^2. The unit operated for 135 seconds to 91% of peak voltage at which time an internal pressure buildup to 760 psi caused a seal failure. The device was activated with a 150-psi pressure head on the electrolytic solution of 34% by weight NH_4SCN in NH_3. The data for these devices are shown in table II.

2.2.3 Corona Conference

Discussions at NOLC dealt primarily with experimental methods and designs, data retrieval and processing, and the problems arising from the characteristics of multi-cell series battery units. The conversations reaffirmed the need for a coherent, mutually understandable system (between all laboratories engaged in liquid ammonia battery research) of statistically designing experiments and analyzing and handling experimental data. The basis for statistical design, as recommended by NOLC personnel,

Figure 1. Encapsulated Battery

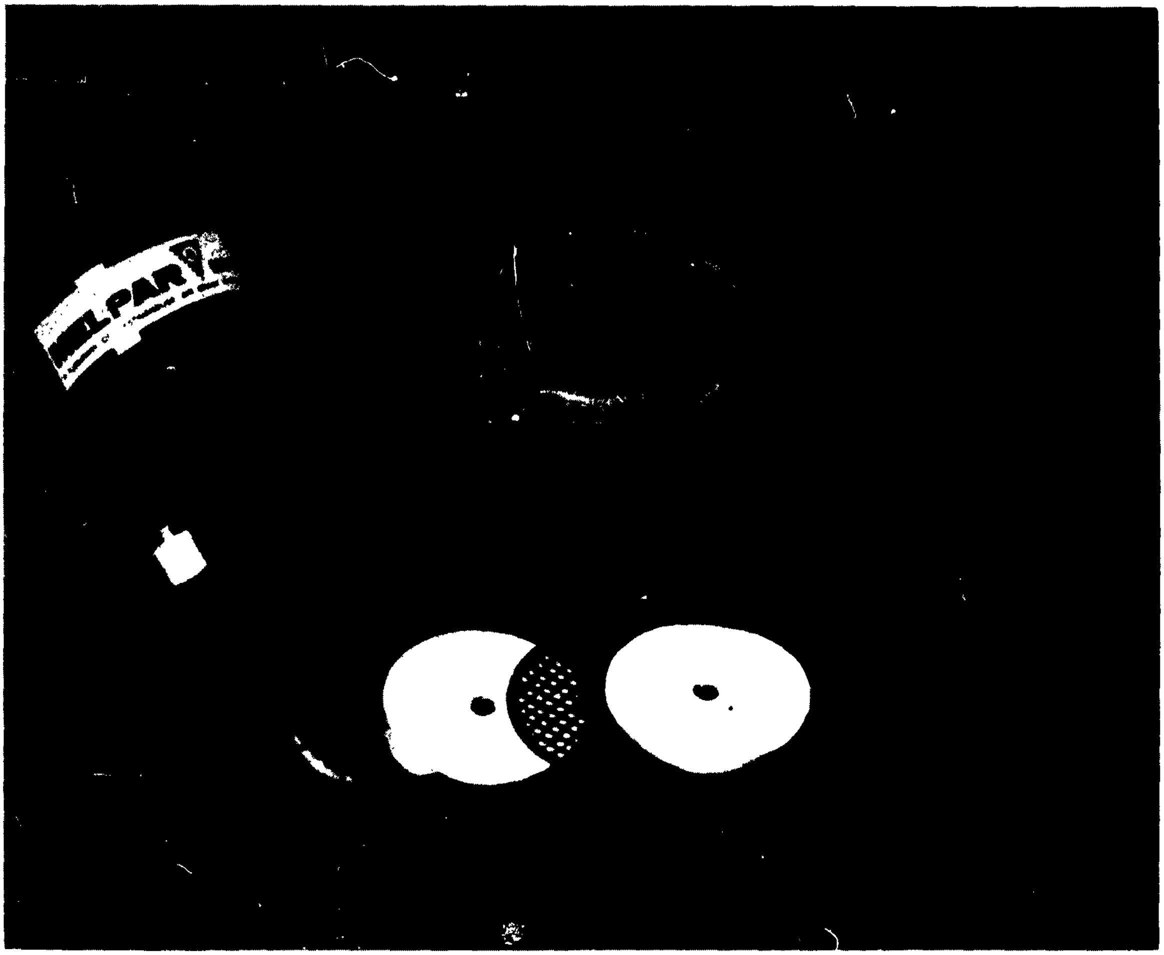

Figure 2. Encapsulated Battery and Plates

Table II

Molded Case Battery

Electrolyte concentration 34% by weight NH_4SCN to NH_3. Reagent grade m-DNB

Battery No.	Type of Battery and Electrical Rating	External Load (ohms)	Peak Voltage (volts)	Cell Thickness (inch)	Current Density (ma/cm^2)	Time to 80% Peak Voltage (sec.)
M-C .1	28 Volts - 0.6 Amps. - Series	50.0	20.0	0.040	35.4	159
M-C .2	28 Volts - 0.6 Amps - Series	50.0	28.6	0.030	50.6	99
M-C .3	28 Volts - 0.6 Amps - Series	50.0	30.1	0.030	53.3	125
M-C .4	28 Volts - 0.6 Amps - Series	Instrumentation Failure				
M-C .5	28 Volts - 0.6 Amps - Series	50.0	29.2	0.040	51.7	Case Rupture at 91% P. V. 135
M-C .6	28 Volts - 0.3 Amps - Series	100.0	30.9	0.040	25.8	Case Rupture at 95% P. V. 36
* M-C .12	28 Volts - 0.6 Amps - Series	50.0	23.6	0.030	39.3	366
M-C .13	28 Volts - 0.6 Amps - Series	50.0	17.6	0.030	29.3	135
M-C .14	28 Volts - 0.6 Amps - Series	50.0	18.0	0.040	30.0	20

* Cells M-C .7 - M-C .11 are being tested at N.O.L., Corona.

is the factorial design. This design allows for the study of parameters separately and interactively, and yields a maximum of information for a minimum of experimental effort. An experimental plan, using this design, will be devised to study the effect on multiple-cell performance of such variables as temperature, pressure, current density, intercell thickness and methods of activation.

The correlation and processing of data, as accumulated from statistically designed experiments as outlined above, can be carried out most efficiently through the use of electronic computing equipment. Methods of establishing a computer program, with respect to fields, punch card designs, and coding systems were explained by Mr. W. Spindler (NOLC). An attempt will be made by this Laboratory to institute such a program within the limits of presently available equipment.

Current progress with encapsulated units tends to confirm a suspicion that the solution to many of the problems encountered in multi-cell work lies in achieving rapid unobstructed injection of the electrolytic solution into the battery-plate compartment. Devices, constructed with a free peripheral volume into which the solution is dumped, appear to activate rapidly and completely. However, a rapid pressure buildup internally attends this activation at high-current density drain rates. Pressures in excess of 700 psi have been encountered within two or three minutes after activation. It remains to be determined whether the pressure increase is a manifestation of gas evolution or heat generation, as a result of electrolytic action, or from attack on cell components, or both. Conversations at this point, at NOLC yielded no definite conclusions.

2.2.4 Battery Test Fixture

It had been suggested by Mr. R. W. McIntyre (BuWeps) that a test fixture be devised which would simulate the conditions produced by an encapsulated unit. The valid contention here is that multiple-cell test data could be accumulated more economically and quickly when compared to the sealed encapsulated units. However, the encapsulated units did, and do, demonstrate eventual hardware feasibility. J. Daley of NOLC proposed that the present epoxy-glass cases be used as the test chambers for multiple-cell evaluation. This idea is exceedingly attractive as suitable case modifications can be made involving quick couples and O-ring seals. Accordingly, a fixture was designed and fabricated along these guide lines.

The multiple-cell test fixture consists essentially of a mantle assembly, an insert sealing assembly, and an eopxy-glass battery-case shell. The epoxy-glass shell is the same type now being used in producing encapsulated batteries. Fixture mounted, the shell acts as a receiver for the anode-cathode plate assemblies. The mantle, formed from stainless steel, supports the shell and acts as a retainer for the sealing insert. The sealing insert, composed of two stainless steel plates and an O-ring, functions as the closing upper plate of the battery assembly. The complete fixture closely approximates an encapsulated unit. It should be possible through the use of this fixture to evaluate the effect on battery performance concerning such factors as cell thickness, activation pressure and method of activating.

The end electrodes of the unit are thermally insulated from the metal section of the fixture. It should be possible, therefore, to obtain reasonable cell internal temperature data through the use of this unit. Additionally, the fixture is fitted with devices for controlling internal pressure. The effect on battery performance of internal pressure regulation is to be investigated along with the parameters enumerated. The fixture components and assembly are shown in figures 3, 4 and 5.

2.2.5 Battery Test Stand

As stated in section 2.3.3, a probable source of difficulty in multiple-cell activation lies in obstructed electrolytic solution flow. To verify this possibility, battery compartment design was and is being investigated. In addition, a new test stand was constructed to eliminate flow obstruction from the solution reservoir to the battery-plate compartment. The plumbing in this stand utilizes 1/4-inch diameter stainless steel tubing throughout, as well as a 1/4-inch high-pressure toggle valve between the reservoir and the compartment. The larger bore tubing permits a more rapid injection of solution than is possible in the present fixture which uses 1/8-inch diameter tubing. This stand has been tailored to receive the new multiple-cell test fixture. The stand contains, among other things, a Plexiglas viewing port and provisions for pressure checking the test fixture. It also contains lines for high-pressure solution activation. The test stand, with the test fixture in place, is shown in figures 6 and 7.

3. CONCLUSIONS AND RECOMMENDATIONS

High performance levels can be achieved from encapsulated units. It appears that they can be made to operate at current densities above 50 ma/cm^2. There are, however, several problems associated with

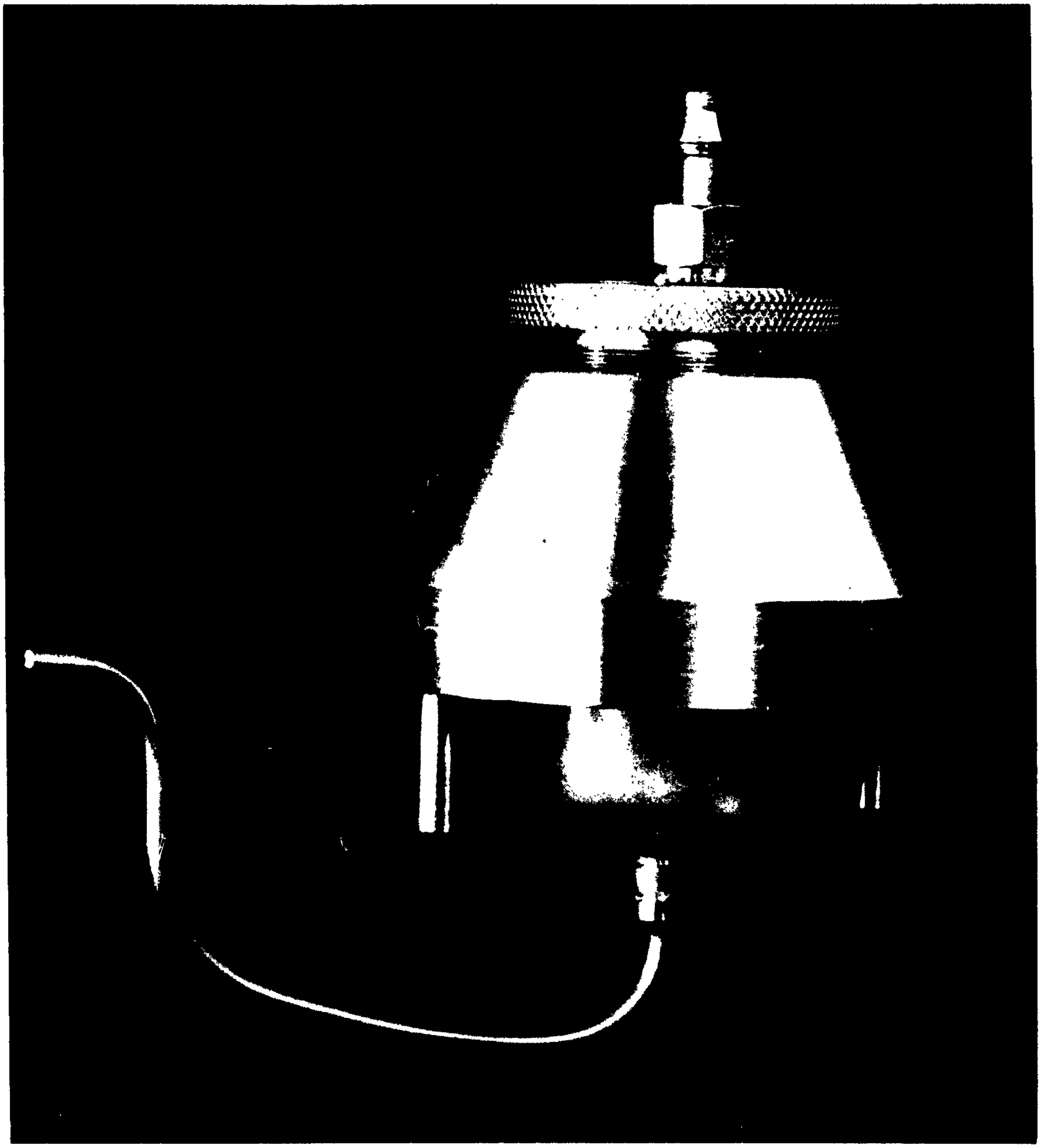

Figure 3. Battery Test Fixture

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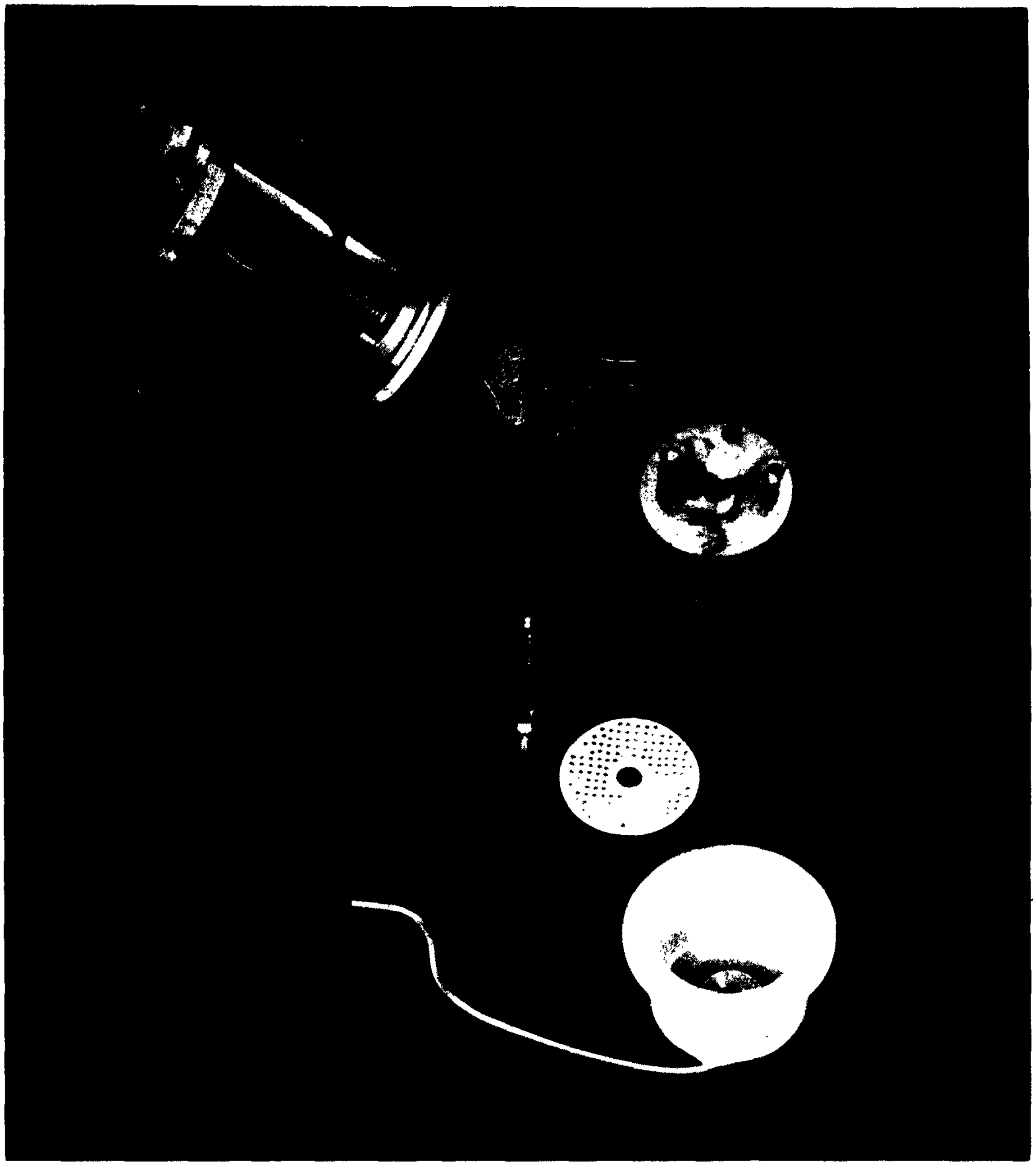

Figure 4. Battery Test Fixture, Inserts

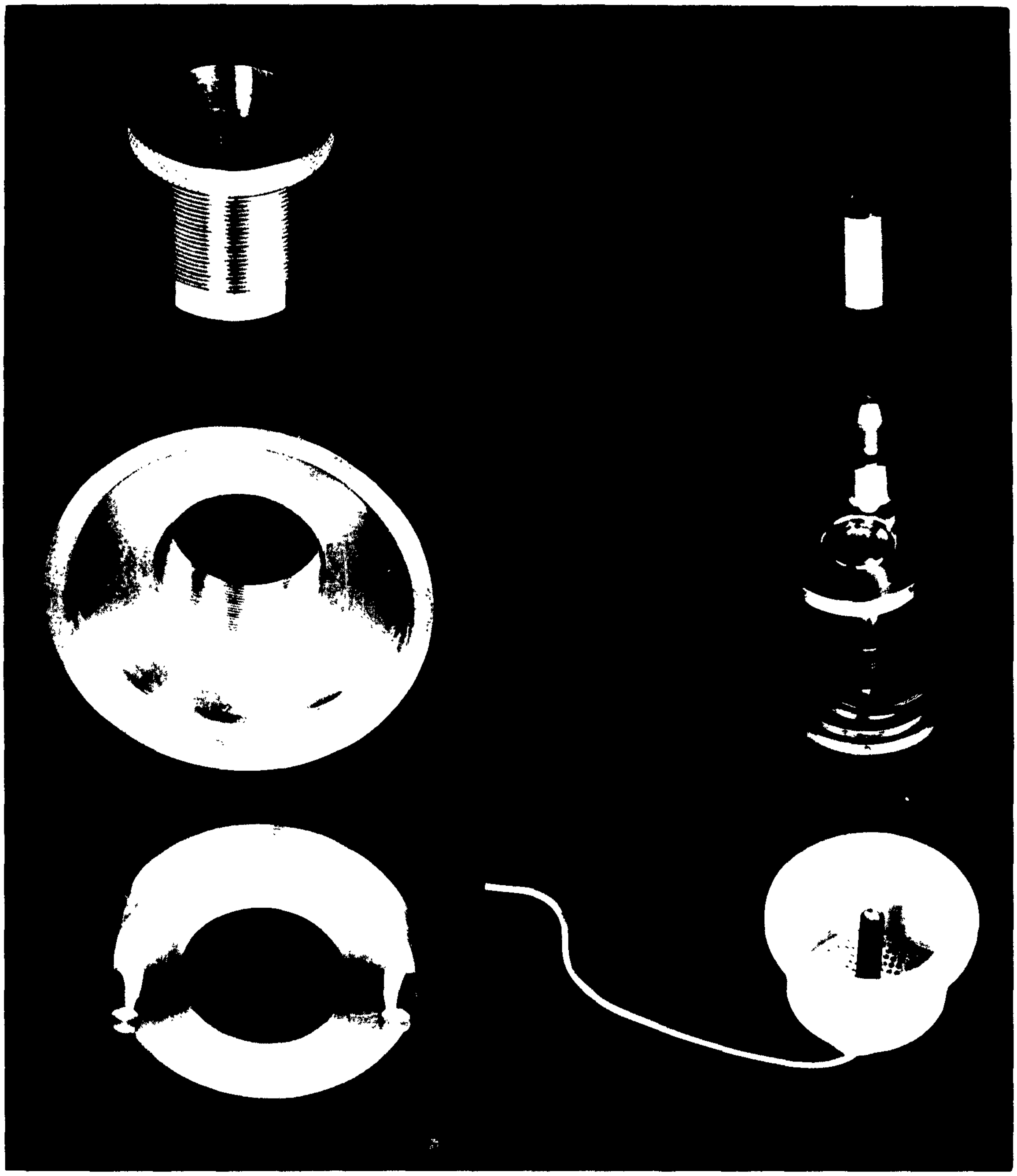

Figure 5. Battery Test Fixture, Inserts and Mantle

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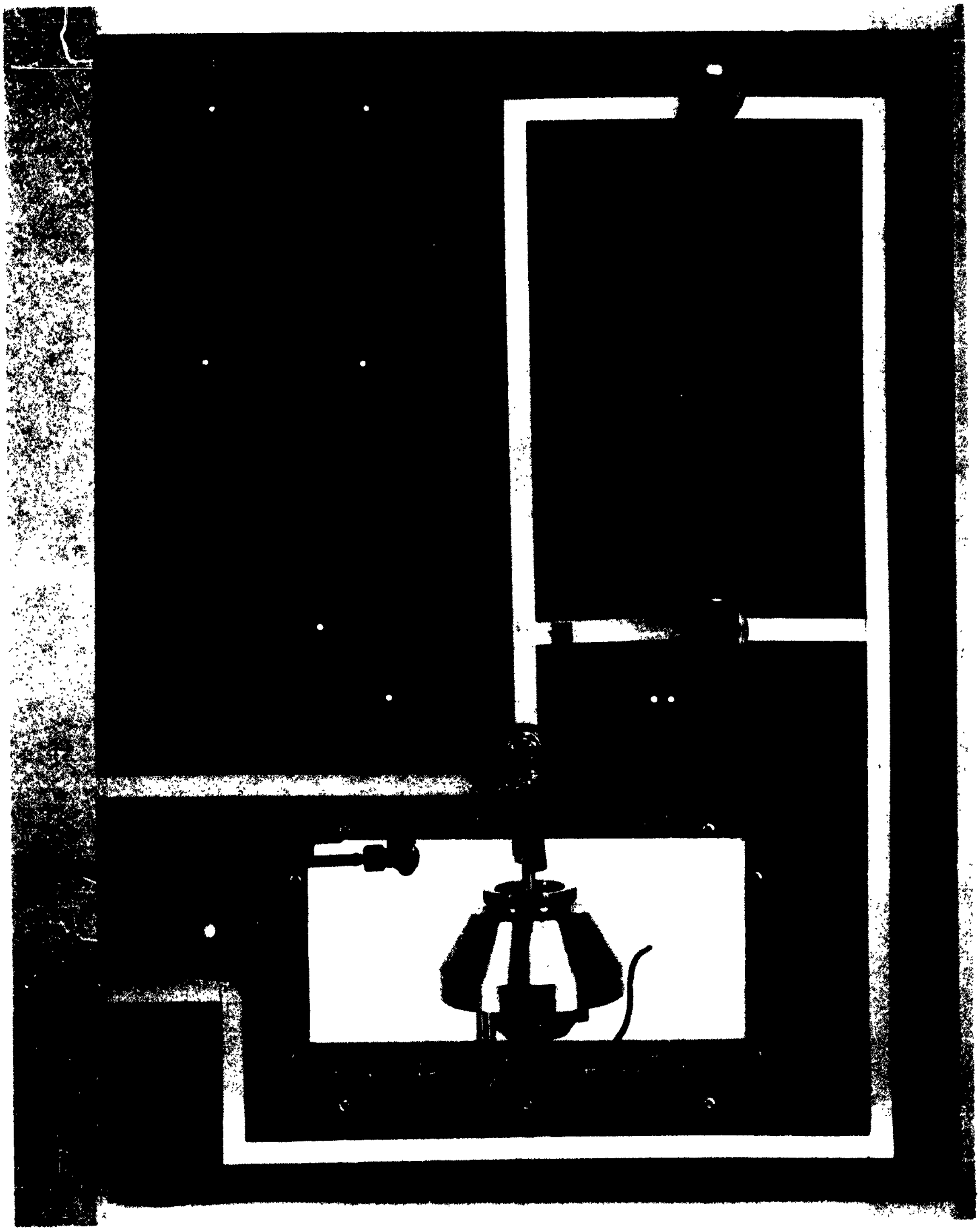

Figure 6. Battery Test Stand, Front

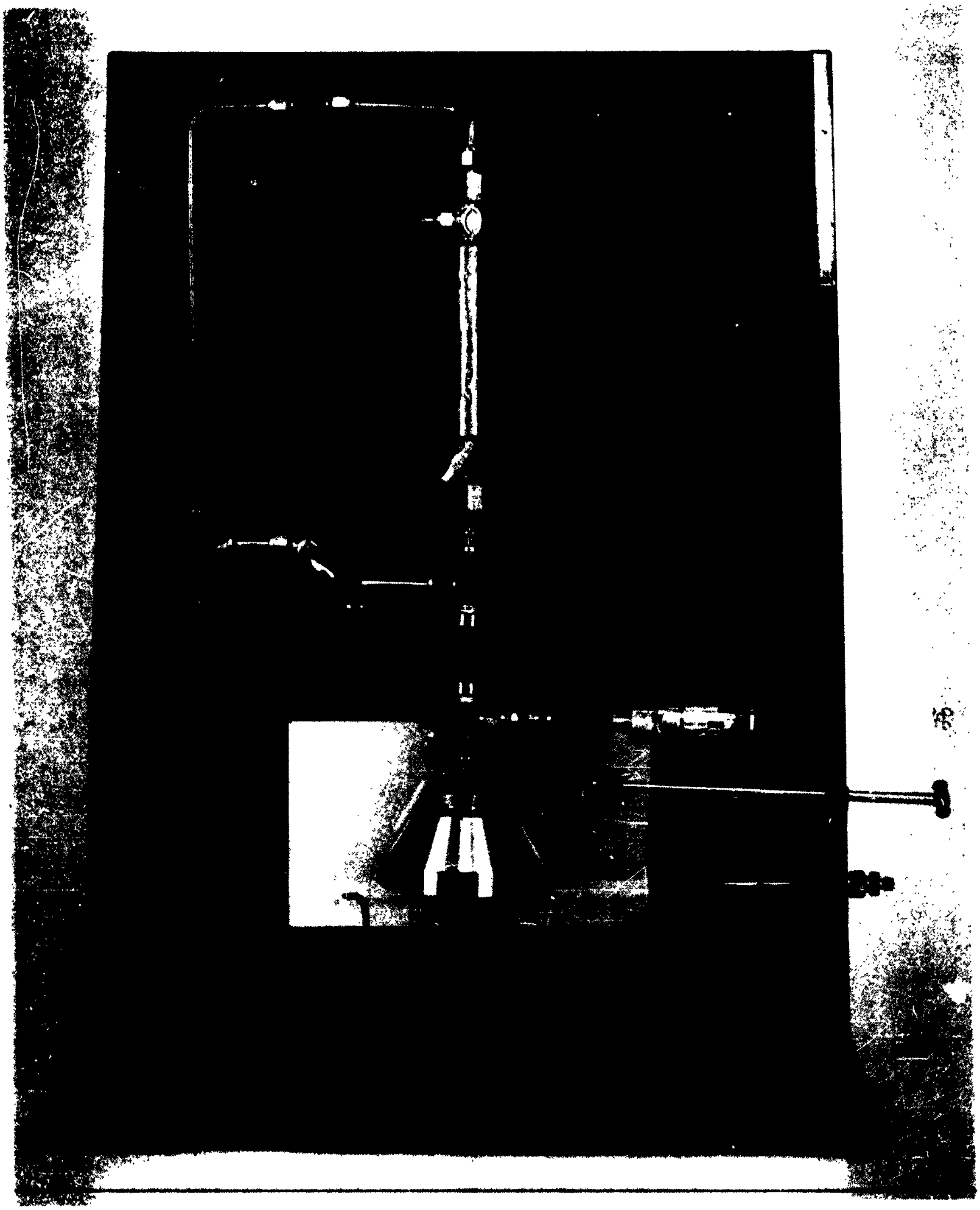

Figure 7. Battery Test Stand, Back

encapsulated unit activation, chief among which is pressure buildup. At this time it is difficult to construct encapsulated units with seals capable of withstanding the pressures generated within the battery. The recommended course of action, and the course to be followed, involves the fixture testing of units that approach in physical characteristics the encapsulated units. The new test fixture will facilitate this course of action.

The fractional factorial design appears to be a satisfactory means for evaluating multi-cell battery performance. Several schemes are being prepared for evaluating five battery variables at two levels. Data acquired from these programs will be processed by Melpar's IBM 1410 computer. Tentatively, the data analysis will be conducted through the use of Fortran language.

4. PROGRAM FOR NEXT QUARTER

Effort during the next quarter will be expended exclusively on the evaluation of simulated multi-cell units. The prime object will be to uncover the source of pressure buildup and to control it. Following this, multi-cell unit performance will be optimized with respect to cell thickness, geometry, activation pressure and vent pressure. The optimization will be sought through statistical analysis of a programmed series of experiments.

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