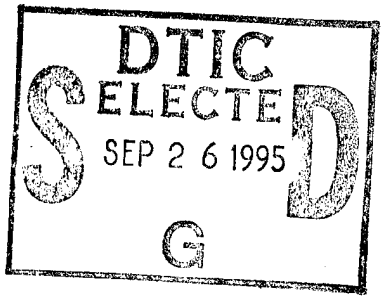
DEVELOPMENT OF AN ULTRA-SAFE RECHARGEABLE LITHIUM-ION BATTERY



Contract # N00014-94-C-0141
ARPA Order # 9332004arp01/13 APR 1994/313ES

R & D Status Report #9

Reporting Period: 16 June to 15 July, 1995

Submitted by:

The Electrofuel Manufacturing Company Inc.

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R&D STATUS REPORT
1931-1009/0

ARPA Order No.: 9332004arp01/13APR1994/313ES
Program Code No.: ARPA-BAA93-32
Contractor: The Electrofuel Manufacturing Company Inc.
Contract No.: N00014-94-C-0141 Contract Amount: $1271728.
Effective Date of Contract: August 15, 1994
Expiration Date of Contract: February 14, 1996
Principal Investigator: J.K. Jacobs
Telephone No.: (800) 388-2865
Short Title of Work: Lithium-ion Battery Development
Reporting Period: June 16, 1995 to July 15, 1995

Description of Progress:

Work is accelerating in a number of areas simultaneously.

The major effort during this period was to start operating and debugging the assembled (flexible prototype production line) system. Upon assembly, the system did not work satisfactorily. The first approach was to use a plastic carrier material through the rollers. This was used to generally align the system. After the plastic material was changed to the Aluminum foil, 12 micron (0.5 thou), it was found that precision alignment of the system was necessary. An optical alignment system using a laser technique was developed using a He/Ne laser along with a number of flat mirrors. Two mirrors were attached to the base of the system and other mirrors were attached to the moving/rotating part of the system. This alignment allowed us to roll the Al foils without warping. This alignment was tested by rolling about 600 feet of Al foils.

Electrode coating: Two methods of coating electrode on the Al foils were developed, constructed and tested. This work was started in the last two months but was completed in this time period. The first approach was to feed the electrode material through a curtain coater slot under hydrostatic pressure. This method has some advantages but because of the very strong dependence of viscosity of materials to the flow rate of the material, this method was difficult to control. The flow properties of this material is non-Newtonian. To improve the flow properties of this material (manganese oxide, Kynar, propylene carbonate), attempts were made to introduce a low amplitude vibration. Both low frequency (60 Hz) and high frequency (ultrasonic - 20,000 Hz) vibrations were introduced during the flow. This improved the flow uniformity and can be developed in the future. In general the cathode coating mix is observed to be very thixotropic with

viscosity changes of several hundred times with increasing shear rate. This is generally characteristic of colloids near the iso electric point and is a difficult material to be used for curtain coatings.

But another method was also developed in parallel in order to provide a fast proof of concept for the flexible production line. This consisted of a modification of tape casting procedure implemented on-line in the lamination process. This method was developed, constructed and tested. The positive electrode material was deposited on the aluminum foil with good uniformity of about 7.5% and an average thickness of 300 microns, before it was squeezed into 170 microns, which is the design electrode thickness.

The thickness of the copper foil used for the negative electrode was reduced from 25 microns to 18 microns. The adhesion of the copper foil to the negative electrode material is sufficient but not excellent. An electrochemical etching process is used to improve the copper foil adhesion characteristics.

Hand crafted cells continue to be produced and tested. Any changes in chemistry is implemented and tested through handcrafted cells. One of the major problem area is the interface adhesion in the cells. A major development this month on the chemistry was the development of an improved method for adhesion of separator to the electrodes. This was done using adhesives which also conduct lithium ions. Cells with these binders are being produced. A batch of six "glued cell" are being constructed and will be cycled soon.

For thin cells it is possible to get high power out of these Planar Lithium ion batteries. To test for high rate capability, unoptimised cells which were undergoing long term testing were used after the 325th cycle. Even operating with these unoptimised cells, it was found that excellent rate performance could be achieved. Discharge of these cells were carriedout at the 1C, 2C and 4C rate. The cells behaved well, and after the high rate discharges, they went back to the normal charge/discharge regime without showing any effect. It appears that thin film lithium ion cells could be a candidate for high rate applications, which are presently being filled by silver/zinc batteries.

A paper was given in the Myrtle Beach Conference outlining the performance and progress of this battery development program.

Change in Key Personnel: None

Summary of Substantive Information Derived from Special Events: None:

Problems Encountered and/or Anticipated: None

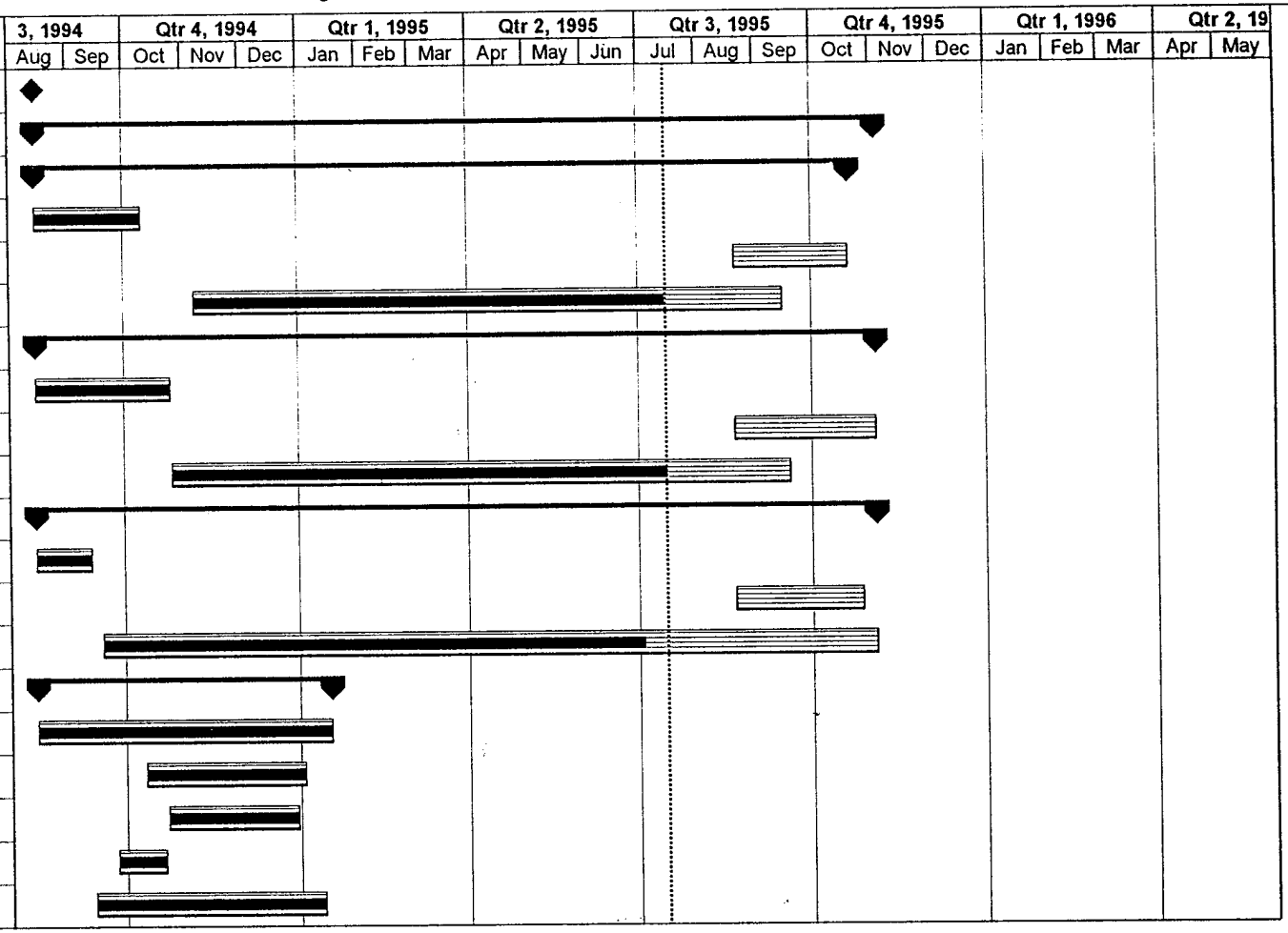
Action Required by the Government: None

Fiscal Status:

	Total Estimate of Program	US Govt Funding Obligation	Electrofuel Contribution
(1) Amt. currently provided on contract:	$1630421	$1271728	$358693
(2) Expenses & commitments to date:	$ 729571	$ 569065	$160506
(3) Funds required to complete work:	$ 900850	$ 702663	$198187

Figure 1: Gnatt Chart

ID	Name
1	Project Start
2	Cell Chemistry
3	Anode Selection
4	Prelim. Anode Choice
5	Final Anode Choice
6	Anode Mat'ls Prep
7	Cathode Selection
8	Preliminary Cathode Choice
9	Final Cathode Choice
10	Cathode Mat'ls Prep
11	Electrolyte Selection
12	Prelim. Electrolyte Choice
13	Final Electrolyte Choice
14	Electrolyte Mat'ls Prep
15	Cell Stack Design
16	Stack-pressure Control
17	Anode Fabrication
18	Cathode Fabrication
19	Current Collector Structure
20	Separator Prep



Project: Li-ion Battery
Date: 8/16/95

Critical
Noncritical
Progress
Milestone
Summary
Rolled Up

Figure 1: Gnatt Chart

ID	Name
21	Packaging Design
22	Folding Methodology
23	Series/Parallel Connections
24	Current Collector Attachment
25	Lead-out Seal
26	Enclosure Fabrication & Seal
27	Charger Design
28	Safety Requirements Review
29	Safety Protection Design
30	Equalization
31	Rate Control
32	User-group Input
33	User Input - part I
34	User Input - part II
35	User Input - part III
36	Flexible Manufacturing Line Design
37	Prototype Equipment Design
38	Pilot Equipment Design
39	Misc. Unit Op.'s Equip. Design
40	Flexible Manufacturing Line Setup

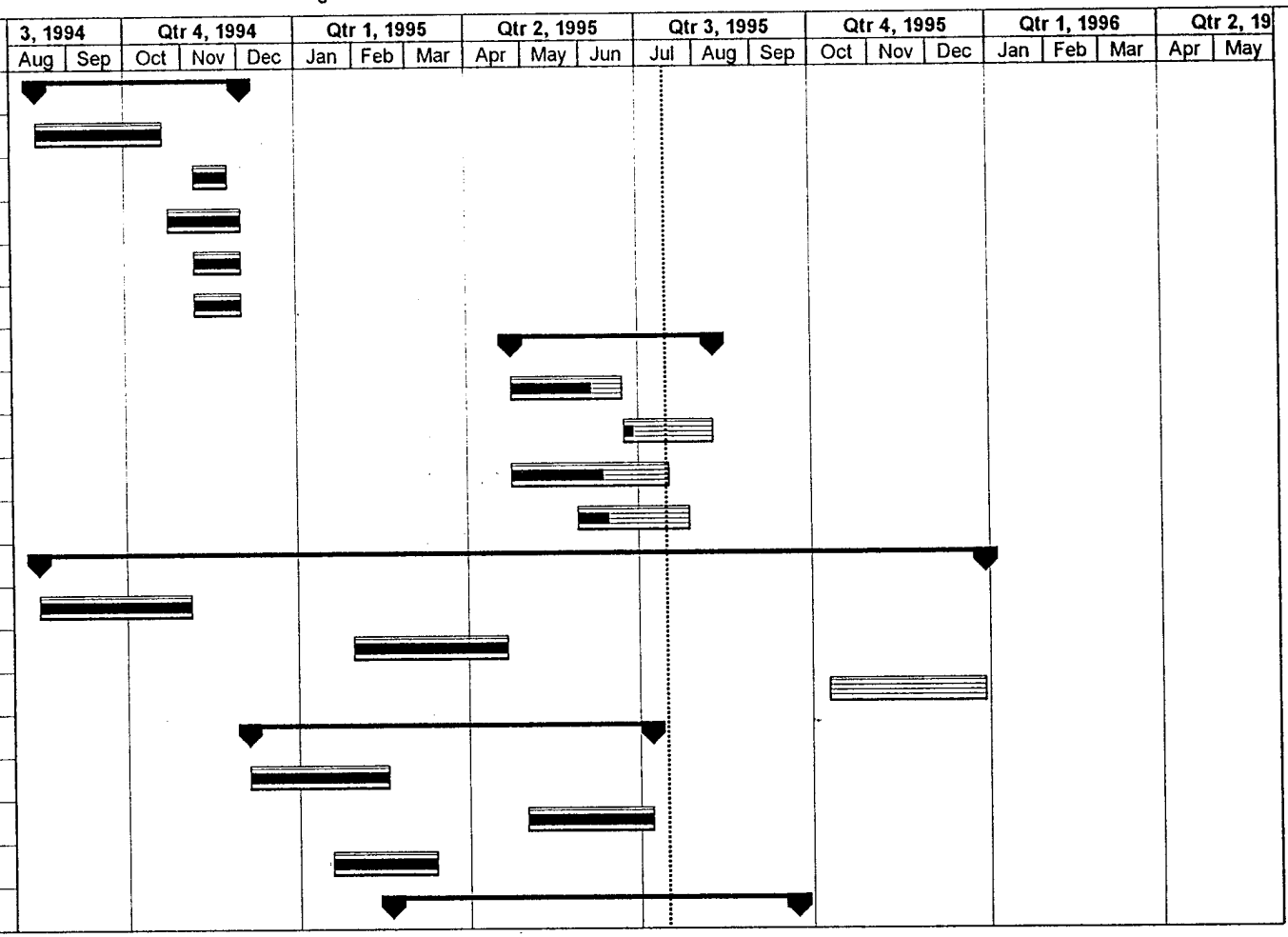


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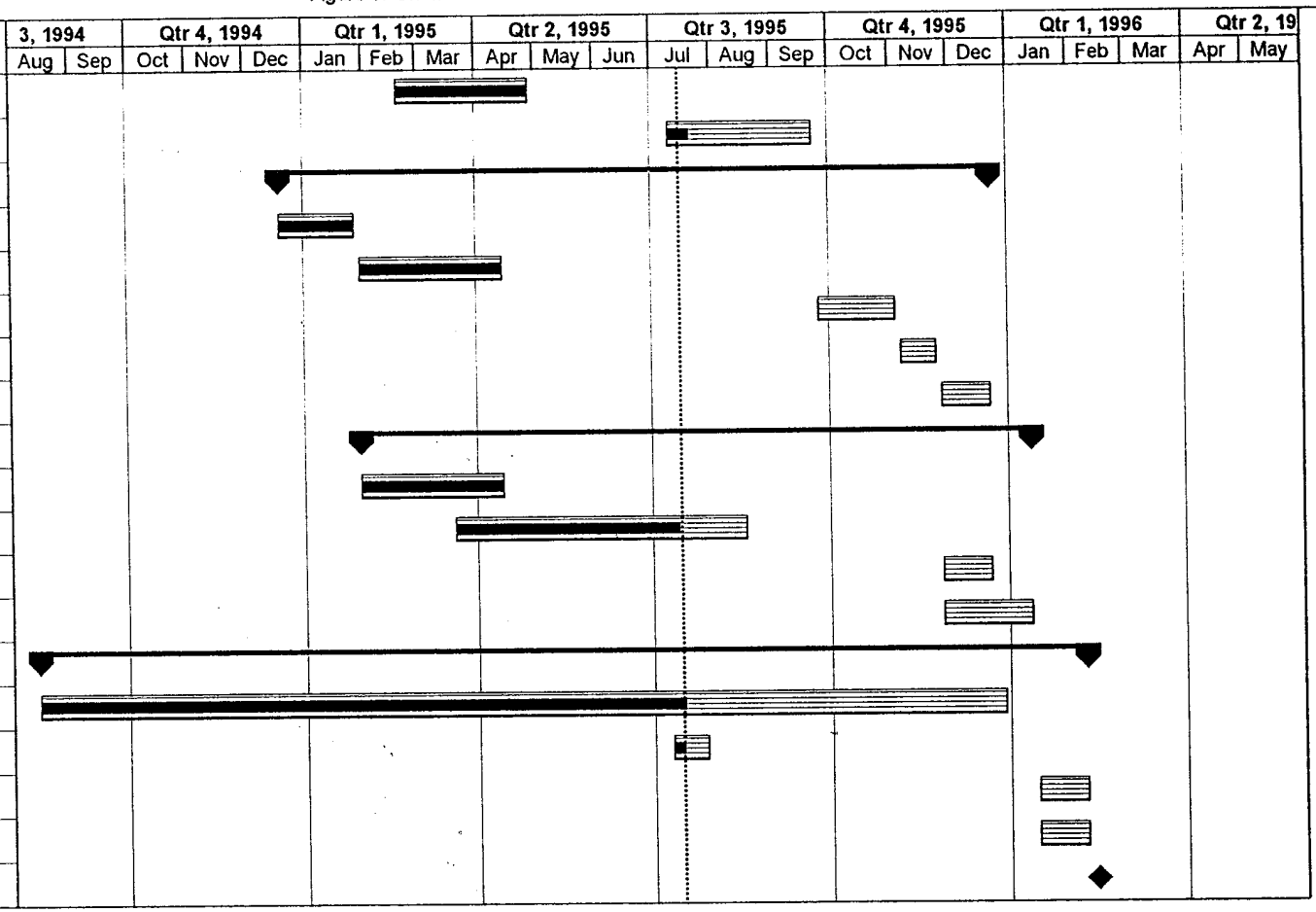
Figure 1: Gnatt Chart

ID	Name
41	Prototype Line Setup
42	Pilot Line Setup
43	Battery Fabrication
44	Button Cell
45	Hand-crafted Cell
46	Prototype Battery A: Credit Card
47	Prototype Battery B: Lap Top
48	Prototype Battery C: B5590
49	Battery Testing
50	Button Cell Performance
51	Hand-crafted Performance
52	Prototype Safety
53	Prototype Performance
54	Reporting
55	Progress
56	Button Cell Report
57	Prototype Battery Test Report
58	Final Report
59	Project Complete



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