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DEVELOPMENT OF LITHIUM-THIONYL CHLORIDE BATTERIES FOR CENTAUR

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Lithium-thionyl chloride ($Li-SOCl_2$) primary cells and batteries have received considerable attention over the last several years because of their high theoretical specific energy and energy density. The development of the technology has been supported by the NASA Hq., Office of Aeronautics and Space Technology at the Jet Propulsion Laboratory for the past several years. The objective is to develop a 300 wh/kg cell capable of safe operation at C/2 rate and active storage life for 5 to 10 years. This technology would replace other primary cell technologies in NASA applications mainly the silver-zinc (Ag-Zn) batteries presently in use. The $Li-SOCl_2$ system exceeds the capabilities of the Ag-Zn in terms of specific energy of 300 wh/kg (compared with 100 wh/kg for Ag-Zn), active storage life of 10-20 times the 3-6 months active storage and has a significantly lower projected cost.

During the course of the NASA development effort, the Air Force/Space Division (AF/SD), was struggling with a significant weight problem for its CENTAUR vehicle. The progress in the JPL development, in which cells produced in-house exceeded the goals listed above, was noticed by the AF/SD. A back of the envelope calculation projected a weight savings for the CENTAUR of more than 250 lbs. (100 Kgs) for the batteries required to meet CENTAUR mission goals. The result was a 3 year AF/SD contract with JPL to develop $Li-SOCl_2$ 150Ah and 250Ah cells and batteries for this application. The effort was to be a cooperative effort between JPL and cell/battery manufactures to meet the AF requirements. This paper will describe the present activities and status of the program with some of the findings to date.

In introducing the subject, it is interesting to note that there are a number of applications in space activities for primary batteries. Among these are space transportation systems; including astronaut backpacks, portable equipment and deployable instruments, transportation vehicles; Centaur, crew escape vehicle, or orbit transfer vehicle and IUS, and most importantly for planetary deep space, probes penetrators balloons and landers. The common denominator, is high specific energy, high volume energy density, long activated shelf life and high discharge rate capability.

The history of the $LI-SOCl_2$ development program at JPL is given in Figure 1. Although some work was done prior, the serious cell design activities started in the early 80's. The result as can be seen is the demonstration of cylindrical and prismatic cell designs resulting in the demo of a 330 wh/kg "D" size cell operated at the 5 amp (C/2) discharge rate. A prismatic 20Ah cell was assembled and tested, achieving 280 wh/kg at the C/4 rate narrowly missing the design goals.

The objectives of the A.F./S.D. effort are given in Figure 2. The program involves a coordinated contractor/JPL effort to produce prototype 150 & 250AH cells and batteries hardware and a design package described as a Manufacturing Control Document (MCD) available for procurement. The in-house work at JPL would involve analysis, cathode enhancement, and quality.

Figures 3 and 4 from General Dynamics provide a schematic view of the CENTAUR and the battery location. There are 6-8 batteries necessary for the power requirements: Figure 5 is a comparison of the present Ag-Zn battery and the projected $LI\text{-}SOCl_2$ battery. The weight savings of more than 50% is indicated. The volume savings is also substantial. The $LI\text{-}SOCl_2$ battery will have to occupy the same footprint and therefore be lower in height. The difference is due to the lower number of cells 9 vs. 19 cells because of the cell voltage of 3.4 V compared to silver-zinc of 1.5 V/cell. It is also due to the difference in specific energy.

Figure 6 includes a power usage scenario projected to the mission. The 80 amps pulse at a 40A average required for the battery are consistent with the 150 Ah and 250 Ah requirements.

One of the areas of interest is the cathode structure. JPL $LI\text{-}SOCl_2$ "D" cells have exceeded the performance at high rates of existing $LI\text{-}SOCl_2$ cell. We believe the basis is the high performance cathode. The baseline cathode data is given in Figure 7. The range of current density required in this application is 1-5 ma/cm^2. This indicates that 1.5 Ah/gm utilization of the cathode is required. The behavior of voltage at this rate must be minimized in order to reduce heat dissipation problems. We have shown that the projected voltage is $3.3 \pm .1$ volts which is quite satisfactory. Projected improvements in cathode design could result in a specific energy of 40 wh/kg at the 100% utilization level shown in Figure 8.

The electrode thickness is being modeled also to optimize specific energy, minimize polarization and capacity. Figure 9 gives the relationship between plate thickness and specific energy. The indication is there is a maximum at 30 mils if the grid design and thickness is constant. Obviously, if the plate thickness was reduced the grid would also have to be modified thus altering the shape of this curve.

The initial internal cell design is given in Figure 9, in which the materials and component size and weight are given. The projected overall mass for a 150Ah cell based on the JPL 20 Ah prismatic cell is given in this figure. The battery mass utilizing 9 of these cells is given in figure 10. The resultant design including a 1.2 factor for battery mass indicates a 55% weight savings.

In summary, the task initiated in October 1987, is a coordinated contractor (probably 2)/JPL effort to develop 150 & 250 Ah cells and batteries to reduce the CENTAUR battery weight by 50%. The contract effort is expected to start in early May. The result will be a design package with drawings and QA/QC to produce batteries for the CENTAUR application.

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FIGURE 1

JPL

PRIMARY Li-SOCℓ_2 CELL DEVELOPMENT ROADMAP

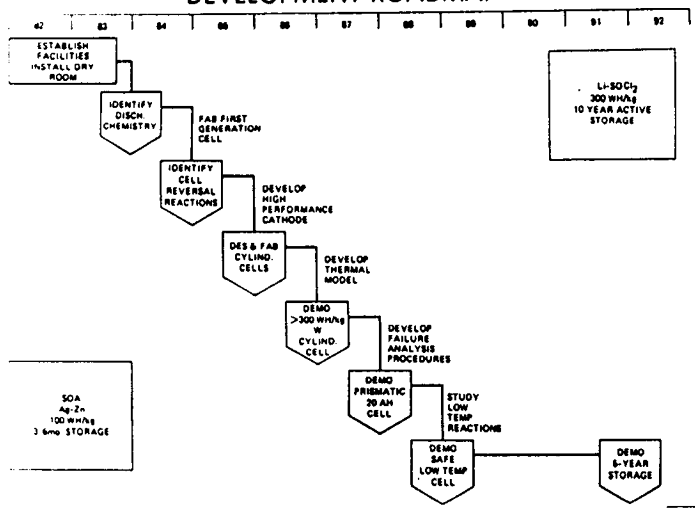

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FIGURE 2

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CENTAUR Li-SOCl$_2$ BATTERY TASK

OBJECTIVE/APPROACH

- O OBJECTIVE
  - O DEVELOP PROTOTYPE 150AH AND 250AH Li-SOCl$_2$ BATTERIES FOR CENTAUR WITH DOCUMENTATION WITHIN 3 YEARS
  - O A PRINT PACKAGE READY TO FABRICATE
  - O MUST BE SAFE
  - O WEIGHT GOAL IS 50% OF EXISTING ZN-AGO BATTERY WEIGHT
- O APPROACH
  - O CO-ORDINATED JPL-CONTRACTOR EFFORTS
  - O CONTRACTOR DEVELOP HARDWARE UNDER JPL DIRECTION
  - O JPL CONDUCT INDEPENDENT DESIGN AND ANALYSES TO CRITIQUE, SUPPORT, AND ENHANCE CONTRACTOR DESIGN AND R & QA
  - O JPL ALSO CONDUCT VERIFICATION AND SAFETY TESTS ON COMPONENTS AND CELLS
  - O SOME CATHODE DEVELOPMENT AT JPL AND CONTRACTOR CENTAUR Li-SOCl$_2$ BATTERY TASK

FIGURE 3 SCHEMATIC OF CENTAUR

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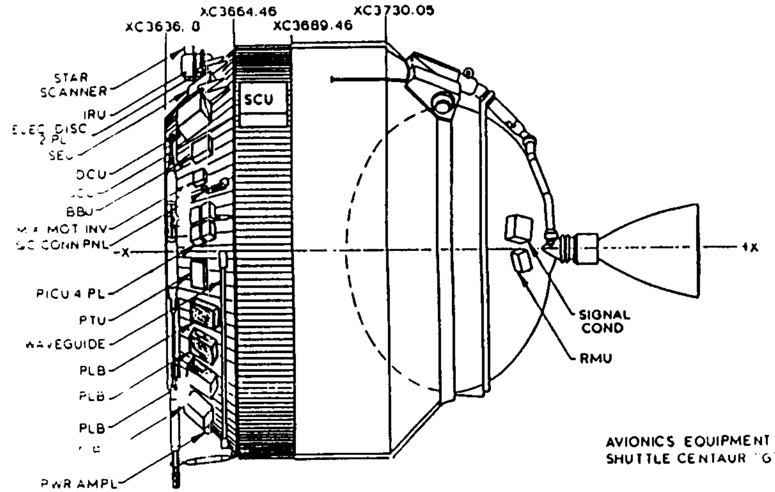

AVIONICS EQUIPMENT SHUTTLE CENTAUR 'G'

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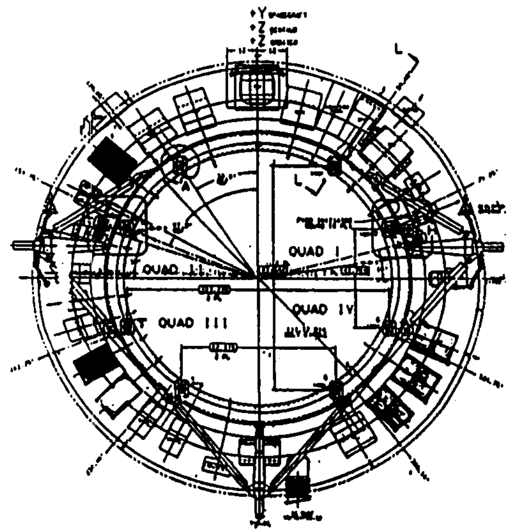
FIGURE 4 CROSS SECTIONAL VIEW OF CENTAUR



CENTAUR 'G', FWD ADAPTER PRELIM EQUIP ARRGMT

FIGURE 5 COMPARISON OF Ag-Zn AND Li-SOCl$_2$ BATTERIES

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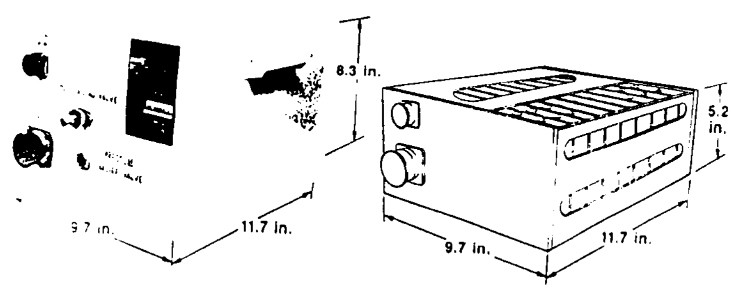
150AH CENTAUR BATTERY



SILVER-ZINC
(STATE-OF-THE-ART)

19 CELLS
28 V NOMINAL (1.5 V/cell)
85 lbs

LITHIUM THIONYL CHLORIDE
(JPL TECHNOLOGY)

9 CELLS
28 V NOMINAL (3.4 V/cell)
< 40 lbs

FIGURE 6 POWER SCENARIO FOR CENTAUR LAUNCH

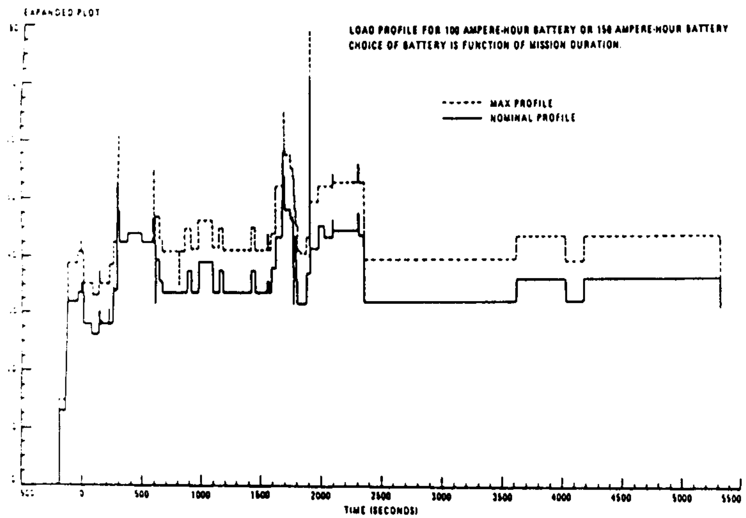


FIGURE 7

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CENTAUR Li-SOCl$_2$ BATTERY TASK BASELINE CATHODE DATA

CURRENT DENSITY (mA/cm^2)

	0.1	1	10	100
CAPACITY (AH/G)	3.1	2.2	1.3	0.5
MID POINT POTENTIAL (VOLTS)	3.50	3.30	3.04	1.50

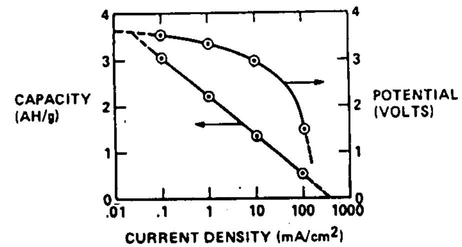

FIGURE 8

DEPENDANCE OF SPECIFIC ENERGY ON CATHODE UTILIZATION

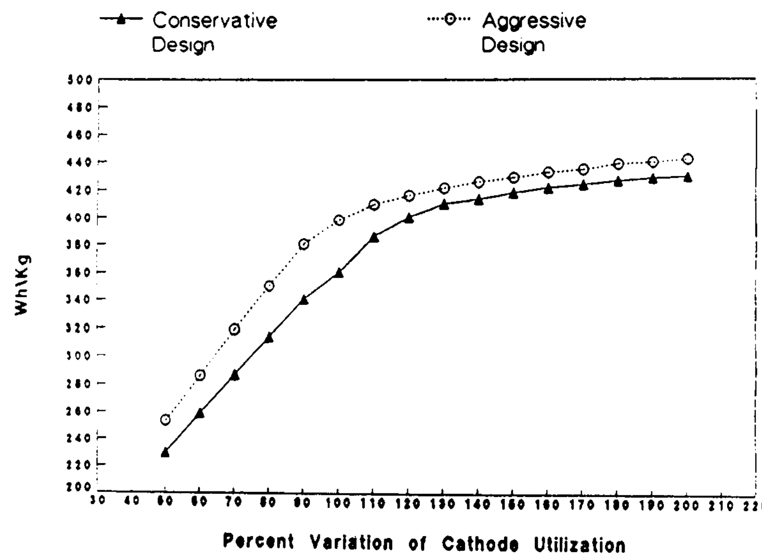

FIGURE 9

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LITHIUM - THIONYL CHLORIDE BATTERIES FOR CENTAUR

OPTIMIZED BATTERY PROJECTION

- CELL WEIGHT .... 1.68 KG (3.69 LBS)
- NO. OF CELLS /BATTERY 9
- WEIGHT FOR 9 CELLS...................... 15.1 KG (33.2 LBS)
- ESTIMATED PACKAGING WEIGHT............... 3 KG (6.6LBS)
- PROJECTED BATTERY WEIGHT................. 18.1 KG (39.8 LBS)
- EXISTING AG-ZN BATTERY WEIGHT............ 38.6 KG (85 LBS)
- PROJECTED WEIGHT REDUCTION............... 53 %

FIGURE 10

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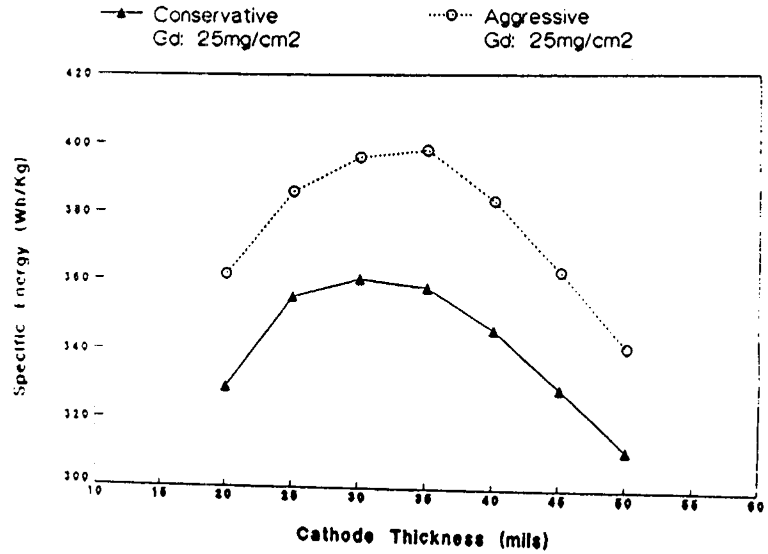
CENTAUR $Li-SOCl_2$ BATTERY TASK
POINT DESIGN FOR A 150 AH CENTAUR CELL
BASED ON JPL 20 AH CELL

ITEM	MATERIAL	L,cm.	W,cm.	t,cm.	#	Wt,gm
Anode	1) Li	11.80	12.00	0.10	29	61.3
	2) Ni, Exp.	11.80	12.00	0.02	29	101.8
	3) Tab			0.02		7.4
Cathode	1) C, 80% Por	11.80	12.00	0.10	30	128.2
	2) Teflon Binder					14.1
	3) Ni, Exp	11.80	12.00	0.02	30	105.0
	4) Tab	,		0.02		7.4
Separator	Glass Mat	11.80	12.50	0.0076		41.2
Electro-lyte	$SOCl_2$					788.2
Case (out-side)	SS,304L	13.80	13.10	5.05*		402.4
Cover	SS,304L					20.0
						1677.0

* Outside Dimension, can wall thickness - 0078 cm

FIGURE 11

DEPENDANCE OF SPECIFIC ENERGY ON CATHODE THICKNESS



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