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DEVELOPMENT OF LITHIUM-THIONYL CHLORIDE BATTERIES FOR CENTAUR

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Summary

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 W h kg^{-1} cell capable of operation at the $C/2$ rate and active storage life for 5 - 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 with its projected specific energy (300 W h kg^{-1}) and lengthy activated storage life (10 years) exceeds the capabilities of the Ag-Zn system (100 W h kg^{-1} and active storage life of 3 - 6 months). It also has a significantly lower projected cost.

Development program

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 saving for the CENTAUR of more than 250 lb (100 kg) for the batteries required to meet CENTAUR mission goals. The result was a 3 year AF/SD contract with JPL to develop Li-$SOCl_2$ 150 A h cells and batteries for this application. The effort was to be cooperative between JPL and cell/battery manufacturers 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,

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crew escape vehicle, or orbit transfer vehicle and IUS. Most importantly for JPL are applications 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 Fig. 1. Although some work was done prior, the serious cell design activities started in the early 80s. The result, as can be seen, is the demonstration of cylindrical and prismatic cell designs, resulting in the demonstration of a 330 W h kg^{-1} "D" size cell operated at the 5 A ($C/2$) discharge rate. A prismatic 20 A h cell assembled and tested, achieved 280 W h kg^{-1} at the $C/4$ rate, narrowly missing the design goals.

The objectives of the AF/SD effort are given in Table 1. The program involves a coordinated contractor/JPL effort to product prototype 150 A h cells and battery hardware and a design package described as a Manufacturing Control Document (MCD) available for procurement. The in-house work at JPL would emphasize analysis, cathode enhancement, and quality.

There are 6 - 8 batteries necessary for the CENTAUR power requirements: the present Ag–Zn battery weighs 85 lb *versus* 40 lb for the projected $Li-SOCl_2$ battery. A weight saving of more than 50% is therefore indicated. The volume saving is also substantial. The $Li-SOCl_2$ battery will have to occupy the same footprint and therefore will be lower in height. There is a difference in the number of cells, 9 *versus* 19, because of the cell voltage of 3.4 V/cell compared with silver–zinc of 1.5 V/cell.

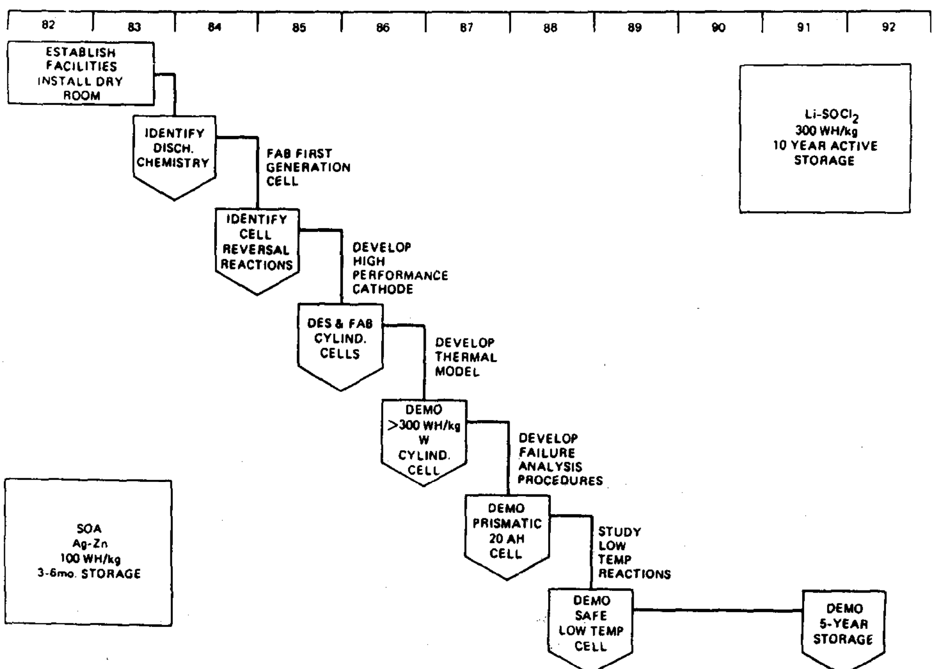

Fig. 1. Primary $Li-SOCl_2$ cell development roadmap.

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TABLE 1

CENTAUR Li–$SOCl_2$ battery task objective/approach

Objective	
o	Develop prototype 150 A h and 250 A h 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
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 2 includes a power usage scenario projected for the mission. The 80 A pulse at a 40 A average required for the battery is consistent with the 150 A h requirements.

One of the areas of interest is the cathode structure. JPL Li–$SOCl_2$ "D" cells, employing in-house developed state-of-the-art cathodes, have, on a normalized basis, exceeded the required performance at high rates of dis-

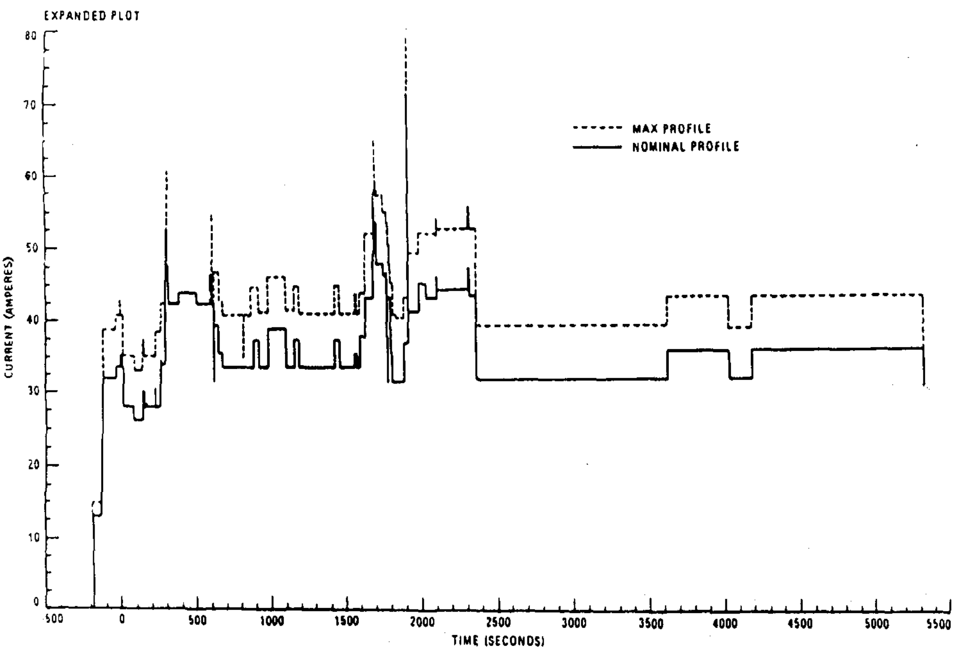

Fig. 2. Power scenario for CENTAUR launch. Load profile for 100 A h battery or 150 A h battery (choice of battery is function of mission duration).

charge. The basis of this is the high performance cathode. The baseline cathode data are given in Fig. 3. The range of current densities required in this application is 1 - 5 mA cm^{-2}. This indicates that 1.5 A h g^{-1} utilization of the cathode is required. There is a need to assure that the polarization be minimized in order to reduce heat dissipation problems. The projected voltage of 3.3 ± 1 V is quite satisfactory. Additional improvements in cathode design could result in a specific energy of 400 W h kg^{-1} at the 100% utilization level shown in Fig. 4.

CURRENT DENSITY

	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

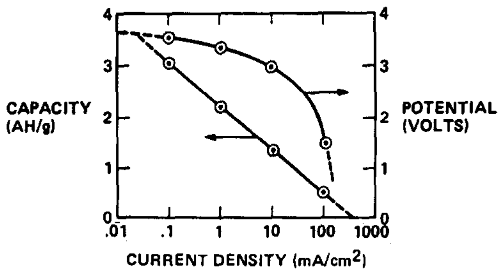

Fig. 3. CENTAUR Li–$SOCl_2$ battery task. Baseline cathode data.

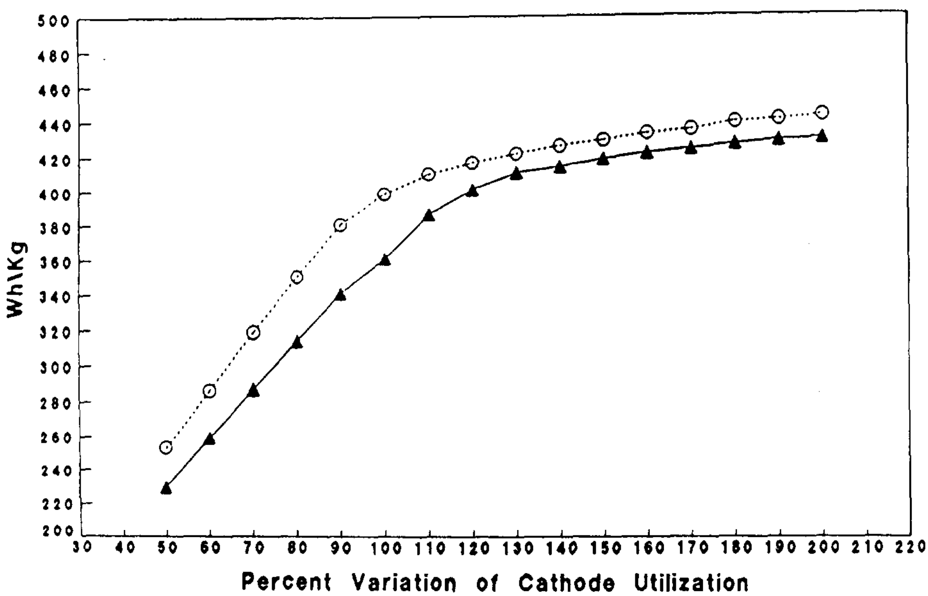

Fig. 4. Dependence of specific energy on cathode utilization. —▲—, Conservative design; ···○···, aggressive design.

Modeling studies have been carried out to determine the effect of electrode thickness on mass energy density. Results show that mass energy density passes through a maximum thickness near 30 mils. The relationship is dependent on grid design which was assumed constant in these initial studies.

Table 2 gives a point design for a 150 A h cell based on a JPL 20 A h cell. Projected overall mass for this cell is 1667 g. Table 3 gives a projection for an optimized battery utilizing 9 of these cells. The resultant design including a 1.2 factor for battery mass indicates a 53% weight saving.

In summary, the task initiated in October 1987 is a coordinated contractor/JPL effort to develop 150 A h cells and batteries to reduce the

TABLE 2

CENTAUR Li–$SOCl_2$ battery task
Point design for a 150 A h CENTAUR cell based on JPL 20 A h cell.

Item	Material	Length (cm)	Width (cm)	Thickness (cm)	#	Weight (g)
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
Electrolyte	$SOCl_2$					788.2
Case (outside)	SS, 304L	13.80	13.10	5.05*		402.4
Cover	SS, 304L					20.0
						1677.0

*Outside dimension; can wall thickness = 0.078 cm.

TABLE 3

Lithium–thionyl chloride batteries for CENTAUR
Optimized battery projection.

Cell weight	1.68 kg (3.69 lb)
No. of cells/battery	9
Weight for 9 cells	15.1 kg (33.2 lb)
Estimated packaging weight	3 kg (6.6 lb)
Projected battery weight	18.1 kg (39.8 lb)
Existing Ag–Zn battery weight	38.6 kg (85 lb)
Projected weight reduction	53%

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. Specific energies in the order of 300 W h kg^{-1} are expected for the flight hardware.

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