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EXAMINATION OF DESIGN OPTIONS FOR 35 Ah AMBIENT TEMPERATURE Li-TiS_2 CELLS

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The Jet Propulsion Laboratory is actively engaged in the development of ambient temperature rechargeable lithium cells for future NASA GEO missions. The Program goals are given in the Figure 1.

To achieve these ambitious goals, we have examined Li-TiS_2, Li-MoS_3 and Li-V_6O_{13} systems in detail. Among these three, the Li-TiS_2 system has shown the longest life cycle and highest rate capability. Experimental Li-TiS_2 batteries (10.5V, 0.4Ah) developed in-house have completed eight simulated and accelerated GEO seasons successfully. Evaluation of these batteries is being carried out at Rockwell International, and some of these results were reported by B. Otzinger in the 1984 Battery Workshop at GSFC. In view of these encouraging results, we have examined the design options for a scaled-up Li-TiS_2 cell. It is hoped that the results of these studies will provide guidelines for prioritizing the research efforts and guiding the selection of optimized materials. In our present study, we have examined designs for 35 Ah Li-TiS_2 cells because present day GEO synchronous satellites are powered by batteries of 35 Ah capacity. We have developed a computer program to evaluate the influence of various design parameters on the specific energy and the rate capability of the cells.

Figure 2 summarizes the important design parameters that have been considered in the present study. Some of the issues that have not been considered are thermal design parameters, utilization of the lithium electrode, and the degradation of the electrolyte. We have also restricted ourselves to the prismatic cell configuration.

The program details are summarized in Figure 3. To date, no engineering database exists in the literature for the utilization of TiS_2 cathodes of different thicknesses and porosities at various current densities. We have created a database for the execution of the program, based on the limited published, and in-house, experimental results. Since the cells are required to operate at the C/2 rate, we considered cathodes in the thickness range of 20 to 40 mil. An anode to cathode capacity ratio of 6:1 has been used in the present studies, as excess of lithium has minimum influence on cell energy density. The various materials that have been considered for the cell case and cover are stainless steel (SS), titanium (Ti), carbon composite (C) and polypropylyne (PP). A thickness of 30 mil is considered for stainless steel, titanium, and carbon composite and 120 mil is considered for polypropylyne.

Figure 4 shows the dependence of specific energy on the cathode thickness. Cathodes of 25 mil thickness provide highest energy density for cells that are required to operate at C/2 rate. All further analysis is based on cathodes of 25 mil thickness.

Figure 5 gives the number of cathodes required for different R ratios (R represents the height to width ratio of the electrode). As can be seen, the number of cathodes required increases with decreasing plate width and R ratio. Current distribution, heat management and ease of fabrication are key issues in selecting the plate width, height-to-width ratio, and the plate number. One needs to make a judicious choice of these parameters, keeping in view the performance requirements and fabrication limitations. For our further analysis, we have chosen a cathode width of 12 cm and height-to-width ratio of 1.5.

Figure 6 gives the specific energies that can be achieved, with different can and grid materials. Aluminum grids are also considered for cathodes current collectors. They are not considered for anodes because of the reactivity of Al with Li. Ti/Al, C/Al, and PP/Al materials all look promising in terms of energy density. While Ti cans are lighter than S.S, they are more expensive. Also, C cases are strong and lightweight, but their chemical and electrochemical stability with the active components needs to be determined. Polypropylene cans are cheap, but in view of their poor mechanical properties, thicknesses of greater than 100 mil are needed for cell cans. In view of their poor thermal characteristics, it may not be the material of choice for space applications.

The details of the cell weight budget (cells with stainless steel can) are given in Figure 7. The can contributes the dominant fraction to the weight budget. Among the active materials, the contribution of the anode active material is the lowest. Grid contribution is more than lithium itself (with respect to weight).

In summary, a specific energy of 80 to 100 Wh/kg at C/2 for 35 Ah Li-TiS_2 cells is feasible. This calls for the use of advanced hardware materials. Cathode widths greater than 10 cm width at 25 mil thickness are needed for 35 Ah cells operating at C/2. Development of an engineering database for the utilization of lithium and TiS_2 electrodes is needed to verify, and make further improvements in cell design. Other cell configurations and active materials will be considered in the future.

ACKNOWLEDGEMENTS

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- DEMONSTRATE FEASIBILITY OF AMBIENT TEMPERATURE SECONDARY LITHIUM CELLS FOR GEO APPLICATIONS BY FY'89
- TARGETS
  - $\geq$ 100 WH/KG
  - 10 YEAR LIFE
  - 1000 CYCLES
  - SAFE

Figure 1. NASA SECONDARY LITHIUM BATTERY PROGRAM GOAL

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CATHODE	ANODE	ELECTROLYTE	SEPARATOR	GRID	CAN
• CURRENT DENSITY	• NEGATIVE TO POSITIVE RATIO	• COMPOSITION	• MATERIAL	• MATERIAL	• MATERIAL
• THICKNESS	• NUMBER	• DENSITY	• POROSITY	• TYPE	• THICKNESS
• WIDTH	• Li FOIL THICKNESS	• QUANTITY	• INTER-ELECTRODE SPACING		• SEAL
• HEIGHT TO WIDTH RATIO			• THICKNESS		• OVERHEAD SPACE
• NUMBER			• WEIGHT		
• POROSITY					
• WEIGHT					
• CAPACITY					

Figure 2. DESIGN PARAMETERS

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INPUTS

- CAPACITY
- OVER RATING
- DISCHARGE CURRENT

CONSTANTS/VARIBLES

- ANODE TO CATHODE CAPACITY RATIO: 6 TO 1
- NO. OF ANODE = NO. OF CATHODE + 1
- PLATE WIDTH: 7 TO 14 CM
- HEIGHT TO WIDTH RATIO: 0.8 TO 2
- CATHODE THICKNESS: 20 TO 40 MIL
- GRID MATERIAL: NI, AL
- CASE MATERIAL: S.S. TI, C, PP
- SEAL: CERAMIC/ZIGLER

DATA BASE

CURRENT DENSITY (mA/cm^2)	UTILIZATION*
1	0.85
2	0.85
3	0.76
4	0.53

*FOR 25 MIL CATHODE THICKNESS

OUTPUT

- DESIGN CAPACITY
- ENERGY DENSITY
- CATHODE NO. AND DIMENSION
- ANODE NO. AND DIMENSION
- GRID DETAILS
- ELECTROLYTE QUANTITY
- SEPARATOR DETAILS
- CAN DIMENSIONS
- COMPONENTS WEIGHT BUDGET

Figure 3. PROGRAM DETAILS

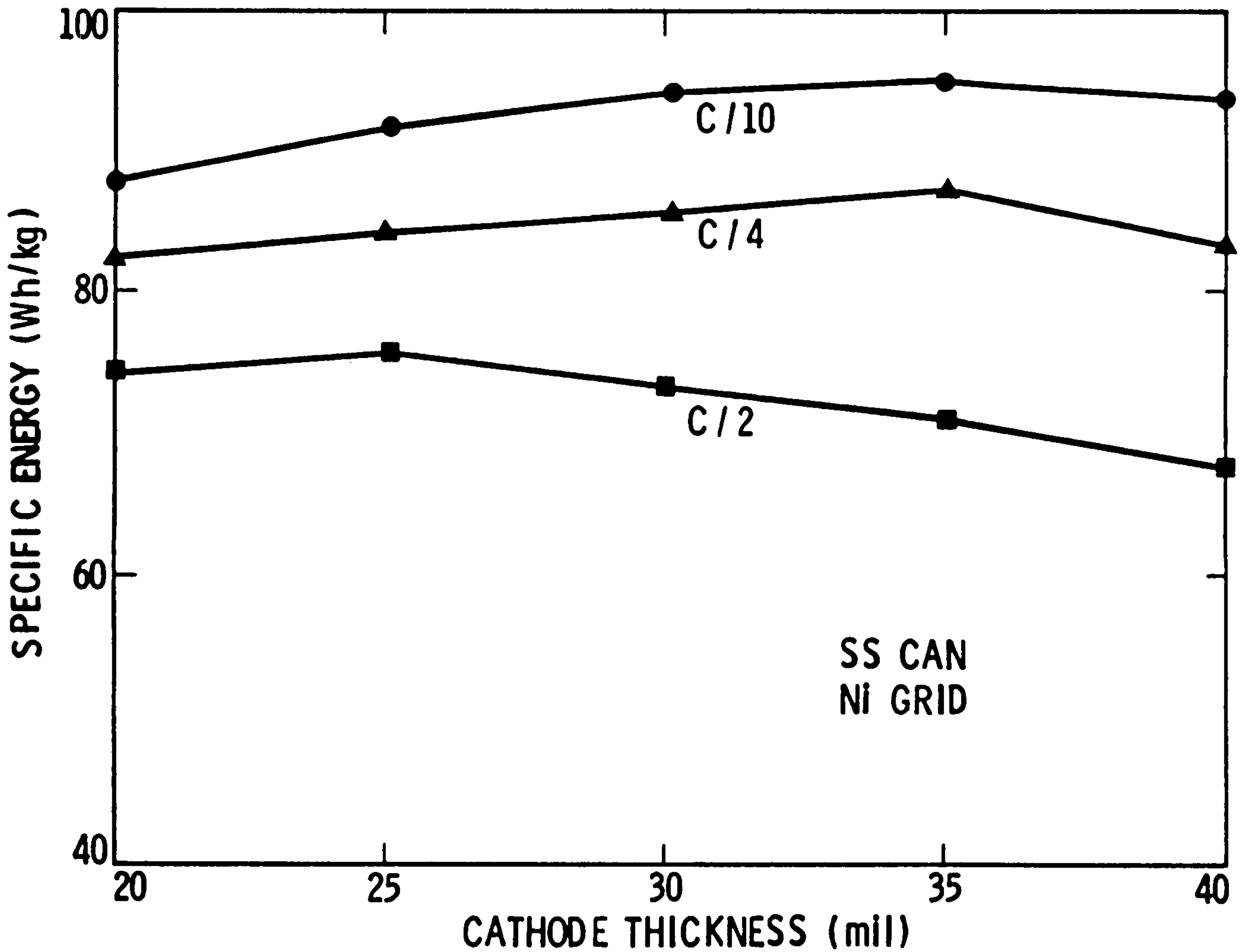

Figure 4. DEPENDENCE OF SPECIFIC ENERGY ON CATHODE THICKNESS OF A Li-TiS_2 CELL FOR VARIOUS DISCHARGE RATES

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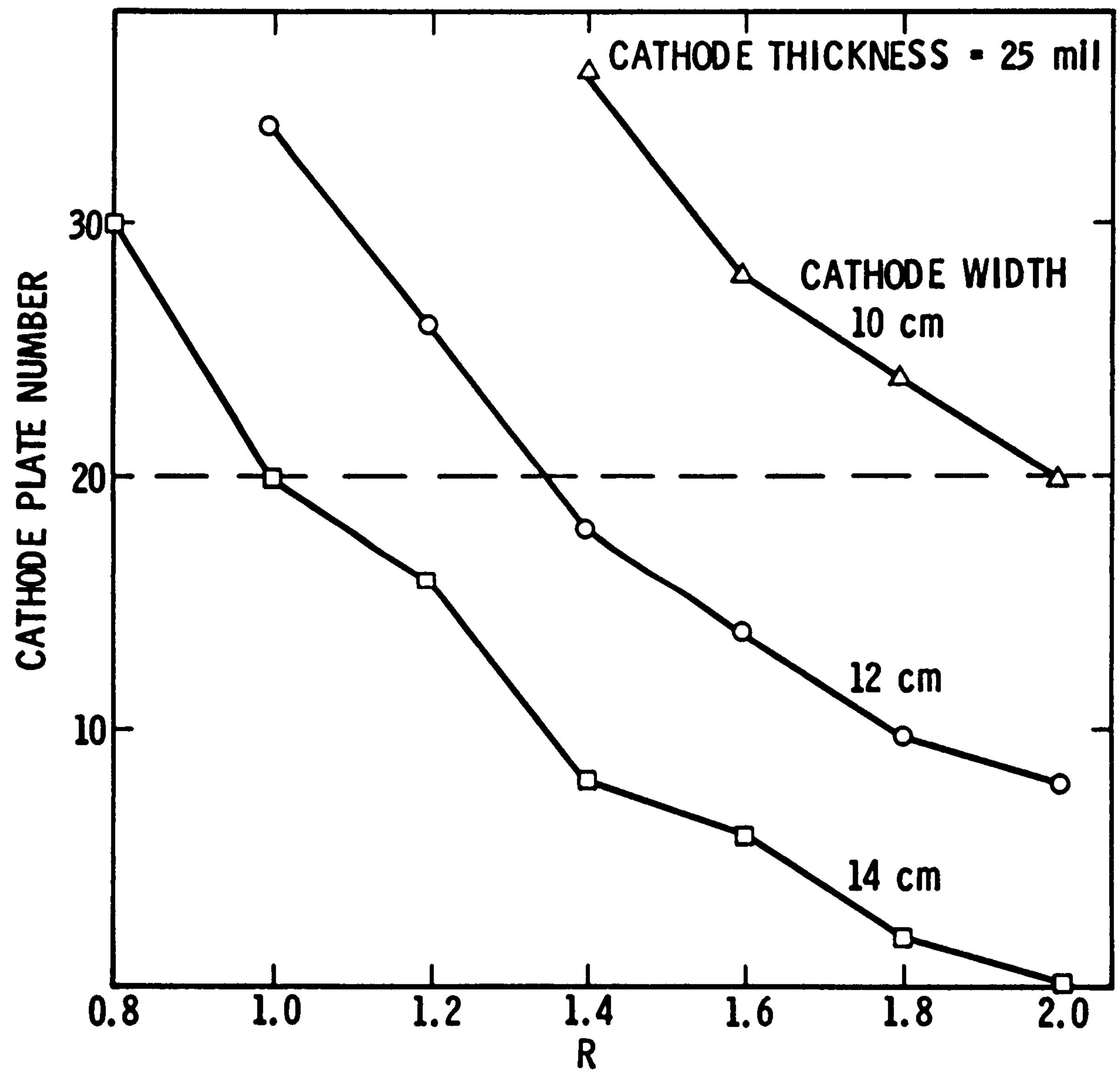

Figure 5. DEPENDENCE OF CATHODE PLATE NUMBER ON CATHODE HEIGHT TO WIDTH RATIO, R

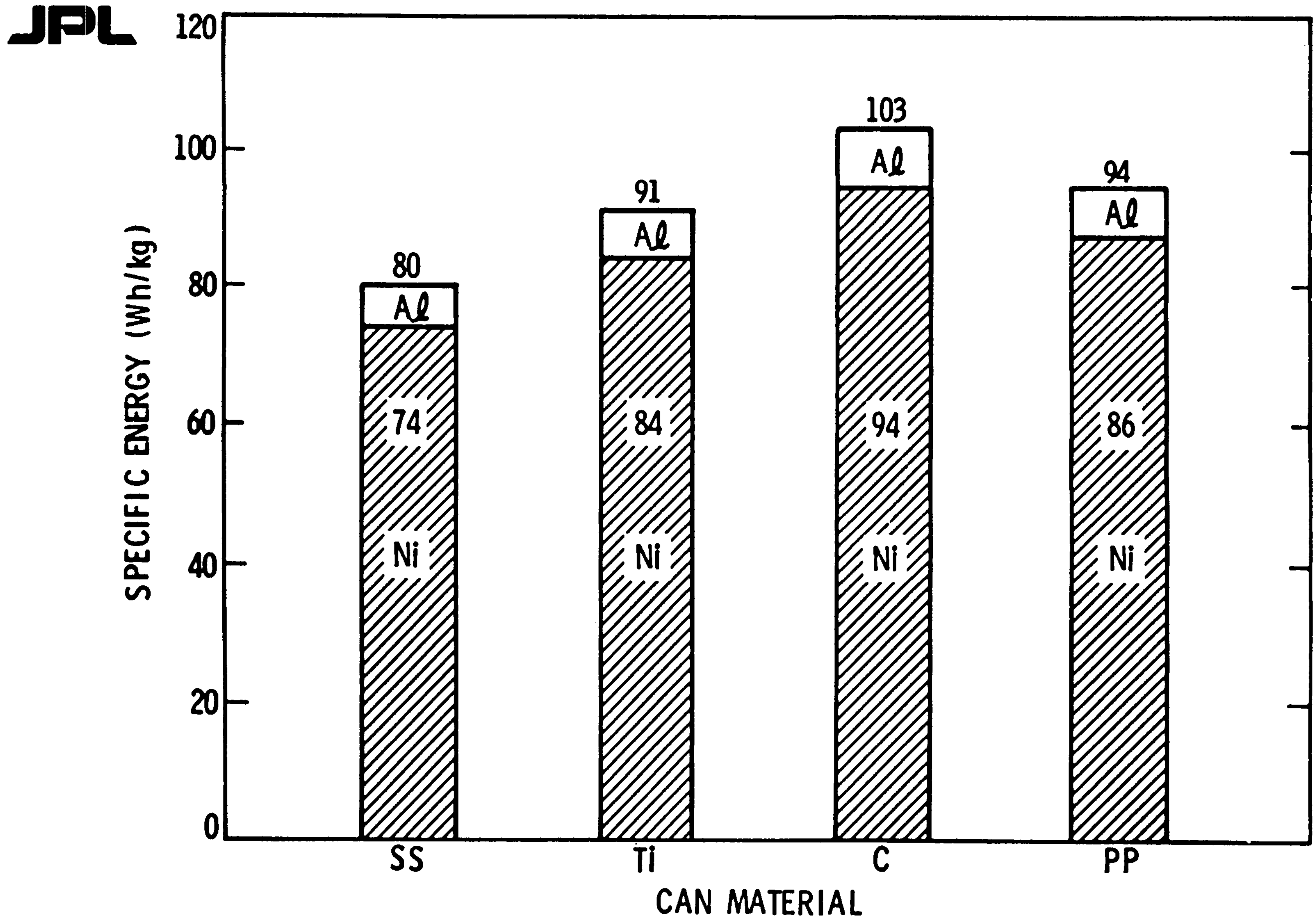

Figure 6. DEPENDENCE OF SPECIFIC ENERGY ON HARDWARE MATERIALS FOR A 35 Ah Li-TiS_2 CELL

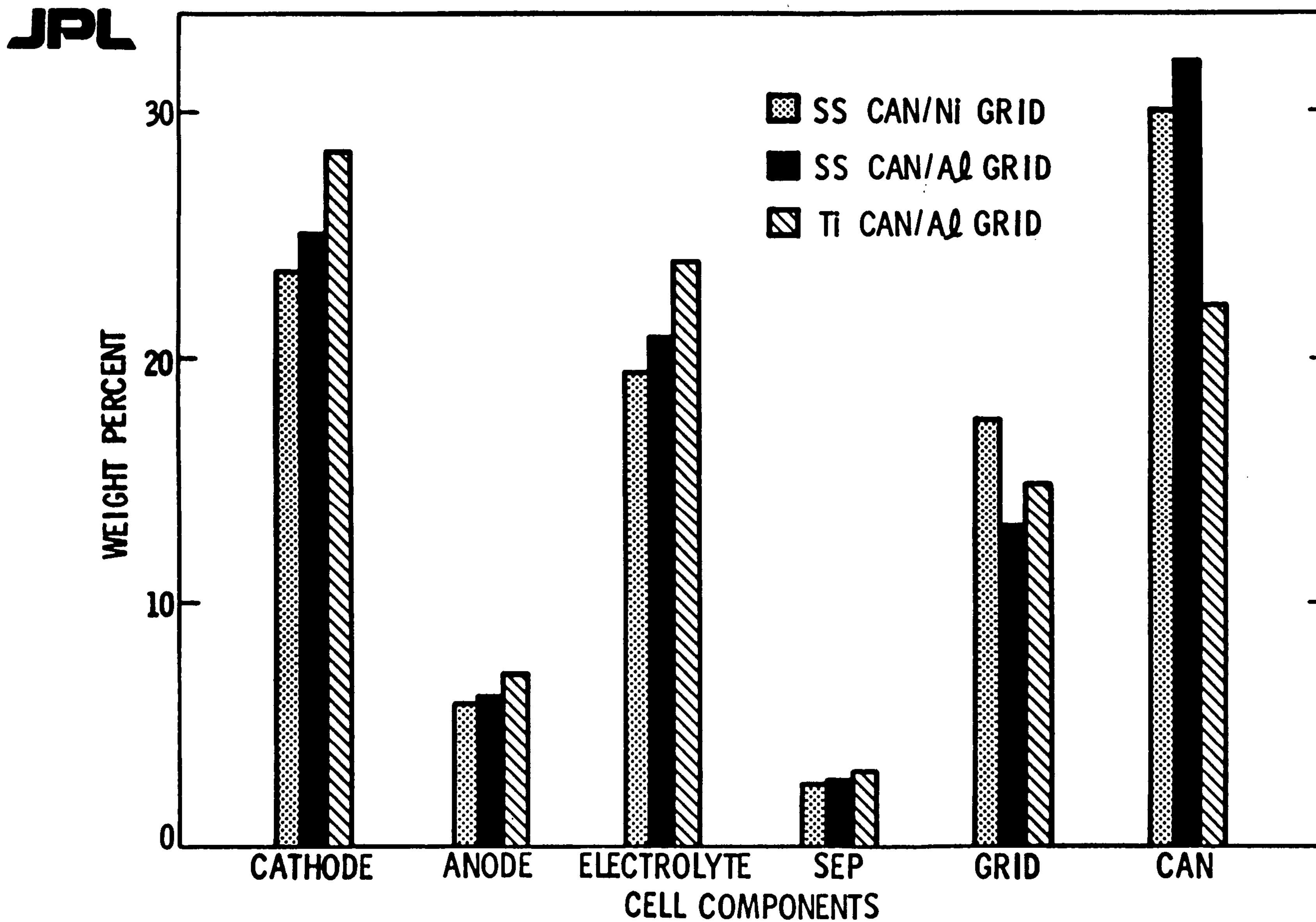

Figure 7. Li-TiS_2 CELL WEIGHT BUDGET