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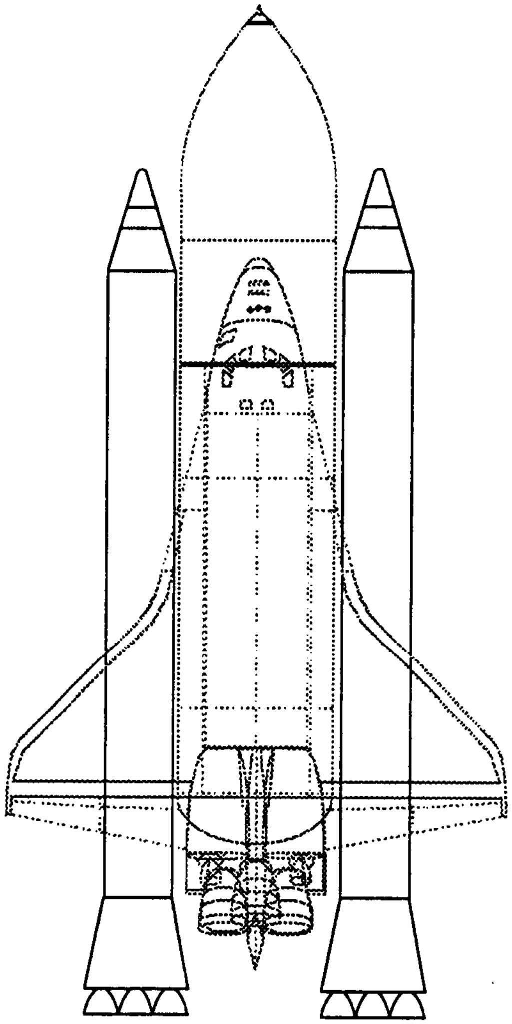
March 1989

Appendix C
Battery Report
for the Liquid
Rocket Booster
TVC Actuators

Liquid Rocket Booster (LRB) for the Space Transportation System (STS) Systems Study



(NASA-CR-183789-App-C) LIQUID ROCKET N90-28603
BOOSTER (LRB) FOR THE SPACE TRANSPORTATION
SYSTEM (STS) SYSTEMS STUDY. APPENDIX C:
BATTERY REPORT FOR THE LIQUID ROCKET BOOSTER Unclas
TVC ACTUATORS (Martin Marietta Corp.) 7 p G3/20 0251594

MARTIN MARIETTA
MANNED SPACE SYSTEMS

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TO: MCSHEEHY
FROM: CHRISTOFFERSON
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Report: Battery Power for LRB Actuators

As suggested by McSheehy, a meeting was held April 15 with T.J. Graves, B.J. Bragg, W. Hoffman, and E.C. Darcy, battery and power specialists at the JSC Engineering directorate. Purpose of the meeting was to discuss LRB battery power, needs and operations, since the LRB is to have "all electric" power.

Overview

The actuators for control of engine valves and gimbals for a booster require 165 KW or more peak power at 270 VDC during the 2 or 3 minutes of first stage ascent; other booster devices require much less power at 28 VDC. It is desired that a booster supply its own electrical power and satisfy rundundancy requirements of the ~~SRB~~ Shuttle, when applicable. The power of an LRB is therefore provided by two subsystems: Actuator Battery Power (270 VDC) Subsystem for the engine actuators, and Electrical Power & Distribution (28 VDC) Subsystem, to power everything else. Boosters will receive no electrical power from Orbiter, only commands and data - according to current plans.

Discussion

People in this discussion have provided battery and actuation power to spacecraft dating from Apollo.
The meeting began with a very brief description of solid burning auxilliary power units (APUs) which could be applied to LRBs should we decide to use hydraulics for actuation.

LRB battery needs were soon addressed: how to layout a redundant battery system, and how to specify the size and quick-dumping batteries needed; types of primary batteries, their construction, how they are activated and serviced for a mission, and their problems. This is the specialty of Mr. Bragg, who provided the following useful information:

- 270 volts are needed because semiconductor electronics (needed for switching power) work well at that voltage.
- Types of batteries considered are:

  - (Heavy) Silver Zinc Primaries, 30 volts each
  - (Newer Lighter) Silver Zinc Primaries
  - Lithium Thionyl Chloride Primaries
  - Nickel Cadmium Secondaries (i.e. rechargeables).
  - Thermal batteries

- A good way to get 270 VDC would be to put nine 30 volt batteries in series.

- The heavy silver-zinc primary batteries which have been much used in spacecraft can be designed to dump about 1 Ampere Hour (AH) of energy in 2 or 3 minutes.

  How much energy is needed for a booster's actuators? According to J.T. Edge's estimate based on four SSMEs per booster, about 37 kilowatt average (or 165 KW peak) power is needed. Since peak power is used only a small percentage of the time, the average power is used knowing peak power can be drawn if the peak time is a small percentage of the time.

$$\begin{matrix}\text{Battery}\\\text{Energy}\\\text{Needed}\end{matrix} = \begin{pmatrix}\text{Power}\\\text{Needed}\end{pmatrix}\begin{pmatrix}\text{time}\\\text{Needed}\end{pmatrix} = (37\text{KW})(3\ \text{min})\left(\frac{\text{hr}}{60\text{min}}\right) = 1850\ \text{WH}$$

$$\begin{matrix}\text{Battery}\\\text{Capacity}\end{matrix} = \text{ampere hours} = \left(\frac{P\ \text{watts}}{E\ \text{volts}}\right)(\text{hrs}) = \begin{matrix}\text{Battery}\\\text{energy}\end{matrix} \Big/ \begin{matrix}\text{volts}\\\text{desired}\end{matrix}$$

$$= \frac{1850\ \text{watt hrs}}{270\ \text{volts}} = 6.85\ \text{amp hrs}\ .$$

--> Seven of the 9-series-battery strings would provide the battery energy capacity needed by a 4-engine LRB having an average power demand of 37 KW. Two additional strings would provide a 2 failure redundancy.

Mr. Bragg said that no transformers or converters would be needed to provide the required voltage and quick energy release, but the batteries would need to be designed for this.

Switching power to individual actuators is done by solid state switches which are commanded by computer.

- All the battery cells are constructed of two plates in an electrolyte. The area of the plates determines the ampere-hour capacity of the cell; plate separation determines the rate it can deliver its energy. All of the batteries under consideration have to be activated prior to use by addition of electrolyte to the cells.

The batteries then have a wet-life time during which they should be used, depending on type and construction from minutes to months. For example, the cells of a heavy silver-zinc primary are filled with potassium hydroxide solution and they then have a 36-day wet-life during which they should be used. The newer lighter silver-zinc batteries have a 2 to 4 month wet-life. The wet-life of lithium-thionyl-chloride batteries is a few days to a week, depending on their design.

Each battery is typically a plastic rectangular box about six inches in size, with perhaps a dozen cells which must be opened, filled with electrolyte and stoppered before being placed in a spacecraft prior to launch. The batteries can have a membrane holding their electrolyte, and by igniting a small charge (squib) the membrane is punctured filling the cells with electrolyte and activating the battery wet-life. The charge activation device is a part of the battery, adds to its size and cost.

The heavy silver-zinc batteries, without the charge activation device, provide about 8 WH/lb. The light silver-zincs provide about 25 WH/lb, and lithium thionyls (still under development) provide perhaps 75 WH/lb.

"Bipolar" lithium-thionyl-chloride batteries means the cells are connected within the battery to give the desired high voltage, etc.

- The candidate batteries can now be listed with their properties:

* Heavy silver-zinc primary,	30 volts each 1 AH battery capacity 36 day wet-life (KOH electrolyte) 8 WH/lb reliable, used in spacecraft
* Light silver-zinc primary,	30 volts each 1 AH battery capacity ~2-4 months wet-life 25 WH/lb reliable
* Lithium-thionyl-chloride primary,	___ ___ days-week wet-life ~75 WH/lb lighter than silver-zinc

	still under development Bipolars used in torpedos
* Nickel-cadmium secondary,	rechargeable heavier than silver-zincs slower to discharge not recommemded for quick discharging
* Thermal battery (primary)	minute(s) wet-life rapid discharge but becomes very hot (400 degr. or more) used in missiles where they are activated by a small charge.

- Battery Manufacturers (see attached separate page)

- For LRB design, it was recommended that the reliable heavy silver-zinc primary batteries be used, with or without charge activation. They have a good wet-life (36 days) and will weigh about 300 lbs (at 8 WH/lb) per LRB.

  As development proceeds, battery choice could switch to the light silver-zincs to save weight. In fact, they would be the author's choice.

  Lithium-thionyl-chloride batteries, still under development, have good wet-life: days to week. When properly developed they may replace silver-zincs as a first choice.

  Nickel-cadmiums (rechargeables) are heavy and slow to discharge and not recommended for LRBs.

  Thermal batteries, not much information on them. Wet-life time is thought to be very small: minute(s). They are charge activated and get very hot. More information is needed to judge them.

- Problems. Costs for the batteries, are not available at at this time, but the silver-zincs and nickel-cadmiums have been used for along time and should be easily priced. The cells can generate explosive or poisonous gases if misused. They can explode. But silver-zincs were used to power lunar spacecraft.

Conclusion

Follow the recommendations of Mr. Bragg for powering an LRB's actuators: use 9 "nine-30volt-silver-zinc-batteries-in-series" to provide the 270 volt, 37 KW average (165 KW peak). The batteries are to be designed to provide about 1 AH, with 7 strings necessary plus 2 spare strings to provide 2 failure redundancy. That's 9 string total. Batteries are to be designed to release this energy within 3 minutes. 9 strings (2379 WH) at 8 WH/lb will weigh 297 lbs including charge activators.

Battery manufacturers can be contacted to estimate the additional weight and cost required to provide batteries with charge activators, and to determine the pros and cons of using charge activators. A decision should then be made as to whether a booster's batteries should be charge activated with electrolyte, or whether a crew will use pipettes to do the job prior to launch.

Information for the light silver-zinc batteries, the lithium-thionyl and the thermal batteries should be gathered for phase B design. The above design can then be updated by newer, lighter, better batteries, if applicable.

Appendix Attachment

BATTERY MANUFACTURERS

(from Mr. Bragg/JSC)

- Inland Electric Co.

  ___

  ? Virginia
  ph. ___

  Manufactured heavy silver-zinc primary batteries used by NASA (they may no longer be in business)

- Eagle Picher Industries, Inc.
  Drawer 130, Bethel Road
  Seneca, Missouri 64865
  ph. (417) 776-2256
  TWX: 62864271
  FAX: (417)776-2257

  Manufacturer of silver-zinc & other batteries

- Whittaker-Yardney Power Systems
  Div.Whittaker Techn.Prods.Inc.
  82T Mechanic St.
  Pawca~~a~~tuck, Conn. 02891
  ph. (203) 599-1100 Ext.330
  TWX: 710-470-0260
  TLX: 6813114 YARDNY

  ditto

- Altus Corporation
  1610 Crane Court
  San Jose, CA 95112-4291
  ph. (407) 436-1300
  TLX: 287580 ALTUS UR
  FAX: (408) 436-0494

  developer & manufacturer of "bipolar" lithium-thionyl-chloride batteries for use in torpedoes.

(from Mr. Gary Hudson, private contractor)

- Inland Electric
  (same as above)

  built dual redundant elevon actuator (weighing 400 lbs) and its batteries. Call them about thermal batteries.

- Catalyst Research
  Div. Mine Safety
  Appliances Co.
  Clarkview & Catalyst Roads
  Baltimore, Maryland 21209-9987
  ph. (301) 296-7000
  TLX: 898095 CATALYST

  Call them about thermal batteries

- Eagle Picher
  (same as above)

  Call them about thermal batteries.