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BATTERIES FOR ENERGY STORAGE IN PHOTOVOLTAIC SYSTEMS

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ANNUAL PHOTOVOLTAIC PROGRAM REVIEW OF
TECHNOLOGY AND MARKET DEVELOPMENT
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ABSTRACT

Sandia has developed and used an optimizing computer simulation code, SOLSTOR, to analyze grid-connected residential photovoltaic systems. Resul indicate that it is economically attractive to have battery storage in the systems for certain conditions. Battery requirements have been defined. A battery testing program and a research and development program have been initiated. Some promising new storage battery systems include Redox and Zinc-Bromine flow systems.

BATTERIES FOR SPECIFIC SOLAR APPLICATIONS

PROGRAM GOALS

INITIAL GOAL:

DEVELOP REQUIRED STORAGE BATTERY TECHNOLOGY IN SUPPORT OF THE DOE PHOTOVOLTAICS MISSION.

SECONDARY GOAL:

DEVELOP STORAGE BATTERY TECHNOLOGY IN SUPPORT OF OTHER DOE SOLAR ENERGY PROGRAMS, INCLUDING WIND AND SOLAR THERMAL.

BATTERIES FOR SPECIFIC SOLAR APPLICATIONS

BATTERY REQUIREMENTS ANALYSIS - TASK I

TESTING

- LABORATORY - TASK II
- PV FACILITY - TASK III
- APPLICATIONS EXPERIMENTS - TASK IV

RESEARCH AND DEVELOPMENT - TASK V

BATTERY REQUIREMENTS ANALYSIS

GOALS:

- ANALYZE DESIRABILITY OF BATTERIES IN SOLAR SYSTEMS
- DETERMINE BATTERY REQUIREMENTS

SYSTEMS ANALYSIS TASK

- Computer Simulation Model "SOLSTOR" is the Prime Tool
- Hour-by-Hour Simulation Over a Year
- Sizes Each System Component to Provide Lowest Overall Cost of Electricity
- Accommodates Sell-Back to the Utility and Time-of-Day (TOD) Rates

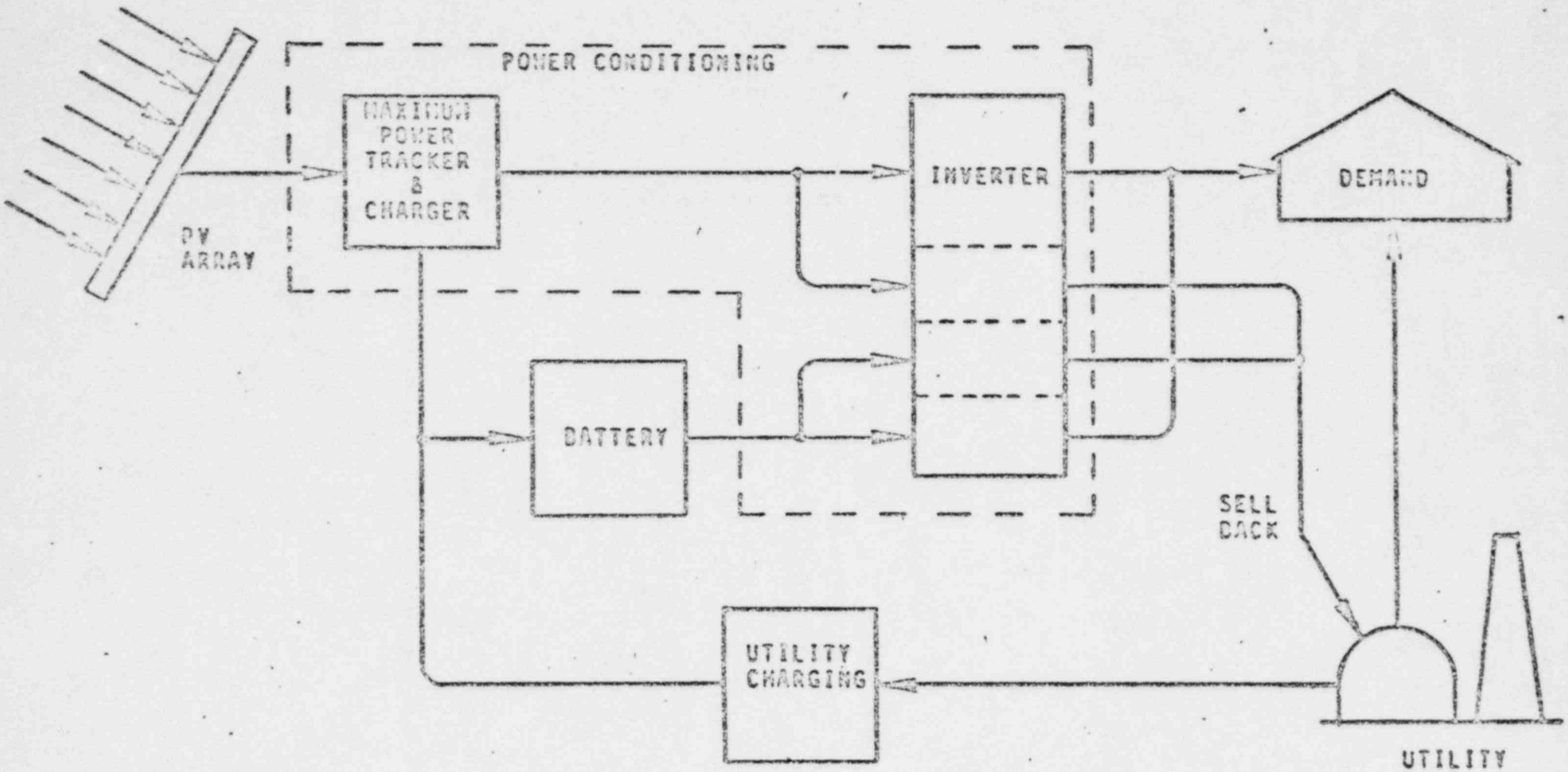
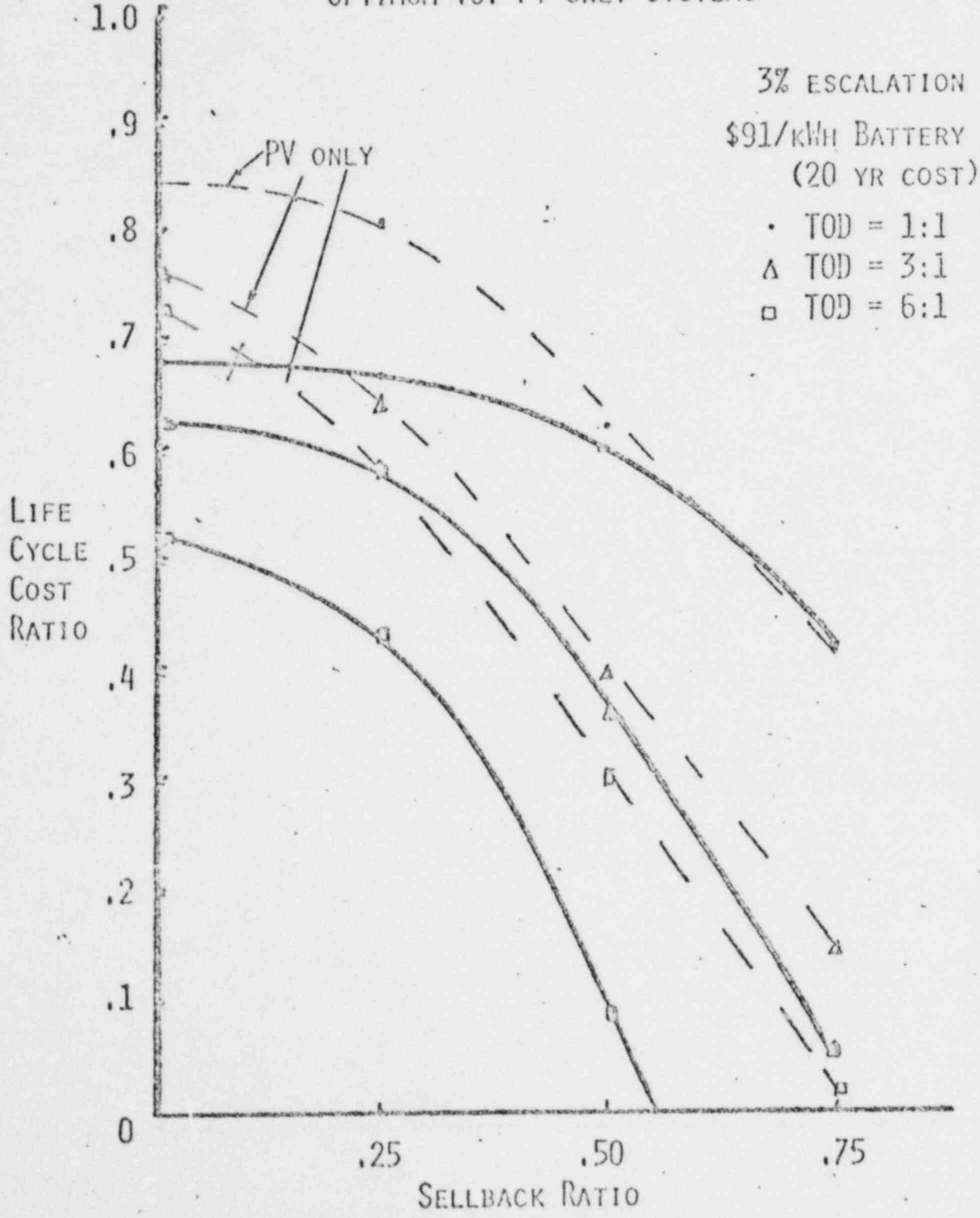


Figure 1. SOLSTOR Model

NEW YORK CITY
OPTIMUM VS. PV-ONLY SYSTEMS



CONCLUSIONS

- Batteries Feasible at a 20 Yr Cost of $100-$150/kWh <u>And</u>
  - Sellback Is Less Than 50%

    <u>OR</u>

  - TOD Ratios Are Greater Than 3:1
- Batteries Can Save Oil Burned During Peak Hours
- Battery Usage Profiles Vary Considerably with Utility Rate Structure

DEEP DISCHARGE PHOTOVOLTAIC BATTERY REQUIREMENTS

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SYSTEM VOLTAGE	160 TO 240 VOLTS; NOMINAL 200 VOLTS
BATTERY VOLTAGE	6 TO 12 VOLTS
CAPACITY	15 TO 50 kWh; NOMINAL 25 kWh
RATE IN SERVICE	1 h RATE MAXIMUM; 6 h RATE NOMINAL
DUTY CYCLE — DAILY	DISCHARGE TO 80% OF RATED CAPACITY
LIFE	5 YEAR MINIMUM; 20 YEAR NOMINAL
ENERGY EFFICIENCY	80% MINIMUM (ROUNDTRIP)
SELF DISCHARGE	1% PER WEEK MAXIMUM
TEMPERATURE RANGE	0 TO + 50 C
MAINTENANCE	MINIMUM ROUTINE MAINTENANCE DESIRED AUTOMATIC MAINTENANCE SYSTEMS DESIRED
COST GOAL	$100/kWh FOR 7000 CYCLES NOMINAL $50/kWh FOR 7000 CYCLES GOAL

NOTES:

(1) MUST BE ACCEPTABLE FROM BUILDING CODE STANDPOINT

(2) MUST BE ABLE TO TOLERATE, WITHOUT DAMAGE, STANDING AT ANY STATE OF CHARGE (0% TO 100%) FOR A MINIMUM OF 7 DAYS DURING ANY THREE MONTH PERIOD

(3) FORCED FULL CHARGES OR DISCHARGES MUST NOT BE REQUIRED MORE THAN ONCE A WEEK

SHALLOW DISCHARGE PHOTOVOLTAIC BATTERY REQUIREMENTS

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SYSTEM VOLTAGE	12 TO 120 VOLTS
BATTERY VOLTAGE	6 TO 12 VOLTS
CAPACITY (8 HOUR RATE)	25 TO 2500 Ah AT 25 DEG C
RATE IN SERVICE	8 h MAXIMUM; 250 h NOMINAL
DUTY CYCLE – DAILY	5% OF RATED CAPACITY
– ANNUAL (1)	100% TO 20% TO 100% SOC
LIFE	5 YEAR MINIMUM; 20 YEAR DESIRABLE
ENERGY EFFICIENCY	80% MINIMUM
SELF DISCHARGE	1% PER MONTH MAXIMUM
TEMPERATURE RANGE	−40 TO + 60 C
MAINTENANCE PERIOD	YEARLY MAXIMUM; NONE DESIRABLE
CHARGE RATE	8 h MAXIMUM
COST GOAL	$100/kWh MAXIMUM; $50/kWh DESIRABLE

NOTES:

(1) MUST BE ABLE TO OPERATE AT LESS THAN 100% STATE OF CHARGE FOR 1 YEAR MINIMUM

(2) MUST WITHSTAND OTHER EFFECTS OF TERRESTRIAL ENVIRONMENT, EG, SALT SPRAY, ALTITUDE, AND HUMIDITY.

COMPARISON OF BATTERY 20-YEAR LIFE CYCLE COSTS

PHOTOVOLTAIC BATTERY REQUIREMENT	\$100/kWH
STATE-OF-ART LEAD-ACID	\$270/kWH

IMPROVEMENTS NEEDED FOR PHOTOVOLTAIC BATTERY

- Lower Purchase Cost
- Increased Cycle Life
- Low Maintenance

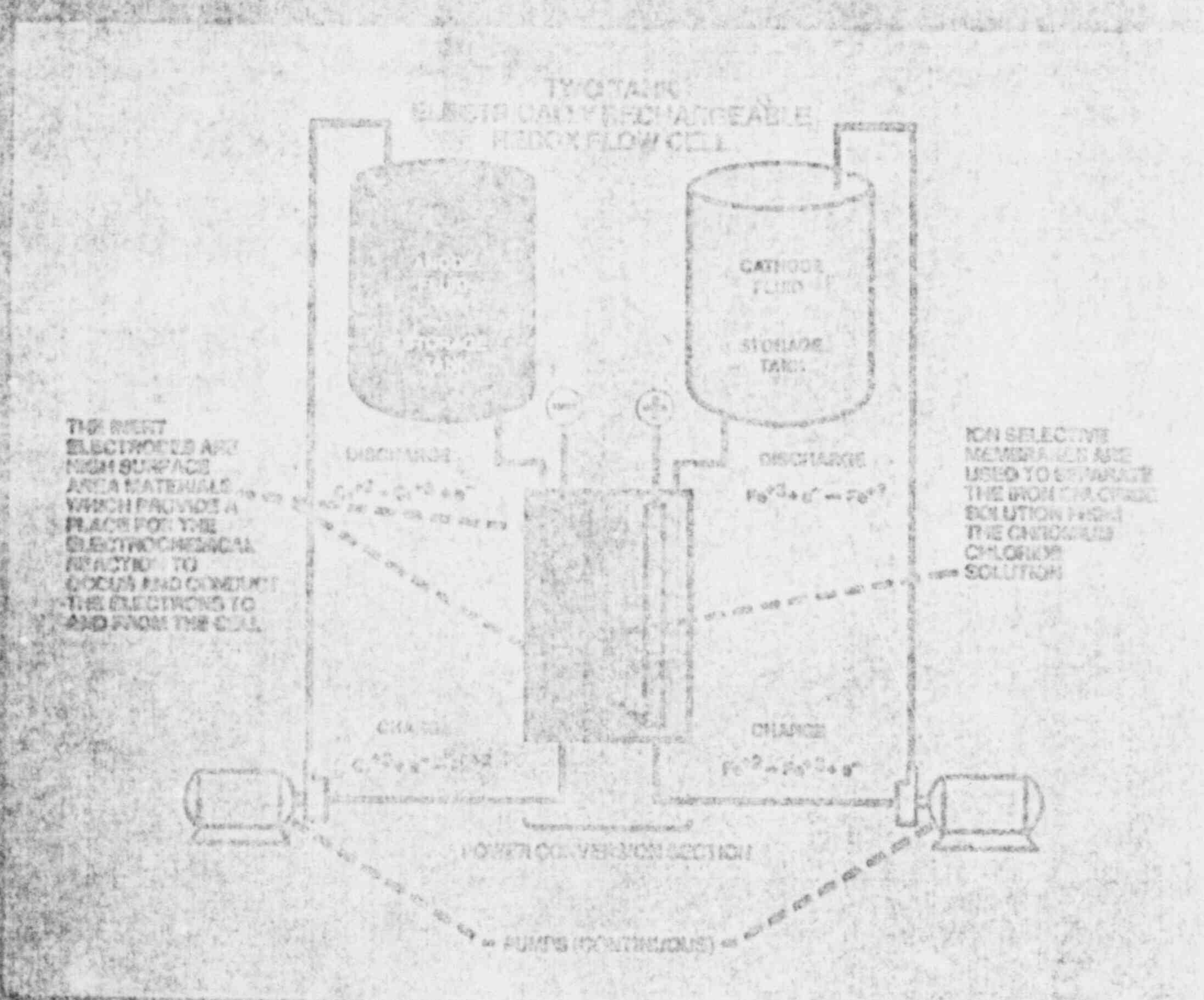
PV BATTERY RESEARCH AND DEVELOPMENT PROGRAM

ADVANCED LEAD-ACID

REDOX FLOW BATTERIES

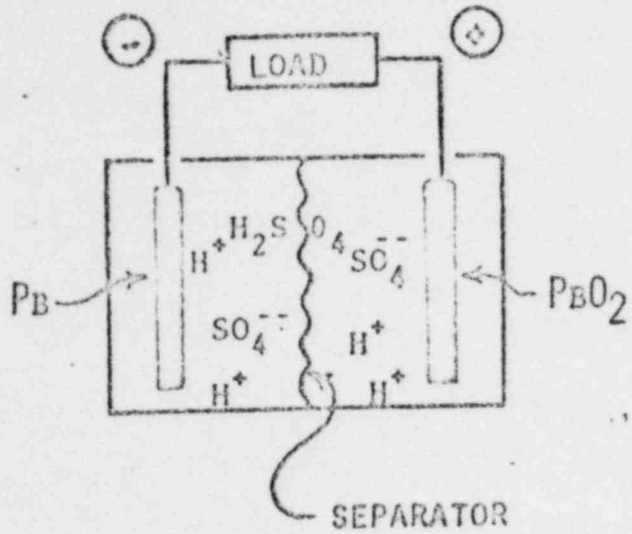
ZINC-BROMINE BATTERIES

AN ELECTROCHEMICAL STORAGE DEVICE, VERY MUCH LIKE A BATTERY WHICH USES TWO LIQUID SOLUTIONS AS REACTANTS



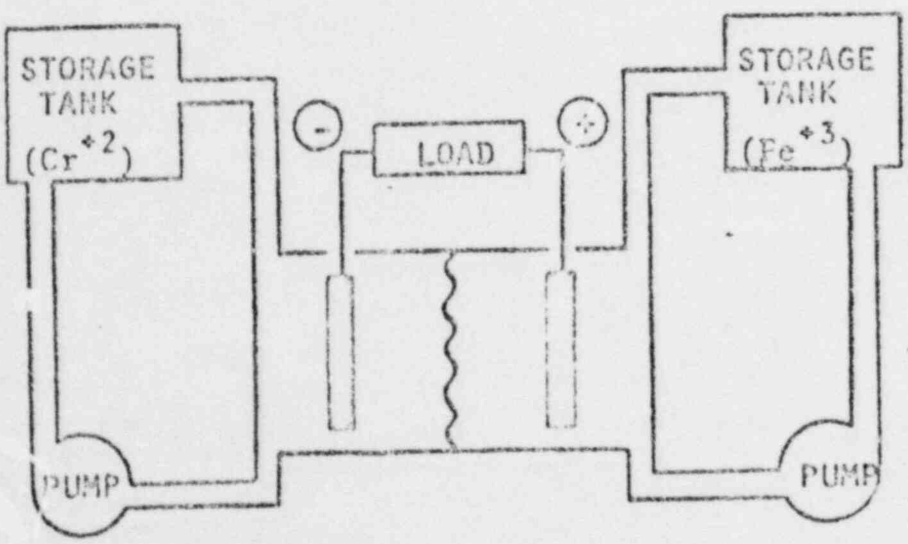
FLOW BATTERIES

STANDARD BATTERY CELL



ACTIVE ELECTRODES

FLOW BATTERY CELL (IDEAL)

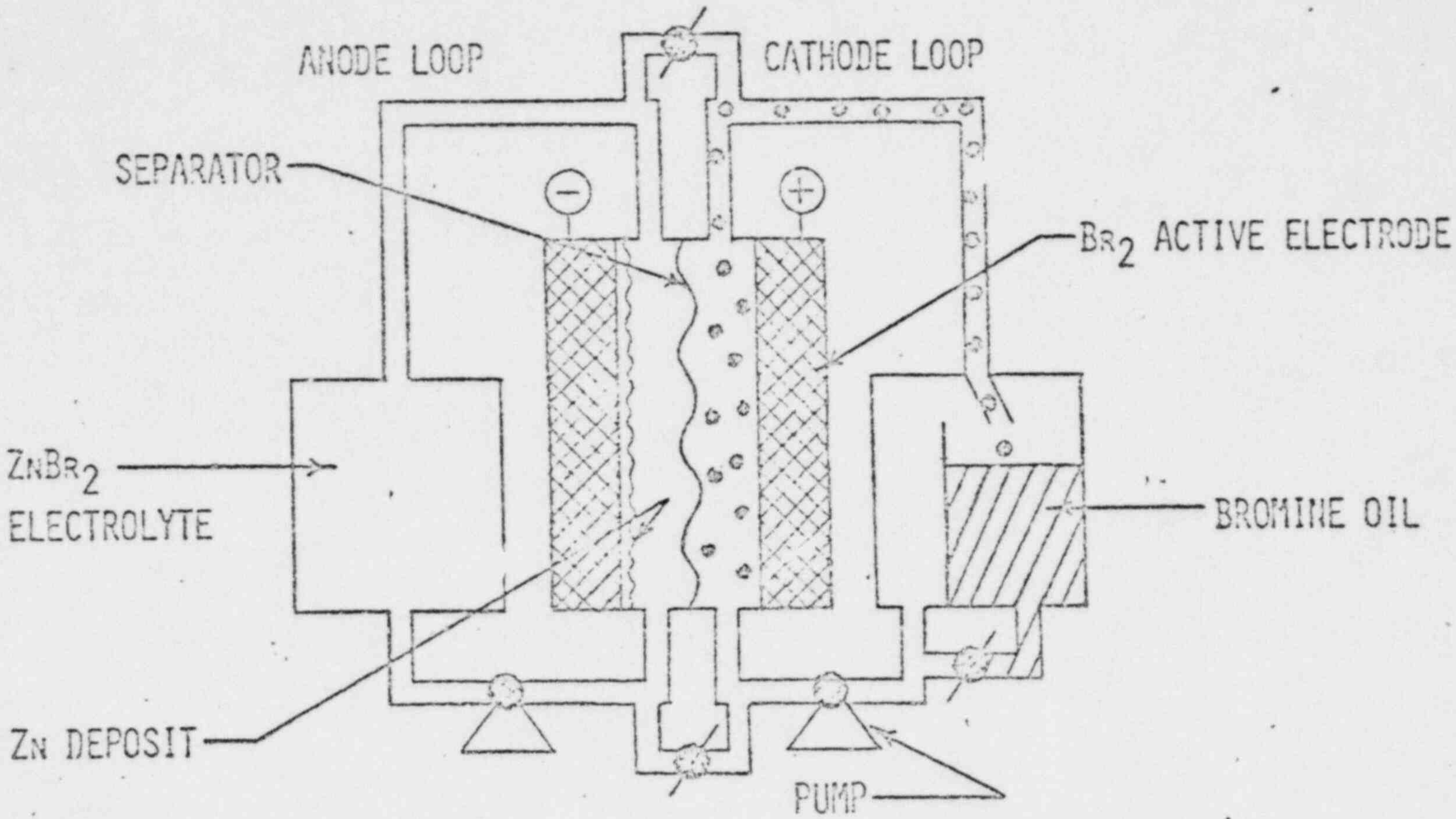


INERT ELECTRODES

MAJOR ADVANTAGES OF REDOX BATTERIES

- LOW COST MATERIALS.
- NO DEPTH OF DISCHARGE LIMITATION.
- LONG CYCLE LIFE (NO SOLID DEPOSITION).
- INDEPENDENT SIZING OF POWER AND STORAGE CAPACITY.

ZINC-BROMINE CIRCULATING ELECTROLYTE BATTERY



CHARGE: $Zn^{++} + 2e^- \rightarrow Zn^0$ $\quad 2\,Br^- \rightarrow Br_2 + 2e^-$

DISCHARGE: $Zn^0 \rightarrow Zn^{++} + 2e^-$ $\quad Br_2 + 2e^- \rightarrow 2\,Br^-$

MAJOR ADVANTAGES OF ZINC-BROMINE BATTERIES

- VERY LOW COST AND READILY AVAILABLE MATERIALS.
- HIGH CELL VOLTAGE.
- GOOD EFFICIENCY.
- LONG CYCLE LIFE (PERIODIC STRIPPING OF ZN).

DEVELOPMENT STATUS

REDOX

12 kWh (2 kW_p) PROTOTYPE IN-HAND

50 kWh (20 kW_p) UNITS BY 1983

ZINC-BROMINE

3.5 kWh (3.5 kW_p) PROTOTYPE IN-HAND

10 kWh (10 kW_p) UNITS BY 1981

20 kWh (20 kW_p) UNITS BY 1982