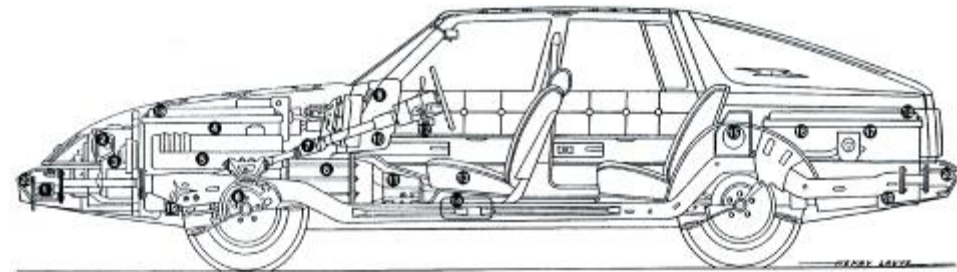
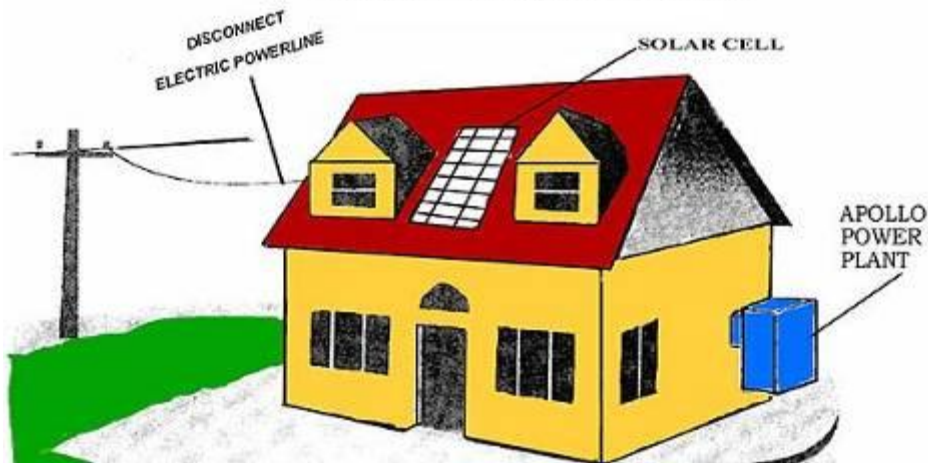




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Web: <http://www.apolloenergysystems.com>

**APOLLO ON-SITE POWER SYSTEM
FOR 3 BEDROOM HOME**



- | | |
|--|--|
| <ol style="list-style-type: none"> 1. FAST CHARGE RECEPTACLE 400 AMPS 2. DUAL HALOGEN HEAD-LIGHTS 3. CONTROL SYSTEM FOR BATTERY 4. BATTERY, SEALED, FAST CHARGE 5. CONTROLLER FOR ELECTRIC MOTOR 6. POWER BRAKES 7. POWER STEERING 8. ELECTRIC MOTOR 144 KW, 240 VOLTS 9. AIR CONDITIONING 10. AM/FM STEREO RADIO WITH CD PLAYER | <ol style="list-style-type: none"> 11. AUTOMATIC TRANSMISSION 12. POWER WINDOWS 13. POWER SEAT 14. PROPULSION FUEL TANK 15. CHARGER, ON-BOARD, 110/240 VAC 16. PROPULSION FUEL CELL 17. CHARGER RECEPTACLE, 110/240 VAC 18. FUEL CELL COVER 19. COLD-WEATHER HEATER 20. PLASTIC BUMPERS WITH STEEL BACKING |
|--|--|

FUEL CELL CHART	Phosphoric Acid Fuel Cell	Proton Exchange Membrane Fuel Cell	Liquid Molten Carbonate Fuel Cell	Solid Oxide Fuel Cell	Alkaline "APOLLO™" Fuel Cell (1)	Direct Methanol "MARS" Fuel Cell (2)
	PAFC	PEM	MCFC	SOFC	AFC	DMFC
Electrolyte	Liquid Phosphoric Acid	Proton Exchange Membrane (solid polymer)	Liquid Molten Carbonate	Ceramic	Potassium Hydroxide	Potassium Hydroxide
Catalyst	Platinum	Platinum	Nickel	Perovskites	Platinum/Silver	Silver
Cell Operating Temp. (degrees C)	205°C	Room temperature to 80°C	650°C	800-1000°C	Room temp. to 80°C	Room temp. To 70°C (3)
Electrical System Efficiency (% LHV)	36-45%	32-40%	43-55%	43-55%	50-60%	>50%
Some Applications:						
1. Cogeneration	✓	✓	✓	✓	✓	
2. Utility Power	✓		✓	✓	✓	
3. Distributed Power	✓	✓	✓	✓	✓	
4. Utility Repowering	✓		✓	✓	✓	
5. Passenger Vehicles		✓			✓	✓
6. Heavy Duty Vehicles	✓	✓		✓	✓	✓
7. Portable Power		✓			✓	✓
8. Specialty Power		✓			✓	✓

1. The APOLLO™ FUEL CELL has been developed by Apollo Energy Systems, Inc (Apollo). It is an Alkaline Fuel Cell (AFC) with circulating electrolyte, which can be shut down when not in use. This extends life of the electrodes and allows for maintenance. It has a higher voltage than other fuel cells. Patents have been applied for by Apollo on this fuel cell and working models have been in operation at Apollo's laboratories.

2. The MARS FUEL CELL has been developed by Apollo. It is a Direct Methanol Alkaline Fuel Cell (DMAFC) with circulating electrolyte and a polyethylene separator (proton exchange membrane separator not needed). The anode catalyst draws hydrogen from the liquid methanol, eliminating the need for a reformer. There are no CO₂ or other emissions from the DMAFC (there are CO₂ emissions from the acidic [H₂SO₄] DMFC). Cell voltage of the alkaline DMAFC is higher than the acidic DMFC. Patents have been applied for by Apollo on the DMAFC. It can be used in a Cell Phone or Lap Top Computer.

3. Or higher temperature if methanol vapor is used.

Properties of the AES System

- ☺ low cost electrodes (carbon-based, plastic-bonded)
- ☺ low cost monopolar stack design, no bipolar plates
- ☺ low cost commercial tools for operating the stack
- ☺ no humidifier, no compressors, no membranes
- ☺ fuel (H_2 , pure or reformed) at ambient pressure
- ☺ air at ambient pressure
- ☺ easy startup (hybrid) within minutes
- ☺ simple shutdown
- ☺ self-regulating water and thermal management
- ☺ tolerates 150ppm CO_2 (air: 300ppm)

Common Demands on Fuel Cells

High total efficiency

Reliability in daily use

during fast startup

during operation

during long periods of shutdown

Many different fuels usable

Simplicity of the whole system

Ease of maintenance

High power density (kW per liter, for small units)

High specific power (kW per lb, for mobile applications)

Low price

Advantages of the AFC

- low cost electrodes
- simple way of stack construction
- higher voltages
- sufficient lifetime for electric vehicles
- low sensitivity to misuse
- low sensitivity to impurities like CO or NH₃
- not sensitive to long periods of shutdown
- fast startup when used in hybrid mode

Fuel Cell Systems Comparison

*Based on current density of 400 mA/cm²
 **Based on published reports

	AFC Alkaline Fuel Cell	PEM Proton Exchange Membrane Fuel Cell
Current Density	300 – 600 mA/cm ²	600 mA/cm ²
Voltage Per Cell	0.8 – 0.85 V	0.65 – 0.70 V
Power Density + Accessories	50 kW / 300 kg 50 kW / 400 kg	50 kW / 200 kg 50 kW / 400 kg
Lifetime Operation mode: Continuous Intermittent	4000 Hours Over 4000 Hours (≈ 200,000 miles)	Est. 5000 Hours** Unknown Unknown
Costs Per kW + Accessories	100 – 150 \$ 200 – 300 \$	500 – 1000 \$ 1000 – 2000 \$
Catalysts: Anode Cathode	Noble Metals No Noble Metals	Noble Metals Noble Metals
Recoverability after misuse	High	Low
Maximum Fuel Impurities Carbon Monoxide (CO) Carbon Dioxide (CO ₂) Ammonia (NH ₃)	Not Critical < 100 ppm Not Critical	< 10 ppm Not Critical Very Critical
Power Density (kW/l)	1.96*	1.75**
Specific power (kW/kg)	2.40*	1.25**

Advantages of Circulating Liquid Electrolyte

- 👍 easy thermal management
- 👍 easy water management
- 👍 barrier against reactant gas leakage established
- 👍 accumulated impurities and carbonate easily removable
- 👍 reduction of concentration gradient
- 👎 some parasitic currents (in multi cell stacks)

K.V.Kordesch's Austin A 40 (1970)



Fuel Cell:

H₂ / air

90V / 6kW

Battery:

SLI lead acid

84V / 7kWh

Hybrid weight:

1600lb

Max. speed:

50miles/hr

Range:

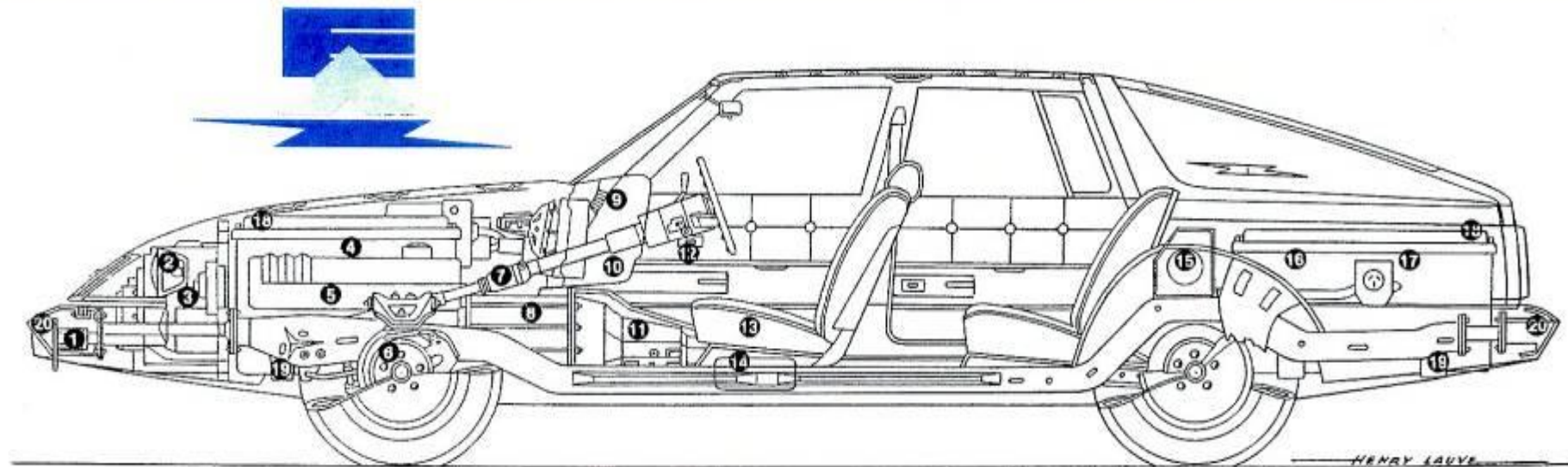
185miles

SILVER VOLT



THE SILVER VOLT

ELECTRIC PROPULSION SYSTEM



1. FAST CHARGE RECEPTACLE 400 AMPS
2. DUAL HALOGEN HEAD-LIGHTS
3. CONTROL SYSTEM FOR BATTERY
4. BATTERY, SEALED, 240 VOLT, 300 AH C/1 - 72kWh
5. CONTROLLER FOR ELECTRIC MOTOR
6. POWER BRAKES
7. POWER STEERING
8. ELECTRIC MOTOR 144 KW, 240 VOLTS
9. AIR CONDITIONING
10. AM/FM STEREO RADIO WITH CD PLAYER

11. AUTOMATIC TRANSMISSION
12. POWER WINDOWS
13. POWER SEAT
14. PROPULSION FUEL TANK
15. CHARGER, ON-BOARD, 110/240 VAC
16. APOLLO FUEL CELL - 288 Volts, 19-AMPS, 5.5kW
17. CHARGER RECEPTACLE, 110/240 VAC
18. FUEL CELL COVER
19. COLD-WEATHER HEATER
20. PLASTIC BUMPERS WITH STEEL BACKING

APOLLO ENERGY SYSTEMS, INC



“Clean Energy for the 21st Century”

APOLLO POWER PLANT OUTDOOR CABINETS, BAKED ENAMEL

For MODEL 115-C (*Fuel Cell can be shut down at night*)



Robert Raymond Aronsson with Outdoor Steel Cabinets for Model 115-C
For Residential, Commercial and Industrial Use

Power Plant Model 106-B

72 kW APOLLO™ POWER PLANT MODEL 106-B

Application: 24-hour power supply for home, farm or commercial establishment for heating, lighting and operation of appliances independent of outside power line (utility grid) supplied by electric utility company. Will operate a 8-HP AC electric motor on a continuous 24-hour basis.

Specification of Power Plant (January 5, 2000):

Lead Cobalt Battery: 240 volts @ 300 amps 1/C – **72 kWh**
One minute surge power: 900 amps. Battery supplies power to inverter.

Apollo™ Fuel Cell: 342 volts open circuit (360 cells @ 0.95 volts/cell)
288 volts (@ 0.8 volts/cell) under 19 amp load = **5.47 kW**. Fuel Cell charges battery (288v @ 19 amps)

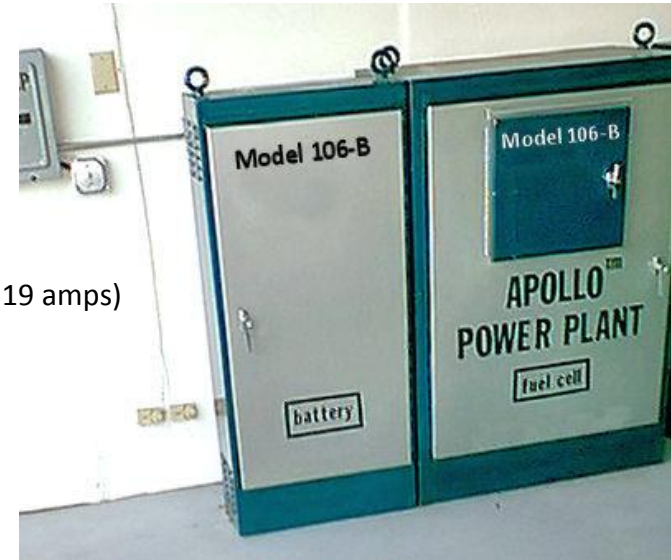
Maximum Heating & Lighting Energy: 5.47 kW x 24hrs = 131kWh x 30 days = **3,930 kWh**

DC to AC inverter for supplying power load:	72.00 kW
Input from Battery; 288v DC, 19 amp:	5.47 kW
1-minute overload; 900 amps @ 288v:	259.00 kW
Output: 240v AC, 50/60 Hertz, 21.6 amps	5.200 kW
230v AC, 50/60 Hertz, 22.6 amps	5.200 kW
120v AC, 50/60 Hertz, 43.3 amps	5.200 kW

Microprocessor for control of entire system

Cables, conduit, plumbing, sensors (i.e. Hydrogen), weather proof cabinets for system integration

Hydrogen Generation Equipment: Ammonia Cracker or Natural Gas/Propane (LPG) reformer



Ready For Mars

RANGE 600 MILES – SPEED 45 MPH



**57.6 kW APOLLO FUEL CELL (288 VOLTS @ 200 AMPS)
48 kWh LEAD COBALT BATTERY (240 VOLTS @ 200 AMPS)**

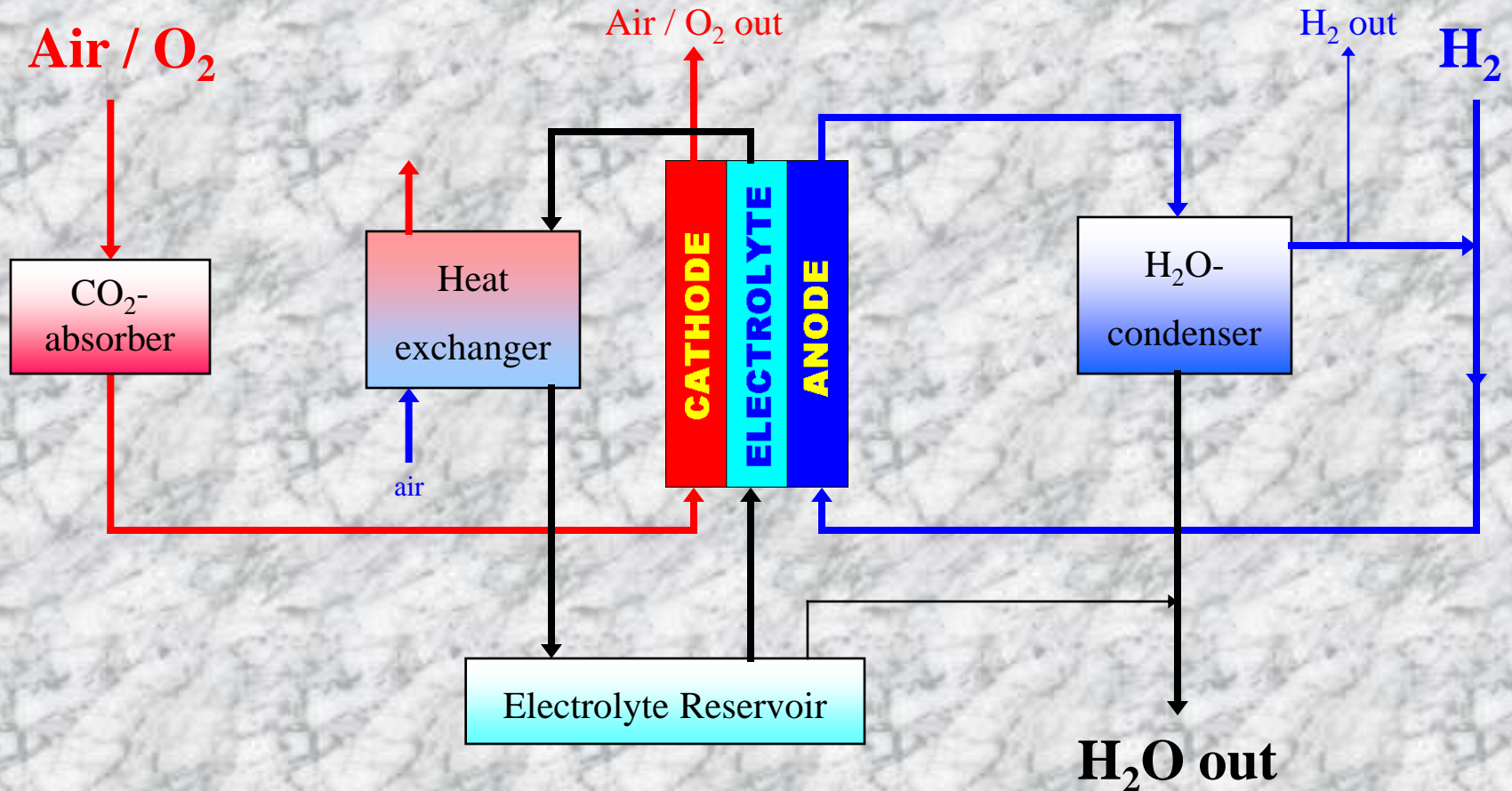
Ready For Mars

MARS RESEARCH CENTER AND HABITAT

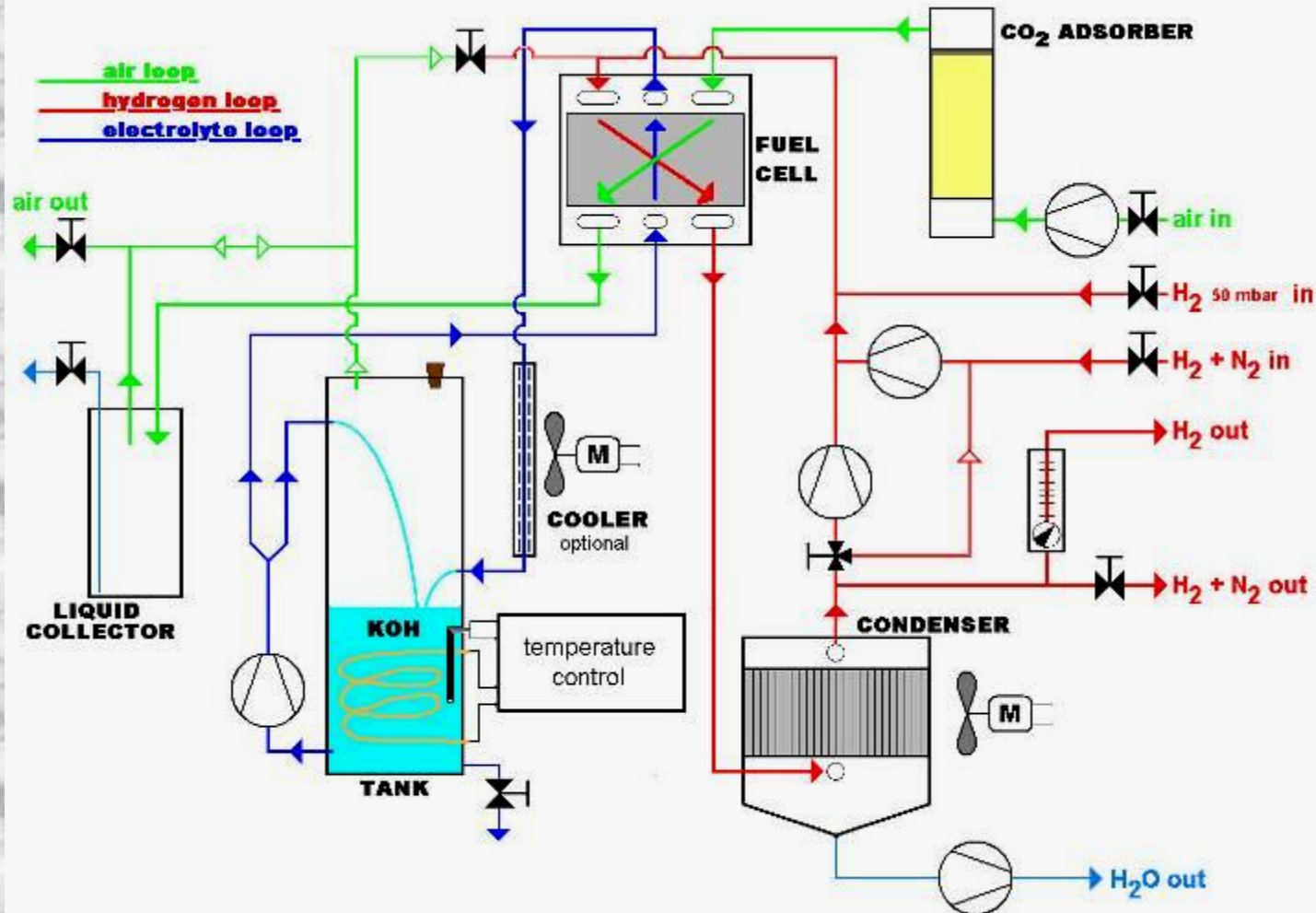


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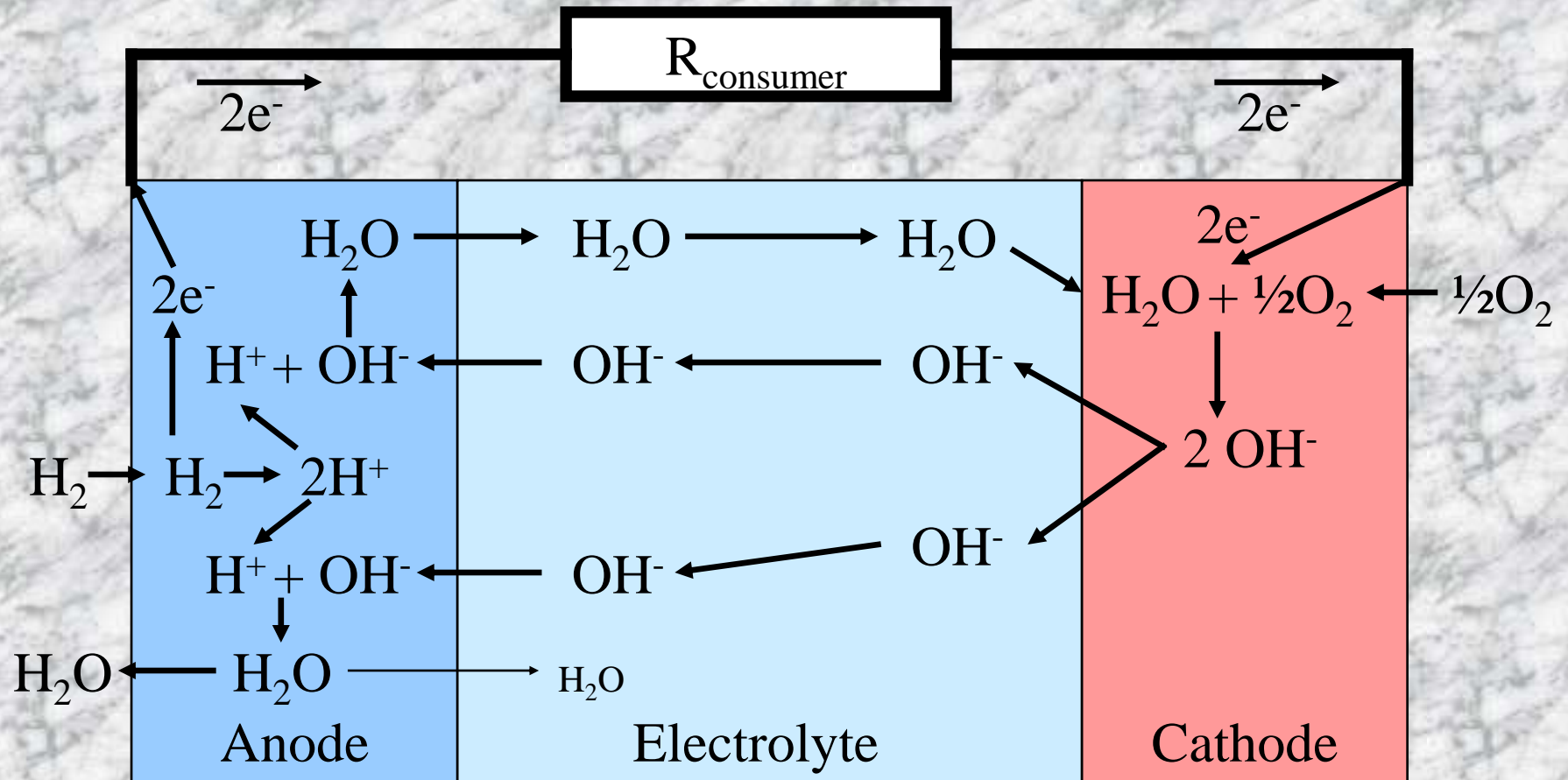
Principle of an AFC-System



Detailed Gas and Electrolyte Flow



Electrochemical Reactions



Advantages of Ammonia



- ☺ Not flammable
- ☺ Liquid at very low pressure
- ☺ 1.7 times more H_2 than liquid H_2 (at same volume)
- ☺ Low cost (third largest chemical produced worldwide)
NH₃: 1.17\$/kWh Methanol: 3.79\$/kWh H₂: 25\$/kWh [Kaye, Bloomfield]
- ☺ Distribution technology available and in daily use
- ☺ Simple cracking (low temperatures if used with AFC)
- ☺ No cleaning of the reformed gas necessary (H_2 , N_2)
- ☺ Not toxic
- ☺ Strong odor, easy to detect

Fuel Cell Running on Ammonia



**Anhydrous
Ammonia**

**Ammonia
Cracker**

Fuel Cell Module II

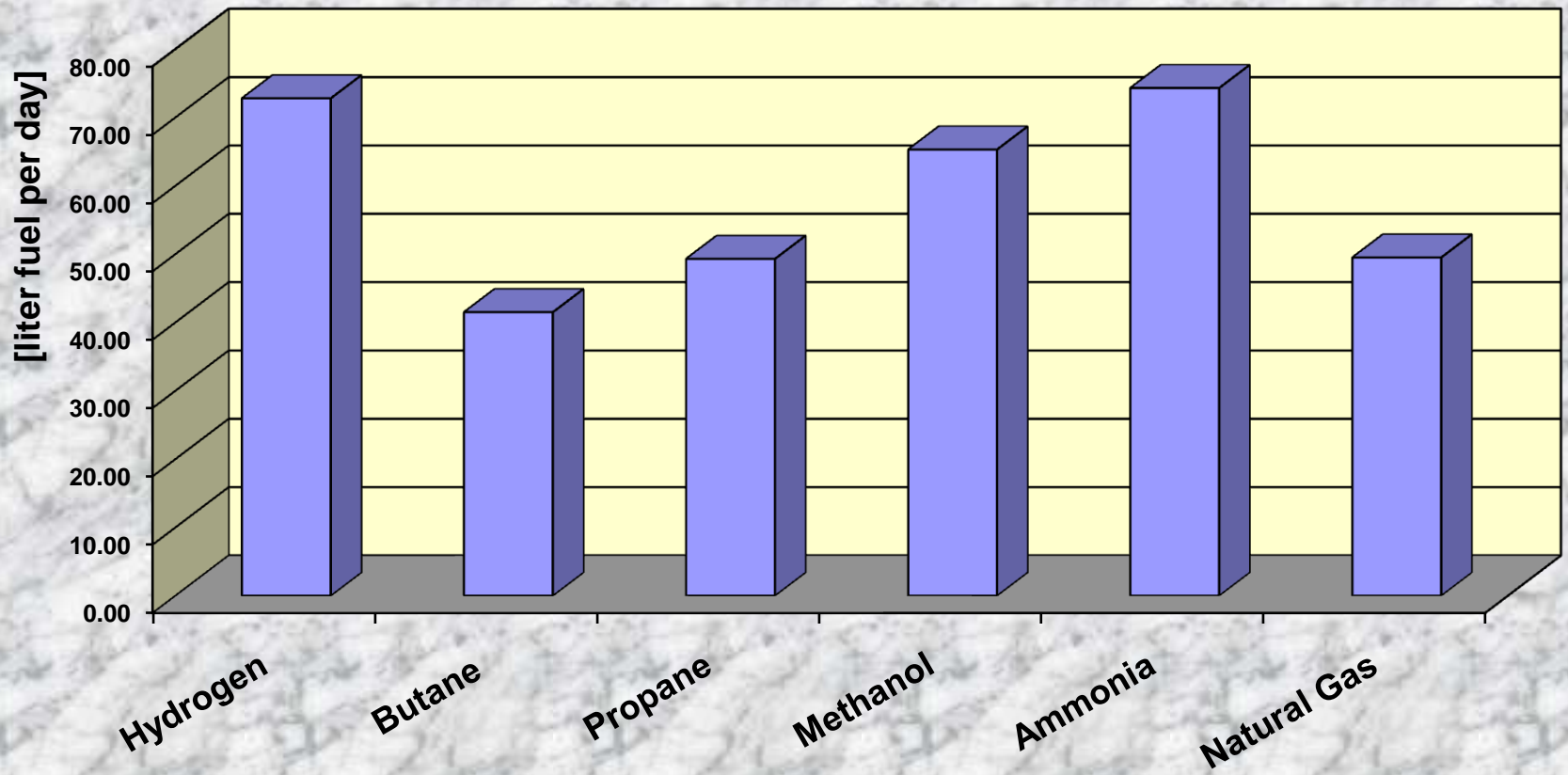
**Hybrid battery
(lead acid)**

**Electric Motor
and Fan**

Fuel Consumption

FOR MODEL 101-B

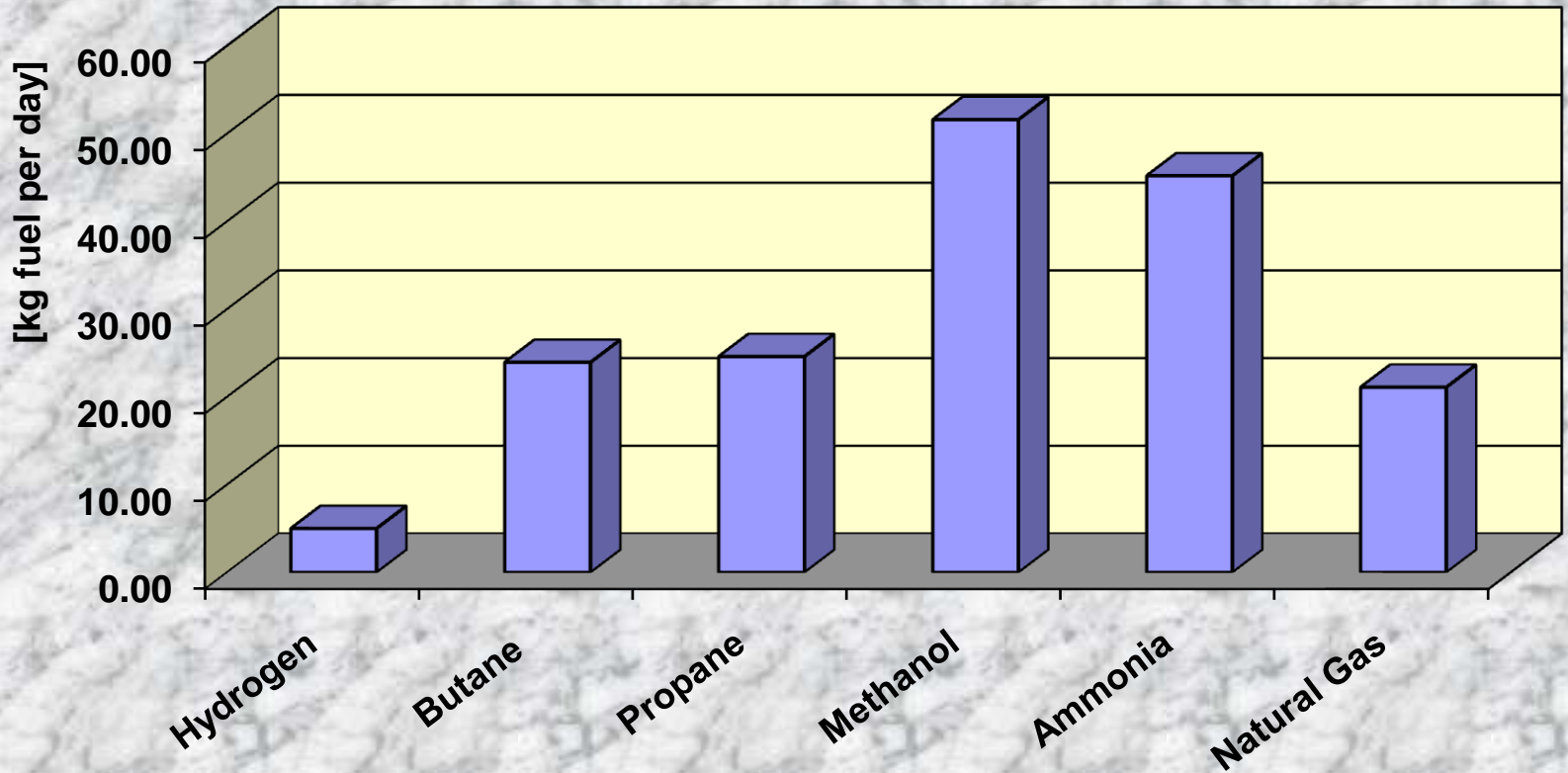
BASED ON POWER CONSUMPTION OF 131.3 kWh/day



Fuel Consumption

FOR MODEL 101-B

BASED ON POWER CONSUMPTION OF 131.3 kWh/day



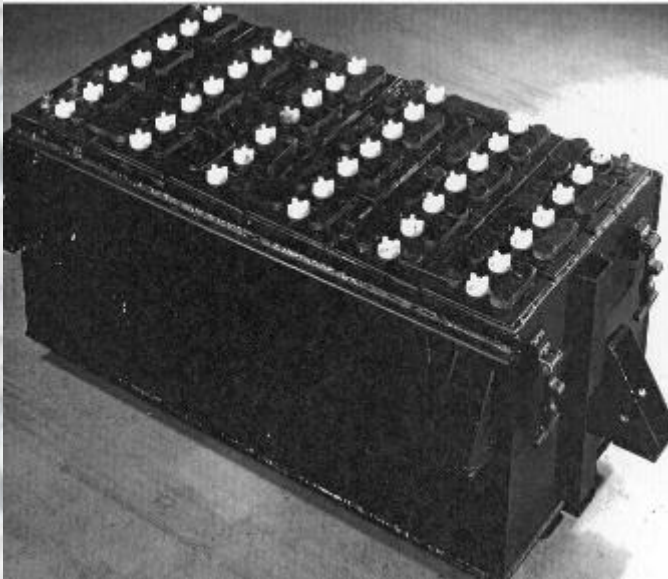
FUEL CELL OPERATING COST – PRELIMINARY

Apollo Power Plant Hybrid Model 106-B

Fuel Type	Hydrogen	Hydrogen	N-Butane	Methanol	Ammonia	Ammonia	Methane	Natural Gas	Propane (LPG)
	Liquid	Liquid			Anhyd	29.0%			
Chemical Symbol	H	H	C ₄ H ₁₀	CH ₃ OH	NH ₃		CH ₄	96% CH ₄	96% C ₃ H ₈
Power Consumption (kWh/Day)	131.3	131.3	131.3	131.3	131.3	131.3	131.3	131.3	131.3
Systems Efficiency (%)	66.0	66.0	40.0	42.0	50.0	45.0	40.0	40.0	40.0
Fuel Consumption (kWh/Day)	199.0	199.0	328.3	312.7	262.7	291.8	328.3	328.3	328.3
Fuel Consumption (MJ/Day) (1 kWh = 3.6 x 10 ⁵ J)	716.3	716.3	1182.0	1125.7	945.6	1050.6	1182.0	1182.0	1182.0
High Heat Value (HHV) (MJ/kg)	143.4	143.4	49.5	21.8	20.9	5.8	56.1	56.1	48.0
Fuel (kg)	5.0	5.0	23.9	51.6	45.2	181.0	21.1	21.1	24.6
Fuel (ft ³ as gas)	2114.2	2114.2	338.8		2075.0		1096.6	1096.6	468.0
Fuel (liters as liquid)	72.8	72.8	41.5	65.3	74.3		49.5	49.5 Values = Methane	49.5 Values = Propane
Fuel Cost Information	\$0.320 per lb	\$1.00 - \$1.40 per lb		\$0.185 per liter (\$0.70/gal)	\$0.09 - \$0.10 per lb	\$0.04 - \$0.06 per lb		\$5 - \$10 Per 1000 ft3	\$0.90 - \$0.95 per gal
Calculation	\$0.32	\$1.20		\$0.185	\$0.095	\$0.05		\$7.50	\$0.925
Cost Per Day	\$3.52	\$13.20		\$12.08	\$9.45	\$19.95		\$8.23	\$12.10
Cost Per Month	\$105.60	\$396.00		\$362.42	\$283.50	\$597.30		\$246.74	\$363.00

The Winning Combination

**LEAD COBALT
BATTERY**

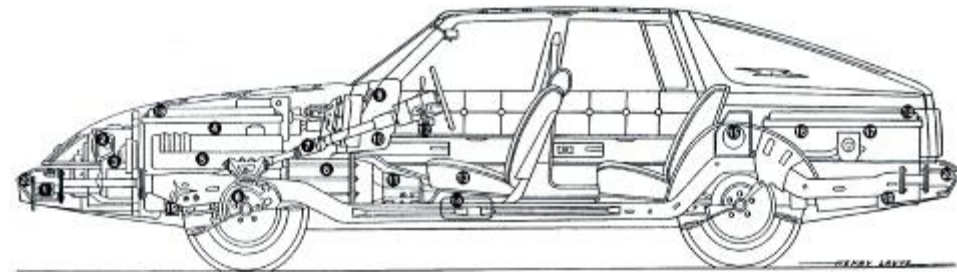
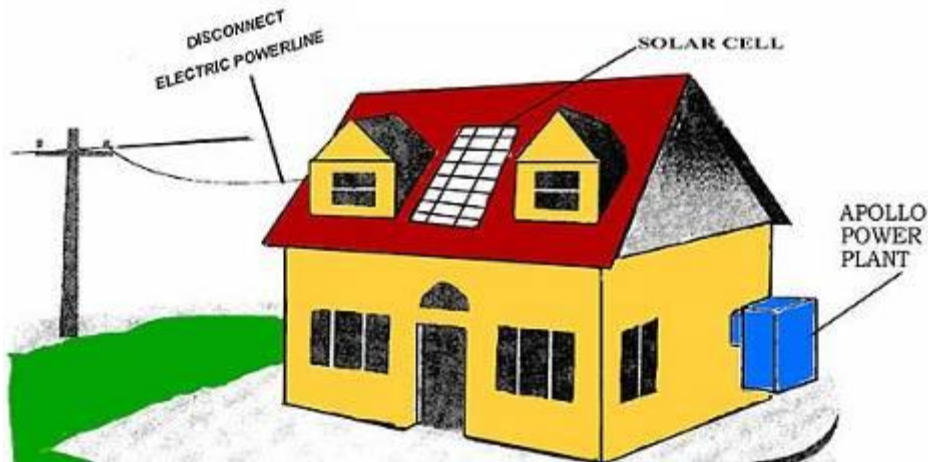


APOLLO FUEL CELL



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