IBM Research

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November 15, 1972

RC 4120

Yorktown Heights, New York

San Jose, California

Zurich, Switzerland

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ABSTRACT: This note contains a tabulation of the density of stored energy attainable in various physical systems, ranging from macroscopic systems such as a mechanical spring to nuclear systems such as nuclei undergoing a fusion reaction.

RC 4120 (#18453)
November 15, 1972
Physics (General)

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Closely related to the production and use of energy are methods of energy storage, such as piles of coal near a conventional thermal generating plant or "smoothing" capacitors in a power supply. The table below gives, in joules per cubic centimeter, the energy density of various physical systems. The second law of thermodynamics is not explicitly considered, although it may have important consequences for the useful work obtainable from a given energy reservoir. The energy stored in a battery can be used more efficiently than that stored in gasoline, for example. Nevertheless the factor of 20, in energy density, in favor of gasoline over a battery gives some indication of the difficulty in designing battery-powered cars to compete with gasoline-powered cars.

Broadly speaking, the energy storage systems may be classified as nuclear; atomic and molecular; and macroscopic; in generally decreasing order of energy density. The thermal energy density at 300°K is somewhat less than most chemical energy densities, as expected from the stability of chemical compounds. The energy density attainable in a macroscopic spring is smaller than typical chemical energy densities by three orders of magnitude, as expected from the fact that elastic behavior of a solid is possible only for small atomic displacements; irreversible deformations occur for relative shear displacements of adjacent atomic planes of much less than an interatomic spacing.

ENERGY STORAGE DATA

Class	System	Energy Dens. (J/cm^3)	Remarks
Nuclear	ρc^2	3×10^{14}	Rest mass energy density, assuming $\rho = \frac{10}{3}$ gm/cm^3.
"	$D_2 \rightarrow He$	5×10^{10}	Energy available from fusion reaction, per cm^3 of liquid D_2.
"	$H^3 \rightarrow He^3 + e^-$	1×10^8	Energy density from the indicated reaction occurring in LiH (used in one type of "nuclear battery").

Atomic & Molecular	Gasoline + liq. O_2	1×10^4	Energy available from complete combustion of gasoline, per cm^3 of fuel and oxidizer (liquid O_2).*
"	H_2, O_2	7×10^3	Energy available from reaction of liquid H_2 with liquid O_2, per cm^3 of initial constituents.
"	Zn-AgO battery	2×10^3	Ref. R. Jasinski, "High Energy Batteries", ch. 8. This number also corresponds to a rough estimate based on a 10v., 100 amp. hour storage battery requiring a volume of 2 liters.
"	Thermal Energy	4×10^2	Thermal energy in solid aluminum at 300°K, assuming Debye temp. ∿ 430°K, molar volume ∿ 10 cm^3/mole.
"	H_2O liq → Solid	3×10^2	Heat of fusion, per cm^3 of liquid H_2O.
Macroscopic	Rotational Energy	2×10^3	Max. energy density in tungsten fly wheel with the mass concentrated near the rim, at the breaking point: $U = 1/2\sigma_T$ = tensile strength = 4×10^{10} dynes/cm. Note relationship to a spring, below. σ_T from Hdbk. of Chem. and Phys.
"	$(1/8\pi)B^2$	9×10^1	Energy density in high-field region of 150 kilogauss superconducting magnet. Higher energy densities may be possible as new superconducting materials become available. A mechanical stress of 900 atm. caused by electromagnetic forces must be withstood by the magnet structure at this field level.
"	Tungsten Spring	2×10^1	Tensile energy which can be stored in tungsten per cm^3, calculated from $U = \frac{1}{2}\frac{\sigma_T^2}{Y}$, where σ_T = tensile strength = 4×10^{10} dynes/cm^2, and Y = Young's Modulus = 35.5×10^{11} dynes/cm^2. Values are from Hdbk. of Chem. and Phys. Note relation to rotational kinetic energy, above.
"	Gravitational pot. energy, 100m. drop	1	Gravitational energy available in 100m. fall, per cm^3 of H_2O. $U = \rho gh$, where $\rho = 1$ gm/cm^3, h = 100m.

* If the O_2 is not stored (as in a car) the gasoline may be said to have an effective energy density of 4×10^4 J/cm^3. Other hydrocarbon fuels have energy densities similar to that of gasoline. We are grateful to H. E. Hunziker for pointing out that the energy density stored in chemical explosives is typically less than that in gasoline.

Macroscopic	$(\epsilon/8\pi)E^2$	1	Dielectric energy density in ruby mica, where $\epsilon = 5.4$ and $E_{breakdown} = 5600$ volts/mil = 7500 statvolts/cm. Data are from Ref. Data for Radio Engineers, 4th Ed., IT&T Corp.
"	3kW laser	10^{-1}	Estimate of energy density (average) inside a 1 cm. long laser cavity, assuming the Fresnel number is approximately unity. $U \approx \frac{P}{c\ell\lambda(1-R)}$, where P = output power = 3kW, ℓ = cavity length = 1 cm., λ = wavelength = 1μm, and R = mirror reflectivity = 99%.
"	Blackbody Cavity (3000°K)	7×10^{-8}	$U = \frac{\pi^2}{15} \frac{(kT)^4}{(hc)^3}$