<u>COMMENTARY ON THE TEXTBOOK FOR 22.351:</u>
"The Nuclear Fuel Cycle: Analysis and Management," 2nd Edition.
by Cochran and Tsoulfanidis

<u>Chapter 1</u>

<u>Page</u>

(1) Australia is currently the world's second largest uranium producer and has the largest reasonably assured resources. The definitive reference for such information is the OECD/NEA "Redbook": most recently "Uranium: 1997 Resources, Production and Demand," OECD (1998).

(3) For more details on LWR features see:
M. Gavrilas, P. Hejzlar, N.E. Todreas, and Y. Shatilla, "Safety Features of Operating Light Water Reactors of Western Design," CANES 2000.

(4) Note recent vendor mergers which have consolidated ABB and Westinghouse. In Table 1.1 power density has units of kW per liter.

(5) Fort St. Vrain has been shut down.

(15) Note limits of $\leq$ 5 w/o U-235 on current fabrication licenses and IAEA safeguards category change at $\geq$ 10 w/o.

(19) Fission of 1 gram of any heavy metal liberates approximately 1 Megawatt day of thermal energy.

<u>Chapter 2</u>

(28) Prof. Driscoll has prepared a recent review of Uranium from seawater.

(35) As acknowledged later, most US mines have been shut down due to the low cost of uranium from Canada, etc.

(42) See the recent Redbook estimates: Kazakhstan is now equal to Australia in terms of resources.

(49) Use of thorium in the once-through LWR fuel cycle only saves about 10% of the natural uranium requirements. Thorium is now primarily a by-product of rare earth production.

Chapter 3

(65-69) USEC has announced it will shut the Portsmouth facility down. USEC has cancelled its AVLIS program. Louisiana Enrichment Services (LES) has cancelled its bid to construct a centrifuge plant due to environmentalist/government objections.

Chapter 4

(80) Average linear heat rates are ~ 7 kW/ft.

(86) PWR fuels are not pre-pressurized to 2000 psi.

(87) In title of Fig. 4.2: "cupped."

(88) Recent advanced designs have considered 19×19 (PWR) and 10×10 (BWR).

(98) Currently LWR cores average less than one defected pin per core.

(99) In Germany, the AVR and THTR pebble bed HTGRs also operated, and like FSV are also now shut down.

Chapter 5

(134) ENDF-B/VI is currently the US standard version.

(142) CASMO-4 is now the up-to-date version. We will be using it in the 22.351 lab sessions.

(146) At the end of life, the Pu power fraction in a LWR can exceed 50%.

Chapter 6

(165) Note that the real objective is to minimize the total cost of electricity: minimum fuel cycle cost is not a suitable sole criterion if it reduces plant capacity factor.

(166) As noted later, dry storage at the reactor site is now the default option being practiced.

(169) There are more recent correlations (see class notes) of attainable burnup vs. U-235 reload enrichment. They tend to be slightly non-linear (i.e., Fig. 6.1 will overpredict the burnup). Also burnup depends on refueling strategy.

In general, this chapter should be supplemented by:
"The Linear Reactivity Model for Nuclear Fuel Management," by M. J. Driscoll, T. J. Downar, and E. E. Pilat, American Nuclear Society (1990).

(171) Note that part of the reactivity decrease with burnup is due to the buildup of non-saturating fission products (i.e., those other than Xe and Sm): at the end of life they can absorb about 15% of all neutrons. Note constraints on soluble boron imposed by the need to maintain a negative moderator temperature coefficient and also a sufficiently high pH.

(182) Optimum LWR end blankets employ slightly enriched uranium and annular fuel pellets.

(187) The pebble bed cores are cylindrical for the most part.

(189) Fig. 6.15 is somewhat confusing. Refer instead to: "Uranium and Separative Work Utilization in Light Water Reactors," by H. J. MacLean, M. V. McMahon, and M. J. Driscoll, MIT-NFC-TR-009, January 1998.

(190) Note that most US PWRs are now on an 18 month cycle, with a few at 24 months as are more BWRs which run at a lower specific power (kW/kg).

Chapter 7

(210) PWR reload enrichments are now ~4.5 w/o and approaching 5 w/o.

(212) Some promote reprocessing because the HLW can be made into an ever more durable waste form (glass or synroc).

(214) Breeding capability is also limited by the buildup of isotopes having an inferior fission-to-capture ratio.

(215) Reprocessing in the US in the future is highly unlikely, due to its poor economics. It is also gradually losing favor abroad. The UK recently admitted that storage is cheaper; and antinuclear sentiment in Europe and Japan has poisoned public opinion.

(225) As they note later U-236 buildup reduces recycled uranium worth significantly.

(228) Fissile Doppler adds reactivity; also note use of erbium to mask the near-thermal Pu-239 resonance.

Chapter 8

(245) The market discount rate includes a base rate (approximately that of GNP growth) plus an allowance for anticipated inflation plus an allowance for estimated risk.

In general, this chapter is a bit too complex for present purposes. Simpler approaches will be provided in the class notes.

Chapter 9

(277) Note the new units:
1 GRAY = 100 RAD
1 SIEVERT = 100 REM

(285) Note the growing prevalence of dry storage as referred to in a later chapter.

(297) Note that one needs to add capture energy of $\sim 6(\nu - 1) \approx 12\text{MeV}$ to the fission energy.

(303) Note the roughly "1/T" decrease in decay power.
Some terminology:
TRU = transuranics, heavy metal beyond uranium.
MA = minor actinides: in general heavy metals beyond Pu but also including Np
Actinides are all including Th and higher Z.

(311) Recent article in Scientific American: Sub-sealed disposal, January 1998; Yucca Mountain, June 1996.

Chapter 10

Chapter 11

(364) The prospects for wind are better than stated here. See chapter on wind in Subject 22.811 class notes.