The Uranium Recovery Industry in the US and the Current Nuclear Renaissance – A Health Physicists Perspective

Steven H Brown, CHP
SENES Consultants Limited
Centennial, Colorado USA

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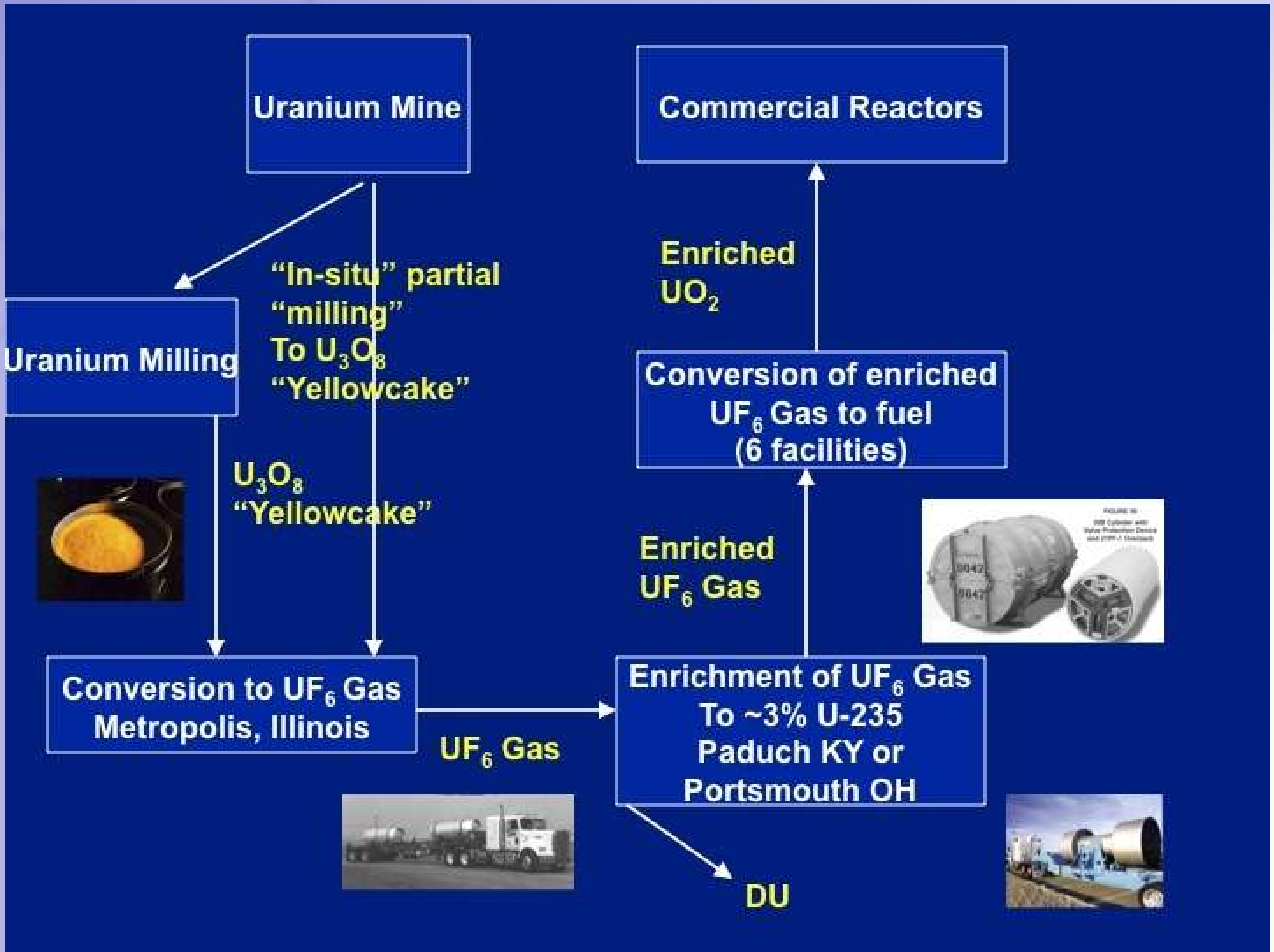
Overview

- Introduction – Background
- Market Conditions
- History of Uranium Recovery in the U.S.
- Overview of Uranium Recovery Technologies – Conventional Mining and Milling, In Situ Recovery (ISR) and Byproduct Recovery
- Environmental Monitoring
- Operational Health Physics
- Human Resource and Labor Market Outlook for Health Physicists
- Conclusions – Opportunities for Health Physicists and other Radiological Scientists

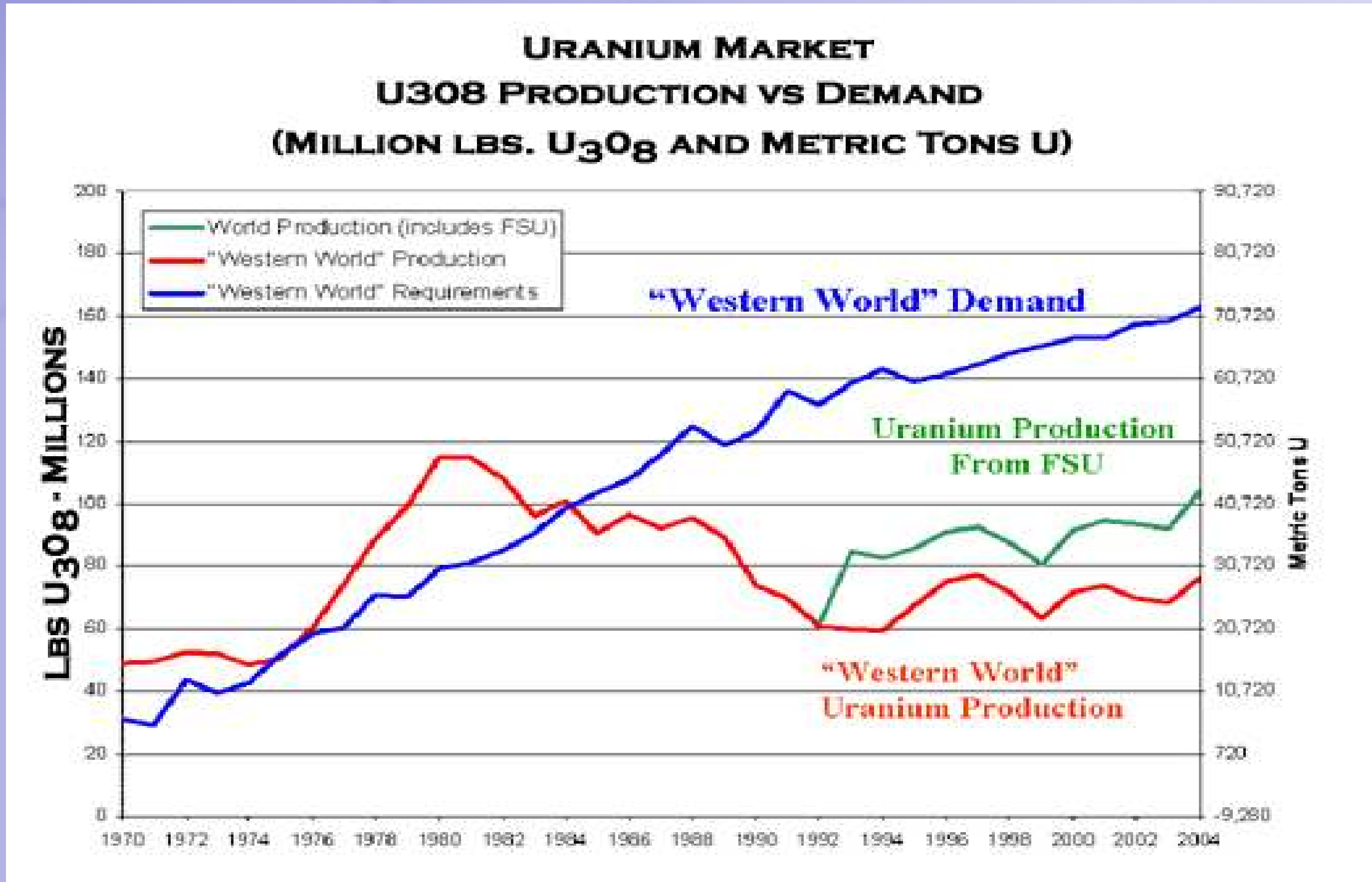
Introduction - Background

- Uranium Recovery = Conventional Mining, Milling, In Situ Recovery and as Byproduct (e.g. from Cu, Phosphates)
- Demand >> supplies today independent of global intent for many new nuclear power plants over next 15 – 20 years
- As a result, many new and reconstituted uranium recovery projects being developed in the U.S. and globally – providing increasing opportunities for radiological scientists
- In U.S., 104 operating reactors consume 50 – 55 million lbs U_30_8 / year – currently, U.S. produces about 5 million lbs / year

Uranium Fuel Cycle



Market Conditions – Production vs. Demand



Uranium Producers of America @ http://www.uraniumproducersamerica.com/

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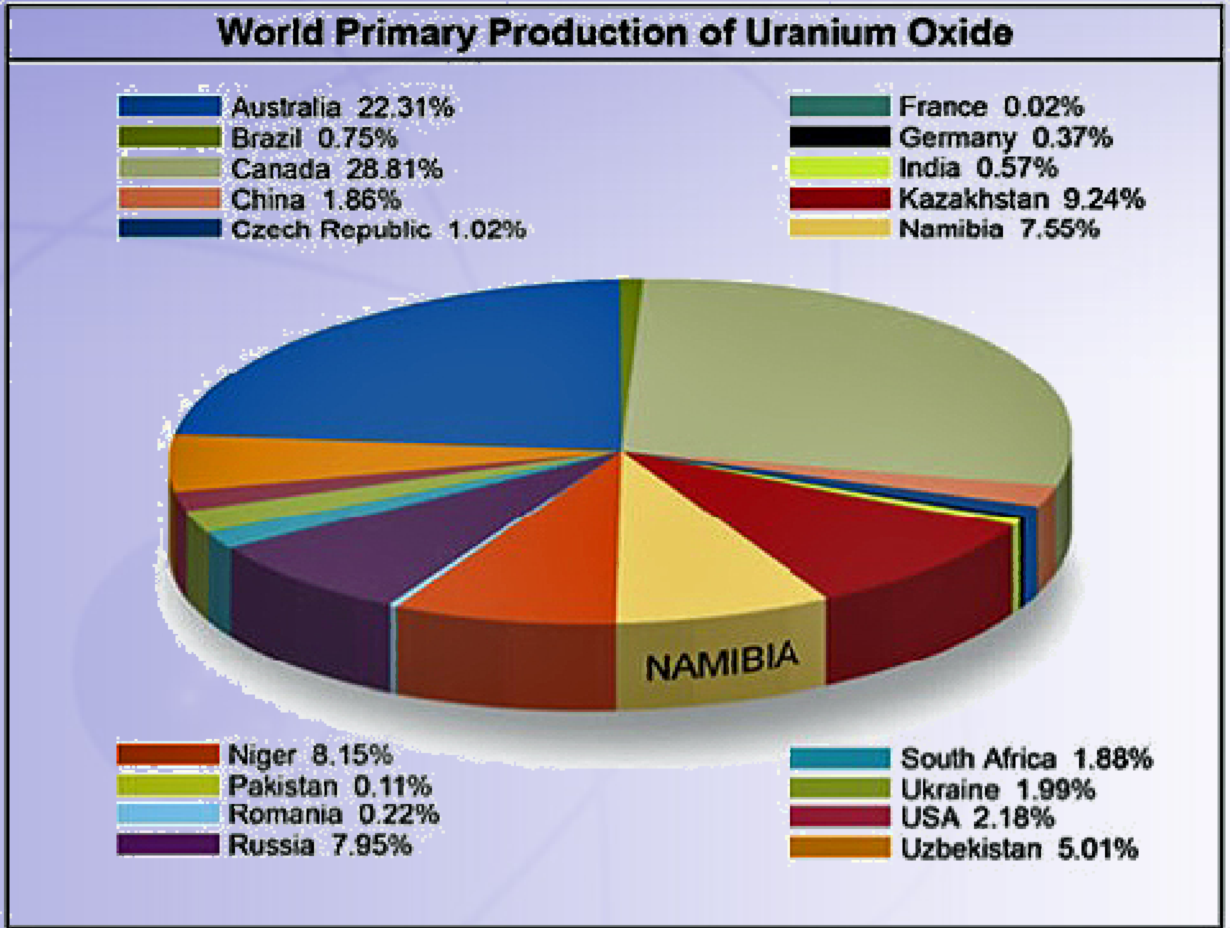
World Wide Uranium Production



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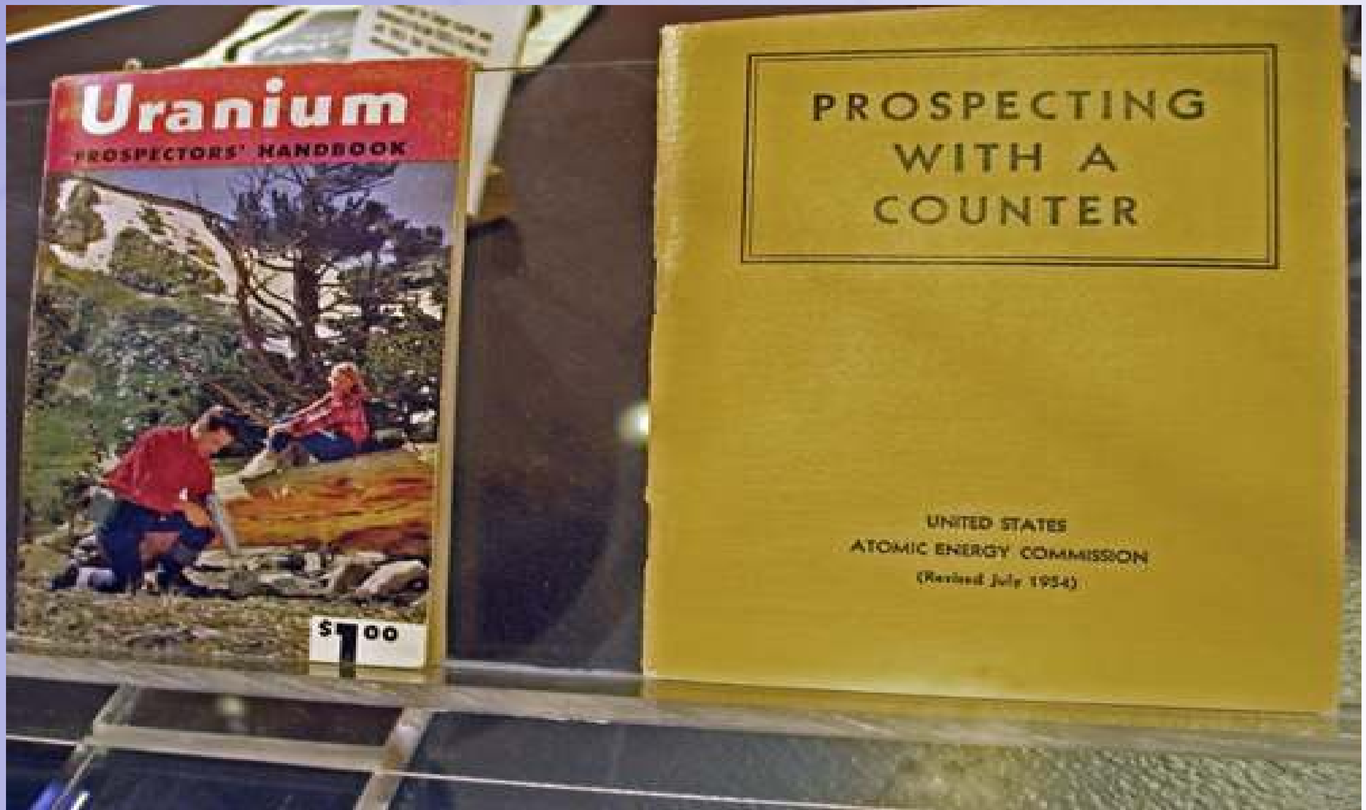
History of Uranium Recovery in U.S.

- Early 20th century – interest was in other minerals that uranium is associated with (vanadium, radium)
- Immediately following World War II – *McMahon Act* of 1946 (became *Atomic Energy Act* of 1954)
- Created Atomic Energy Commission (AEC) and U.S. government as exclusive buyer of U (for weapons program)
- Resulted in large number of independent prospectors trying to get rich throughout Colorado Plateau (4 Corners – AZ, CO, UT, NM)
- Creation of numerous government ore processing sites (MED – Manhattan Engineering District) in Midwest and Northeast – later known as the FUSRAP sites

U.S. Government Ore Buying Program Sent Prospectors "Crawling Over the Colorado Plateau"



Courtesy Western Museum of Mining and Industry, Colorado Springs

History of Uranium Recovery in U.S. (continued)

- AEC incentives end in 1962 – mining and processing on larger scale by private companies
- Commercial nuclear power industry develops in late 1960's / early 1970's – U.S. government no longer the exclusive buyer
- Prices peak around 1980 – commercial nuclear power industry becomes stagnant post TMI – supply > demand which remains constant for about 20 yrs
- Higher grade Canadian and Australian deposits dominate world markets

Current Circumstances

- Combination of depletion of historical supplies and renewed interest in new power plants ("Nuclear Renaissance") have changed economics
- Long established global mining companies and many new startups ("juniors") developing new projects in Western U.S.
- Currently about 8 licensed source material facilities – some in standby (WY,CO,UT, TX) Note: Mines not licensed
- But currently and over next 2 years, NRC expects numerous new applications

Facility	Quantity
New ISL Facility	14
New Conventional Mill	7
Combined ISL-Conv.	1
ISL Expansion	7
ISL Restart	1
Conventional Restart	1
TOTAL	**31**

L. Camper, USNRC, NRC / CMA Workshop, Denver, April 2008

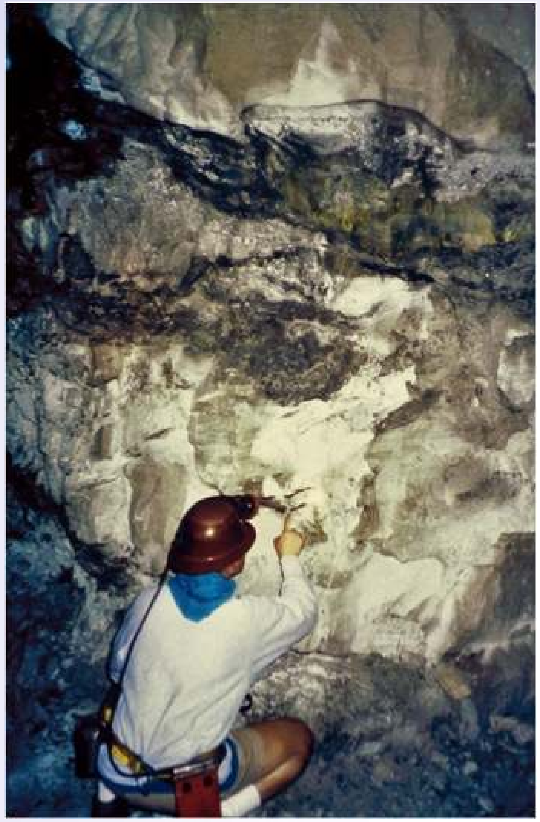
Licensed / Active Uranium Recovery Facilities In US

- White Mesa Conventional Mill (Denison) – Utah
- Canyon City Conventional Mill (Cotter) – Colorado (under modernization program – temporarily inactive)
- Smith Ranch-Highland ISR (Cameco) – Wyoming
- Alta Mesa ISR (Mestena) – Texas
- Crow Butte ISR (Cameco) – Nebraska
- Hobson ISR (Uranium One) – Texas
- Kingsville Dome ISR (Uranium Resources) – Texas
- Several other ISRs licensed but inactive and/or under restoration

Conventional U Mining

- Usually means open pit or underground mining
- Mines not regulated under AEA since raw ore not "source material" but H/S regulated by U.S. Department of Labor (MSHA) and permitted and regulated by state agencies
- Open pit: overburden removed to reach ore, typically <150 meters, ore removed by conventional earth moving equipment, stockpiled and sent to mill for processing
- Underground: declines or shafts excavated and drilled from surface (hundreds of meters) to reach ore bearing strata, stopes extended from main shafts to access ore, removed via shafts or elevators to surface, stockpiled and sent to mill for processing

Conventional Uranium Mines

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Conventional U Milling

- Mills are licensed facilities since they produce source material under the AEA (10 CFR 40)
- Raw ore crushed / ground to produce uniform and increasingly smaller particle sizes
- Slurry pumped to tanks for leaching of U (alkaline and/or acid)
- U liquor separated from solids and dissolved into solvent
- Uranium stripped from solvent, then precipitated and dried to final yellowcake product (“U_30_8”)

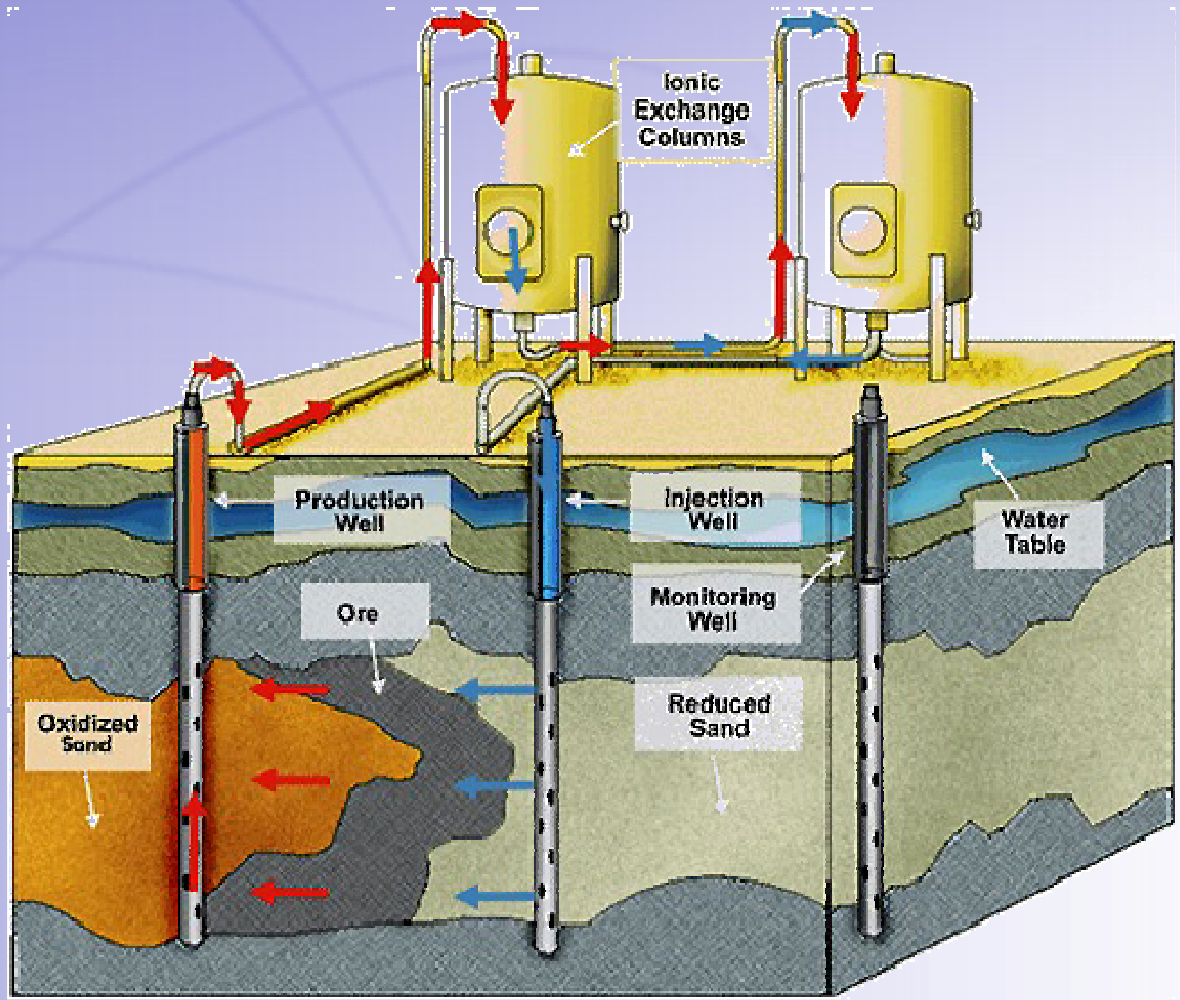
Conventional Uranium Mill

Photos courtesy Cotter Corporation

In Situ Recovery

- Technology generally limited to specific geological, hydrological and geochemical environments
- U deposition into ore bodies occurred when groundwater conditions changed from oxidizing to reducing forming “roll front deposits”
- Like conventional mills, ISRs are licensed facilities since they produce source material under the AEA (10 CFR 40)
- In the U.S., typically involve circulation of groundwater fortified with oxidizing (O_2) and complexing agents (e.g.,CO_2) through ore body, solubilizing the U in situ
- U bearing solution passed through IX system followed by subsequent concentration process similar to conventional U mill to produce yellowcake

Basic ISR Mining Method



Courtesy Wyoming Mining Association

ISR Plant and Well Field

Courtesy Wyoming Mining Association

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Current Generation ISR

Courtesy Wyoming Mining Association

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Byproduct Recovery Possibilities

- In 1970's and 1980's, U also recovered as byproduct of copper and phosphate production
- Copper: U plant co – located with the Bingham Canyon (Utah) copper mine produced 200,000 lbs U_3O_8/ yr U_30_8
- Phosphate: several licensed U facilities co – located with phosphoric acid plants in west central Florida produced similar annual quantities
- Given uranium's well known occurrence in phosphate rocks, economic re-evaluations of these reserves may soon occur

Environmental Monitoring

- Based on U.S. NRC Regulatory Guide 4.14, Rad. Effluent and Environmental Monitoring at U mills, 1980 – under revision
- Sampling of soil, vegetation, food crops in site environs (natural U series)
- Radionuclide particulate and radon sampling in air at site boundary locations
- Offsite sampling of surface and groundwater potentially impacted by site activities
- Direct radiation measurements at site boundary locations

Operational Health Physics / Radiation Safety Programs Typically Include:

- Airborne monitoring for long lived alpha emitters (U, Th, Ra) in the underground and in precipitation, product drying, and packaging areas
- Radon progeny monitoring in the underground, front end (ore bins and pads) and back end (tailings/waste storage areas)
- For ISRs, may also need to monitor radon gas in addition to progeny where solutions return from underground and are initially exposed to atmosphere
- External exposure monitoring primarily in areas where large quantities of uranium concentrates (ADU, $U0_4$, $U0_3$,U_30_8) are processed, packaged, and/or stored
- Additionally for ISRs, external exposure monitoring in areas where radium build-up can occur (resin columns and tanks, filters, etc.)

Operational Health Physics / Radiation Safety Programs (continued)

- Surface area contamination surveillance and control throughout plant and ancillary areas
- Bioassay (urinalysis) programs appropriate for the uranium products to which employees are potentially exposed
- Respiratory protection programs, if necessary
- Training programs and work control via formalized procedures
- Internal audit and quality control oversight by senior management – ensure execution of safe work practices, ALARA, and regulatory compliance

Standards of Good HP Practice Defined by NRC Regulatory Guides

- 8.22 – Bioassay @ U Mills
- 8.30 – HP Surveys in U Recovery Facilities
- 8.31 – ALARA Programs @ U Recovery Facilities
- 8.34 – Monitoring Criteria and Methods to Calculate Occupational Radiation Dose
- 8.37 – ALARA Levels for Effluents From Material Facilities
- 3.56 – Emission Control Devices @ U Mills
- 3.59 – Estimating Airborne Source Terms for U Mills (MILDOS)
- Others (e.g. material facility licenses) also applicable

Human Resource and Labor Market Outlook for Health Physicists

Sources:

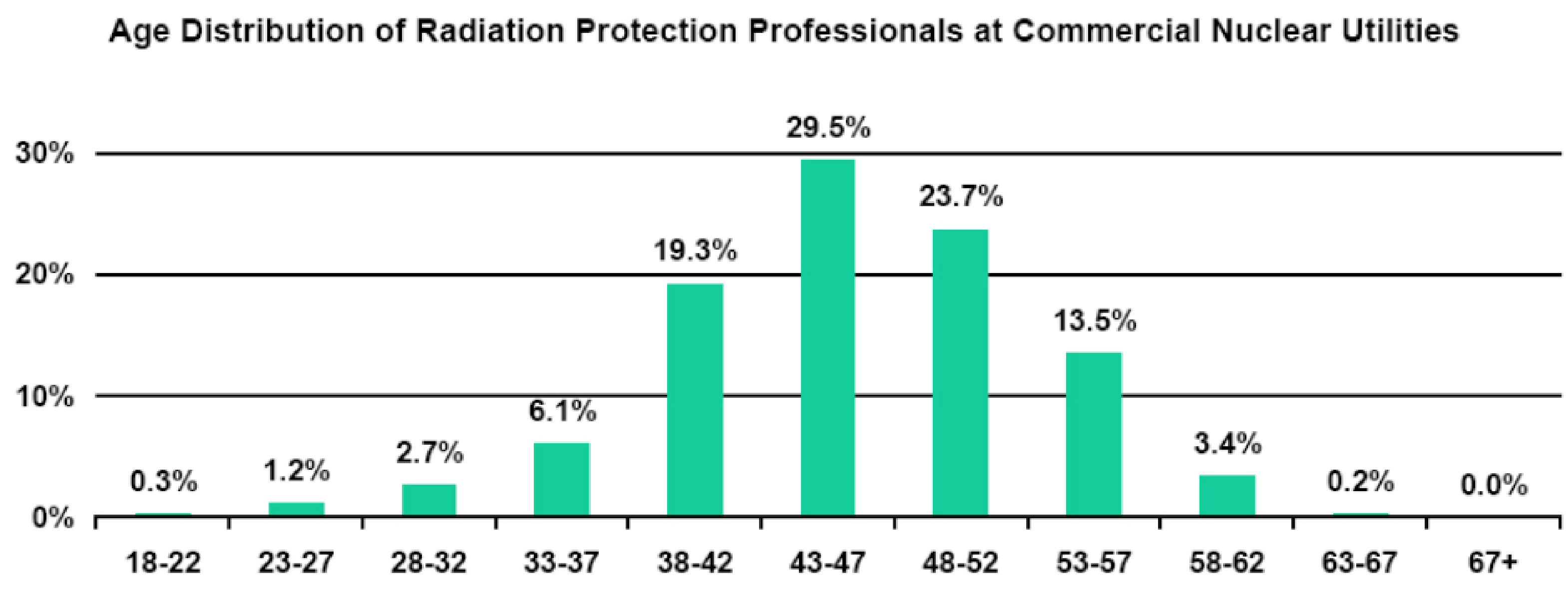
Health Physics Society Human Capitol Crises Task Force Report (Health Physics Society 2004)

Labor Market Outlook For Health Physicists Updated Through 2010, Oak Ridge Institute for Science and Education, prepared for Office of Human Resources, US Nuclear Regulatory Commission (ORISE, 2007)

Projected Shortfall in Sufficiently Educated and Experienced Radiation Safety Professionals Results From:

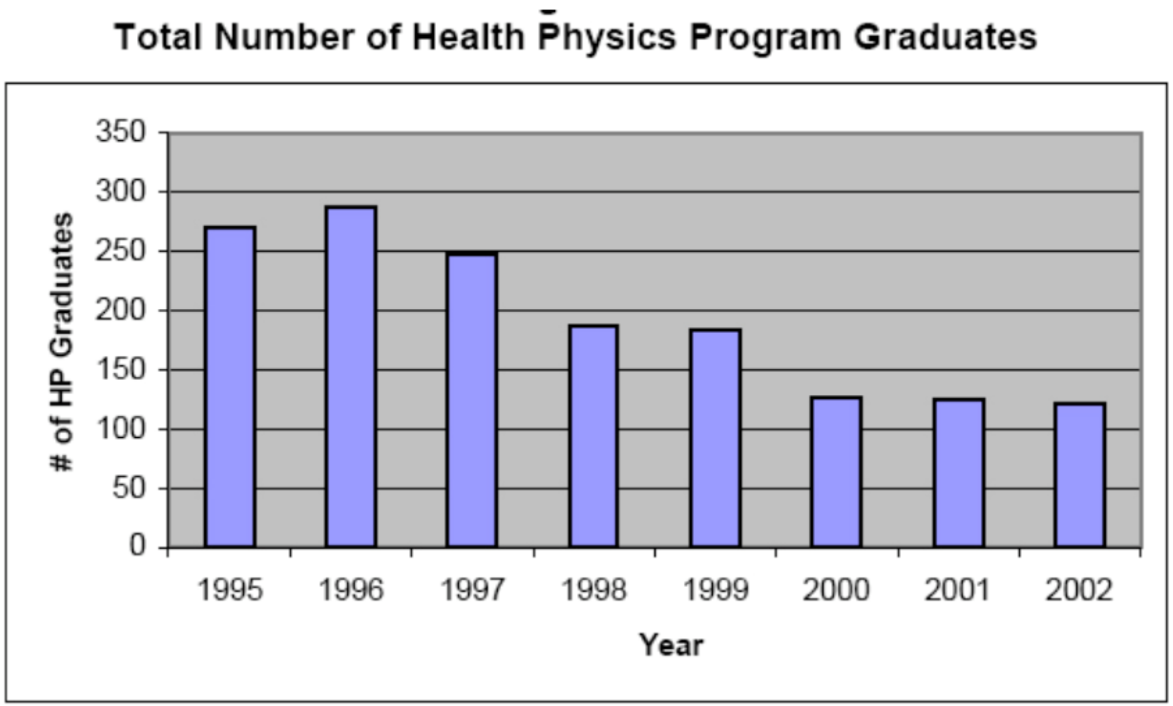
- Several decades of stagnancy of nuclear industry in United States and globally
- Little incentive for students to pursue health physics and related radiological science university programs
- Large number of radiation safety personnel reaching retirement age
- Lack of funding of academic research and educational health physics programs

We Are Getting Older



Health Physics Society, 2004

Until Recently, #s of New Graduates Declining



Health Physics Society, 2004

But Trend is Changing – More New Graduates in Recent Years

Health Physics Enrollments, Degrees, and Estimated Available Supply

Year	Total Enrollments	Total Degrees	Estimated Supply of New Graduates
1999	478	192	109
2000	393	136	81
2001	447	131	60
2002	425	137	73
2003	505	154	80
2004	568	132	60
2005	624	169	81
2006	639	173	83
2007 estimated		*~195*	*~95*
- - -			
2010 estimated		*~205*	*~100*

ORISE, 2007

Current Trends 2005 – 2007: Some Good News (ORISE, 2007)

- Number of undergraduate and graduate degrees increasing relative to previous few years
- Enrollments continue to increase therefore more graduates expected
- Modest growth in total number of new HP positions available
- Over 200 / year new job opportunities for graduate level HPs
- However, need for replacement due to attrition also increasing – more retiring
- Approximately 2:1 ratio in number of job opportunities vs. number of new graduates

Conclusions: Opportunities for Radiological Scientists, Engineers and Health Physicists in the U.S. Uranium Recovery Industry

- Increase in number of new and re-constituted uranium recovery projects in last few years is creating needs for radiological scientists and engineers:
  - Radiological engineering to incorporate ALARA in design
  - Preparation of permit and license applications
  - Environmental monitoring and radiological impact assessment
  - Operational health physics / radiation safety
  - Independent QA audits / assessments of performance (ALARA)
  - Worker training
  - Public education and outreach

Questions?

Steve Brown, CHP
SENES Consultants Ltd
Englewood, Colorado USA
sbrown@senes.ca

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