Safeguarding Uranium Enrichment: The Challenge of Large Gas-Centrifuge Facilities

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Outline

- Overview of uranium enrichment
- Application of International Atomic Energy Agency (IAEA) safeguards at uranium enrichment plants
- Safeguards challenges presented by large gas centrifuge facilities
- Safeguards measures being investigated

Overview of Uranium Enrichment

- **Existence of isotopes discovered at beginning of 20th century**

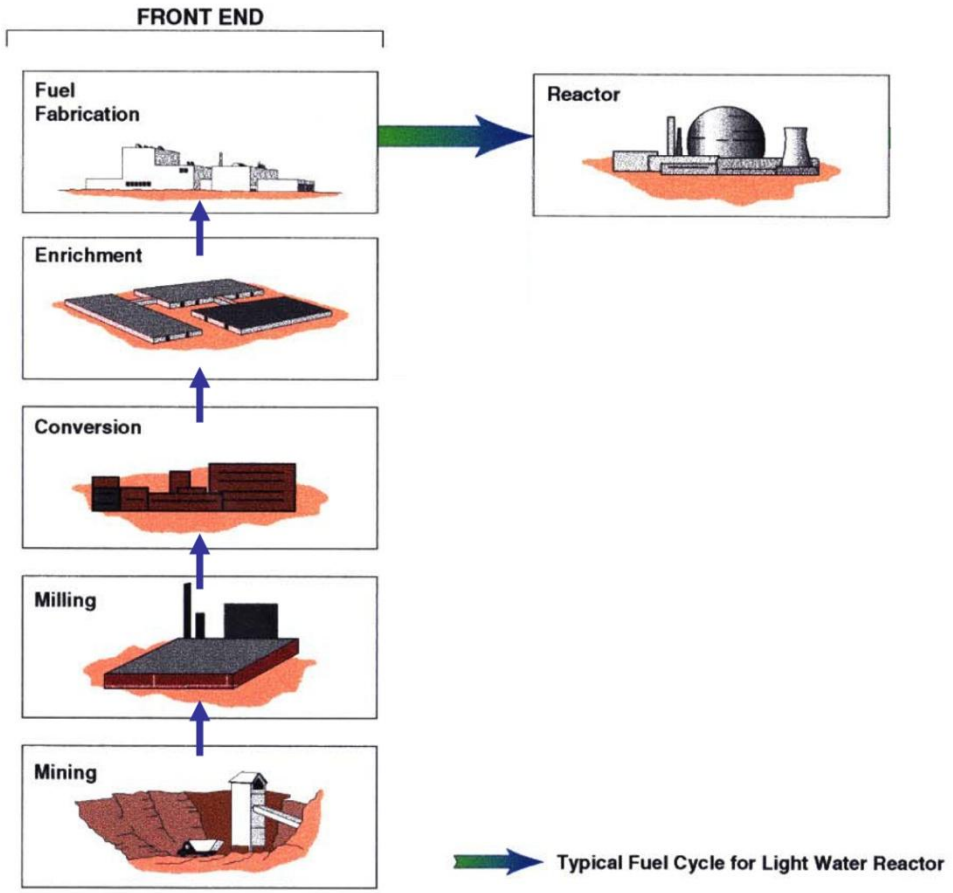
- **Early isotope separation**
  - **1920s-1930s: extremely small quantities of neon, chlorine, etc., separated using a variety of techniques (e.g., gaseous diffusion, thermal diffusion, gas centrifuge)**

Overview of Uranium Enrichment (Cont)

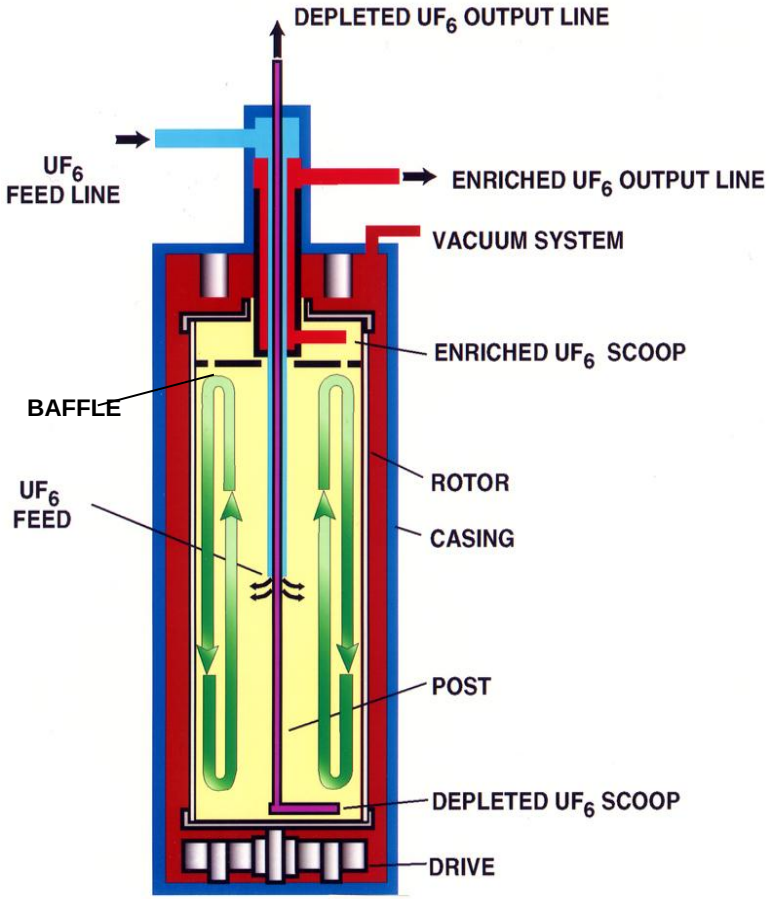
- **1940s-1950s: uranium enrichment was pursued on industrial scale for military motives**
- **Gaseous diffusion plants in U.S., Russia, England, France, and China**

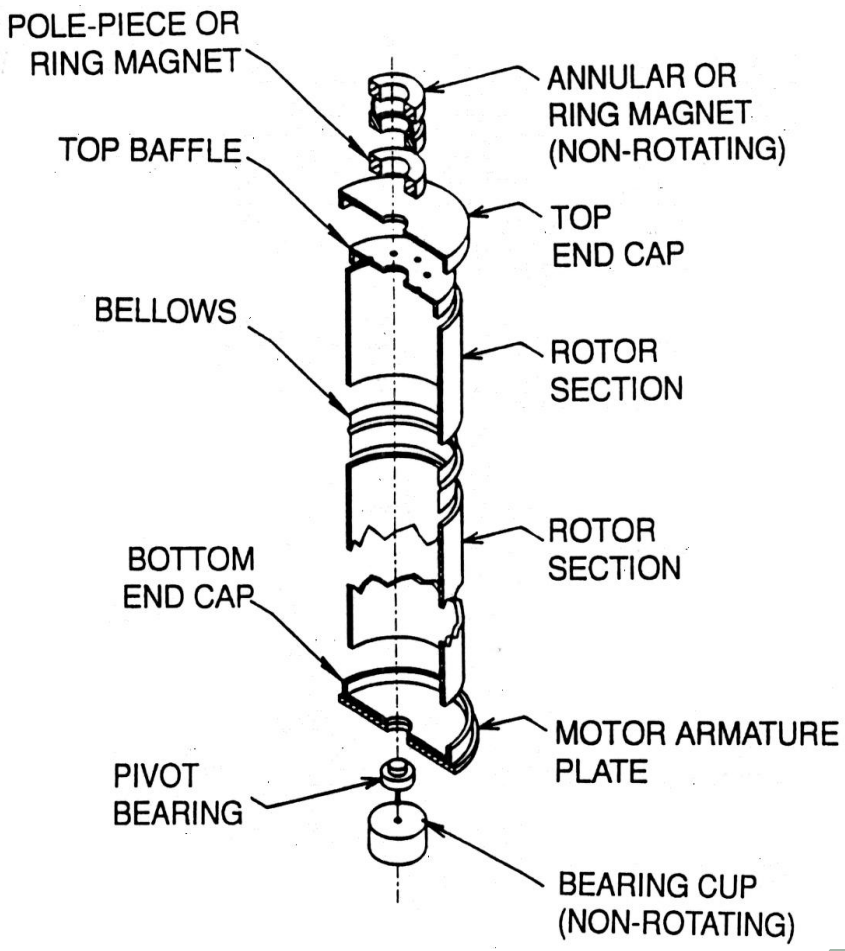
Overview of Uranium Enrichment (Cont)

- 1960s-1980s: Focus shifted to peaceful uses
- Gas centrifuge programs emerged in U.S., Russia, England, Germany, Netherlands, and Japan

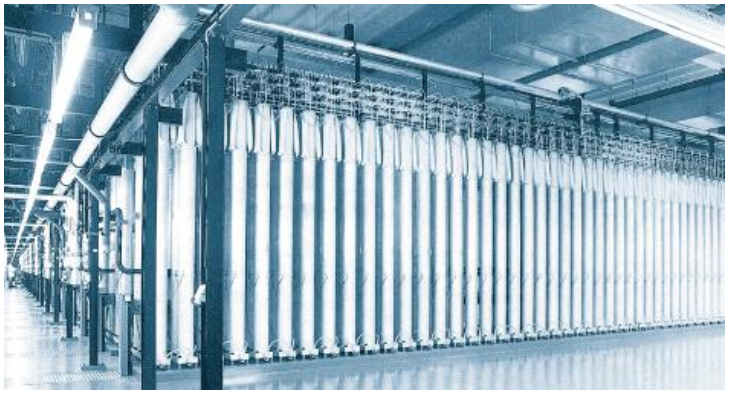


Schematic of a Gas Centrifuge

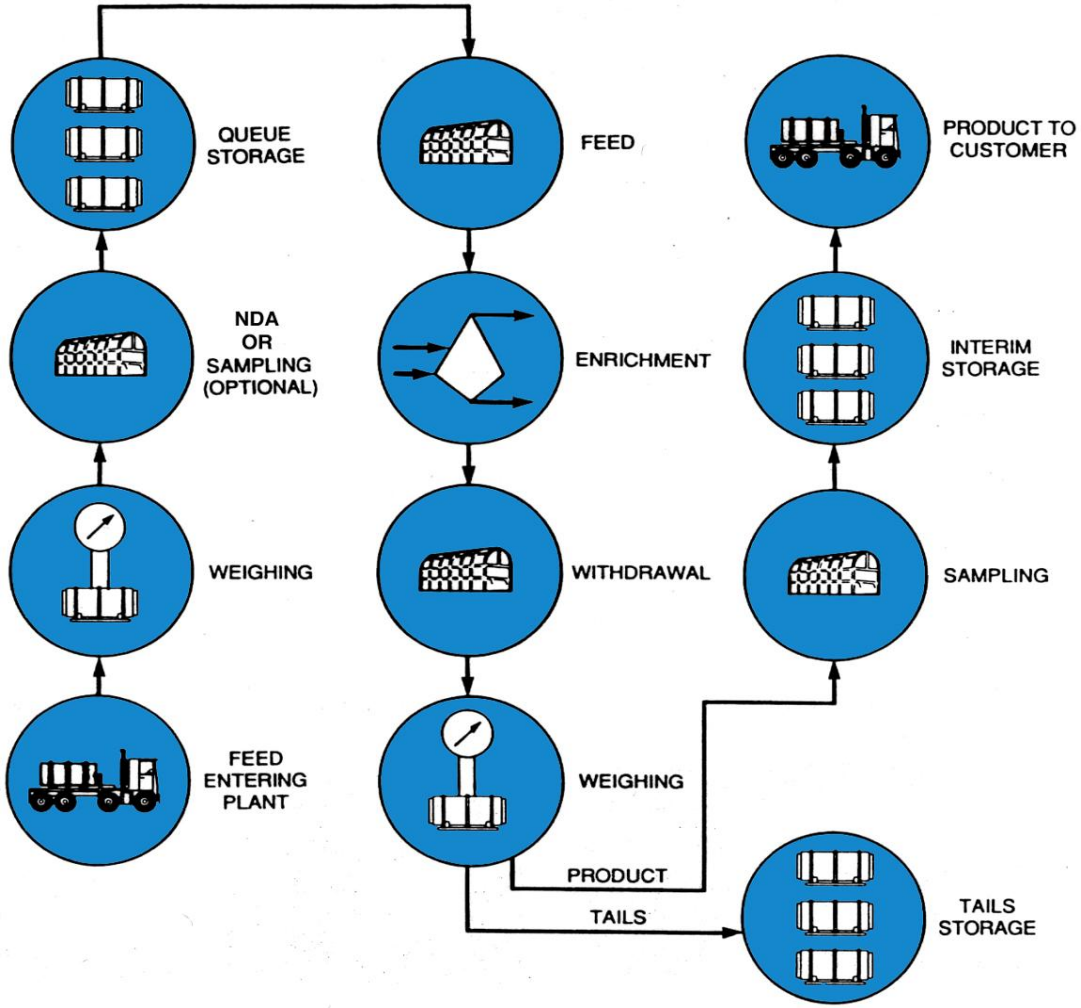




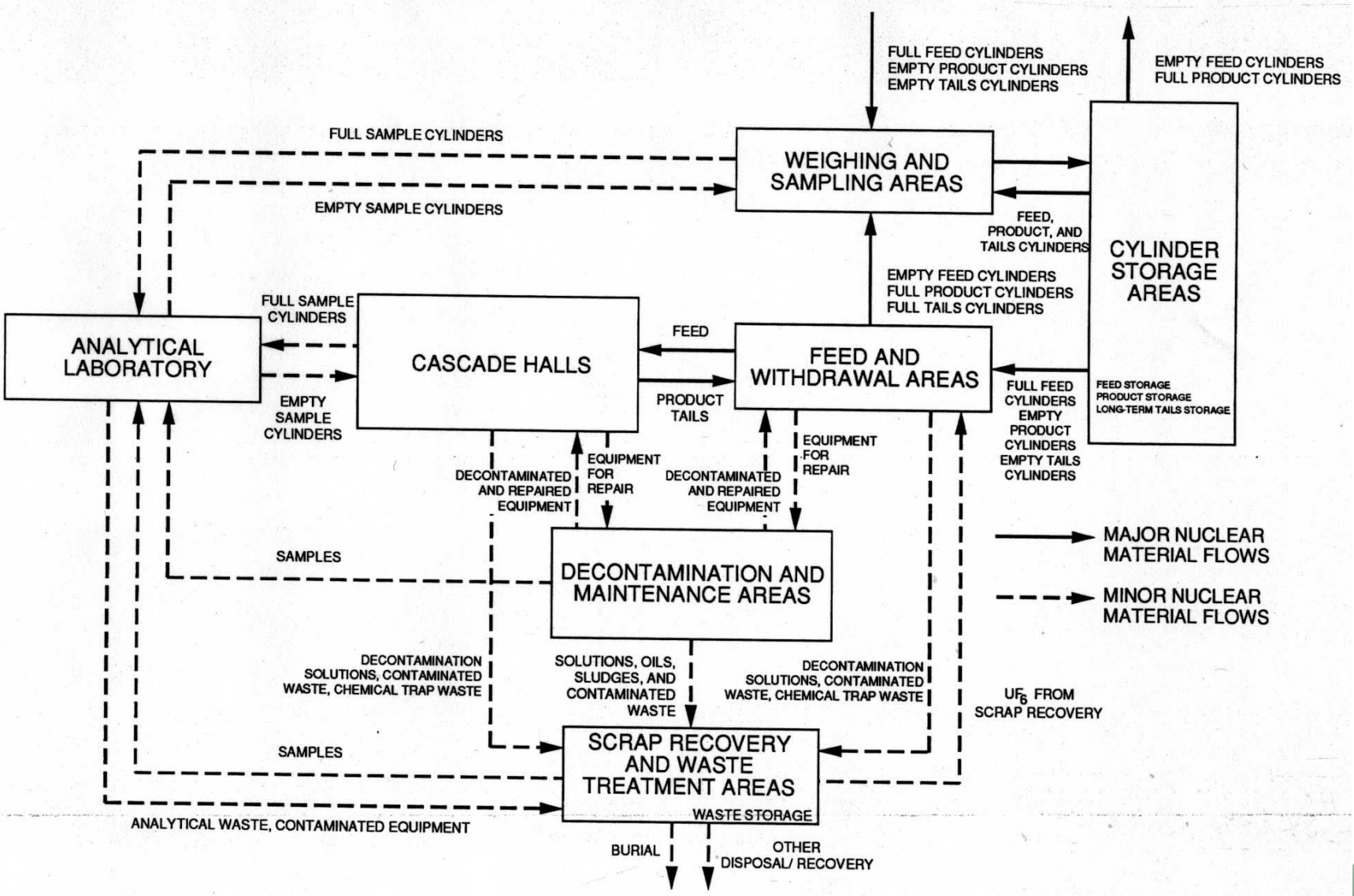
Examples of Gas Centrifuge Cascades



Typical Operations at a UF_6-based Enrichment Plant



Typical Material Flows



Large-scale Enrichment Facilities

Plant Name	Operator	Separative Capacity (t-SWU/year)
George Besse I, Tricastin, France	CEA	10,800: Gaseous Diffusion
Gronau, Germany	Urenco	3,200: Gas Centrifuge (still expanding)
Rokhasho, Japan	JNFL	1,050: Gas centrifuge
Almelo, Netherlands	Urenco	4,600: Gas centrifuge (still expanding)
Capenhurst, UK	Urenco	5,000: Gas centrifuge
4 plants, Russia	Rosatom	2,500 – 12,800: Gas centrifuge (>27,000 total and expanding)
Paducah, Kentucky	USEC	11,300: Gaseous Diffusion

Introduction to IAEA Safeguards

- Provides international assurances on voluntary declarations made by members through various treaties
- Established in 1957
- 151 member states
- ~2,300 professional and support staff from ~100 countries
- 2010 inspection statistics:
  - Applies safeguards to >600 facilities and LOFs
  - Applies safeguards to ~172,000 SQs of material
  - ~2150 inspections
  - ~116M Euro (~$150M) budget + 18.2 Euro extrabudgetary

IAEA Safeguards Objectives

- **Objectives of IAEA safeguards at uranium enrichment plants:**
  - **Timely detection of the diversion of UF_6**
  - **Timely detection of the misuse of the facility to produce undeclared product (at declared enrichment levels) from undeclared feed**
  - **Timely detection of the misuse of the facility to produce UF_6 at higher than declared enrichment level – in particular, HEU**

IAEA Safeguards Measures

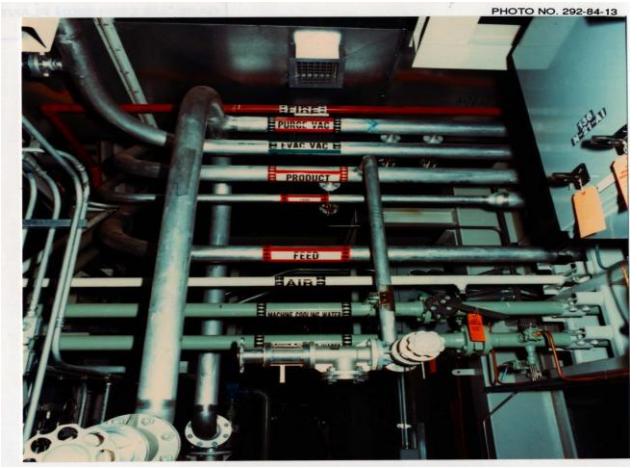
- **Nuclear material accountancy**
- **Containment and surveillance (C/S)**
- **Inspection**

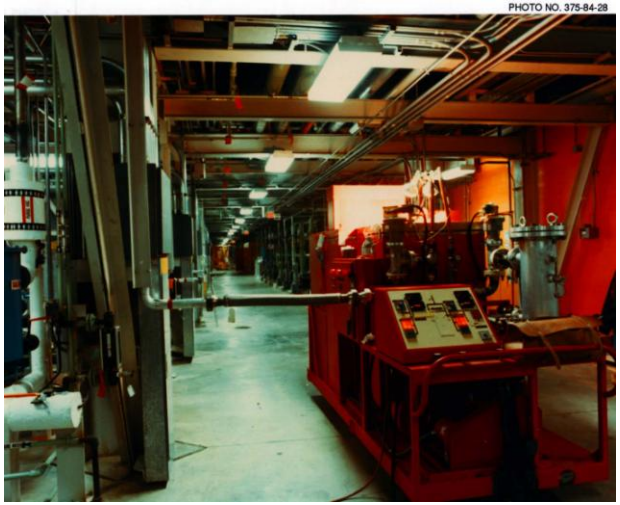
Safeguards Challenges at Enrichment Plants

- No current means to independently verify actual separative capacity
- Many aspects of cascade design and operation are classified or proprietary
- IAEA budgetary constraints
- Necessity to minimize impact on operations

Indicators Associated with HEU Production

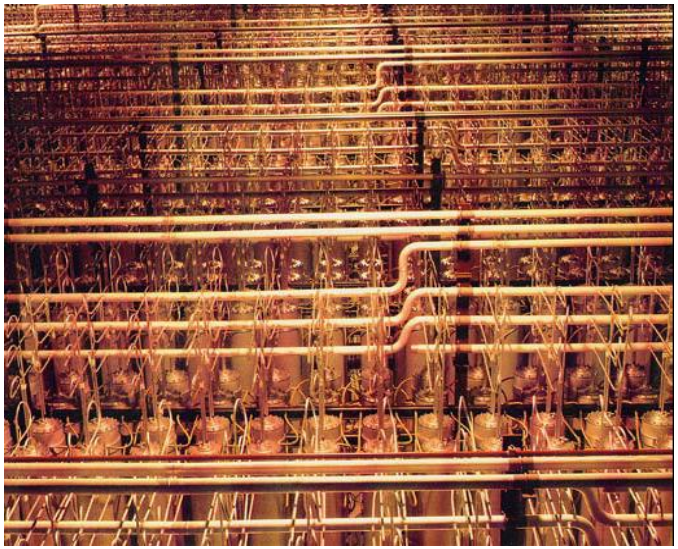
- Reduced throughput
- Portable feed and withdrawal equipment/stations in cascade area
- Extra UF_6 cylinders in cascade area
- Valve settings
- Piping reconfigurations (e.g., inter-cascade piping, feed/ withdrawal points)
- Radiation signatures indicating HEU
- Ratios of minor isotopes

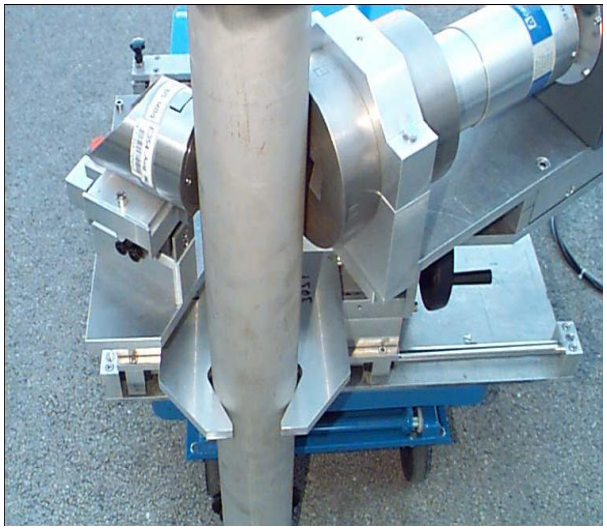




Initial Cascade Area Inspection Activities

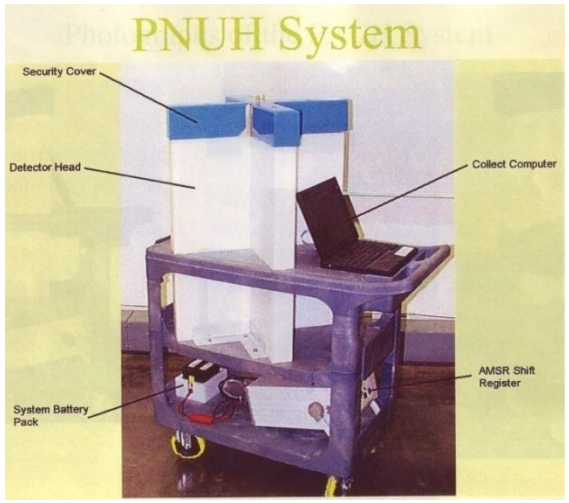
- **Limited-Frequency, Unannounced Access (LFUA) – 1980s**
  - **Visual observation**
  - **Radiation monitoring and NDA measurements**
  - **Sampling**
  - **Application and verification of seals**

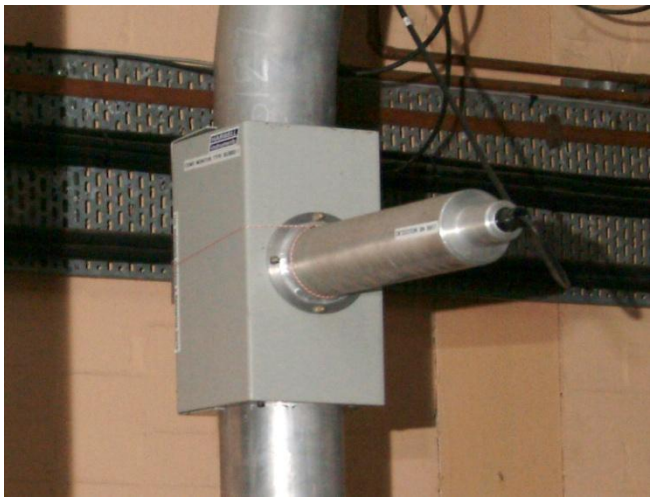




Additional Cascade Area Inspection Techniques

- Added since early 1990s
  - Environmental sampling
  - Continuous on-line enrichment monitors
  - Portable neutron uranium hold-up counter





Global Enrichment Capacity is Expanding

- Advanced Centrifuge Plant in U.S. (USEC) – 3,800 t-SWU
- URENCO USA (Urenco) – 3,000 to 5,700 t-SWU
- George Besse II in France (Areva) – 7,500+ t-SWU
- Eagle Rock in U.S (Areva) – 3,300 t-SWU
- Global Laser Enrichment (GE-Hitachi) – 3,000-6,000 t-SWU

Current Safeguards Challenges

- Still no means to independently verify actual separative capacity
- Many aspects continue to be classified or proprietary
- Continued IAEA budgetary constraints
- Large-capacity plants make LFUA inspections difficult
  - More cascades to verify
  - Operationally more flexible & automated
  - <.2% capacity of 3,000 t-SWU plant needed to produce 1 significant quantity

Recent Events Influencing IAEA Safeguards Approach

- Meetings among technology holders
  - IAEA hosted meeting in Vienna (April 2005)
  - DOE hosted meeting at ORNL (July 2008)
  - Urenco hosted meeting in U.K. (Dec. 2009)
- IAEA developed “Model Safeguards Approach” (2006)

IAEA Needs

- **Needs identified during April 2005 technology holder meeting**
  - **Short-notice random inspections**
  - **Continuous monitoring of operations**
  - **Shared use of operator data**
  - **Continuous item monitoring**
  - **On-site analytical capabilities**

Safeguards Measures Being Investigated

- Continuous, unattended UF_6 verification
  - Cylinder tracking
  - Process scale monitoring
  - Enrichment monitoring
  - Accountancy scale monitoring
- Portable analytical instruments
- New design information verification (DIV) tools

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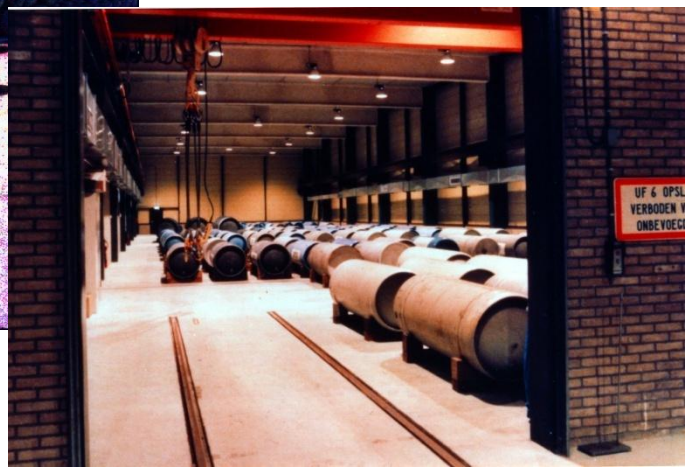
Cylinder Tracking

Enhanced tools for inventorying of UF_6 cylinders



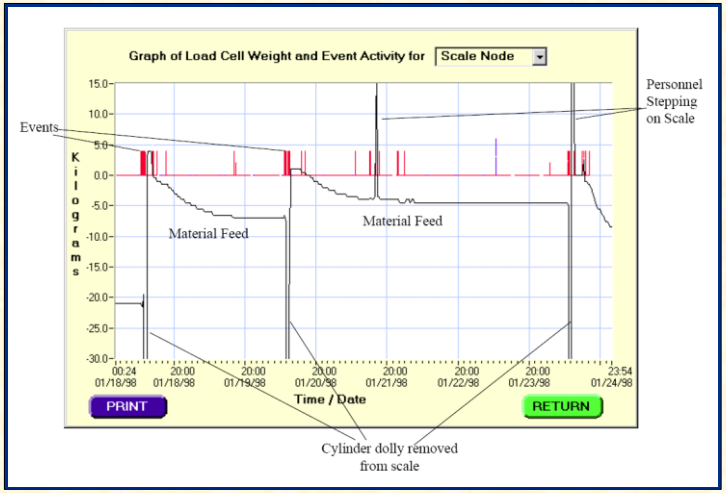
Continuous Feed & Withdrawal Area Verification

Continuous monitoring of feed and withdrawal operations

Continuous UF_6 Flow Verification

Continuous monitoring of process load cells in feed and withdrawal areas

Continuous Load Cell measurement helped IAEA Inspectors verify declared activity



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DIV Instruments

- 3 dimensional – DIV systems to identify changes in piping
- Gamma and neutron imaging to identify changes in material flows

Smaller Enrichment Facilities

- **New safeguards measures should be applicable to smaller enrichment facilities:**
  - **Natanz, Iran: ~100 t-SWU/year**
  - **Resende, Brazil: ~120 t-SWU/year**

Final Thoughts

- **The increase in separative capacity of current plants and the start of construction of future large-capacity plants has reinvigorated the safeguards community to evaluate the effectiveness of the IAEA safeguards approach**
- **The IAEA has already established a new model safeguards approach and is investigating additional novel tools and techniques**
- **Several member states (including the U.S.) are evaluating new safeguards measures (based on current technology) to better address the verification of process flows**
- **These new measures will likely be applied globally and strengthen IAEA safeguards at all enrichment facilities**