Introduction to Gas Centrifuges

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Topics to be covered

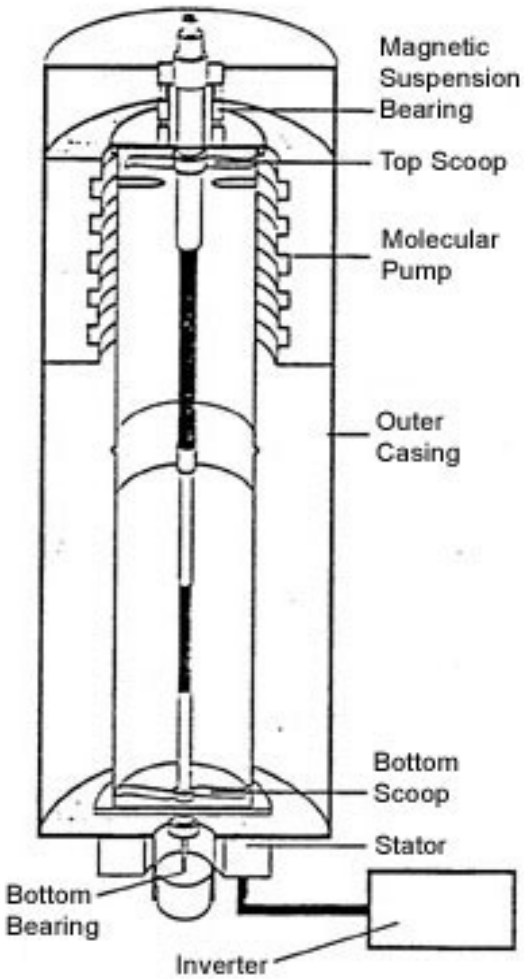
- History
- A typical centrifuge
- Cascades
- Examples of existing centrifuge cascades
- Lifecycle of a gas centrifuge

Early Days

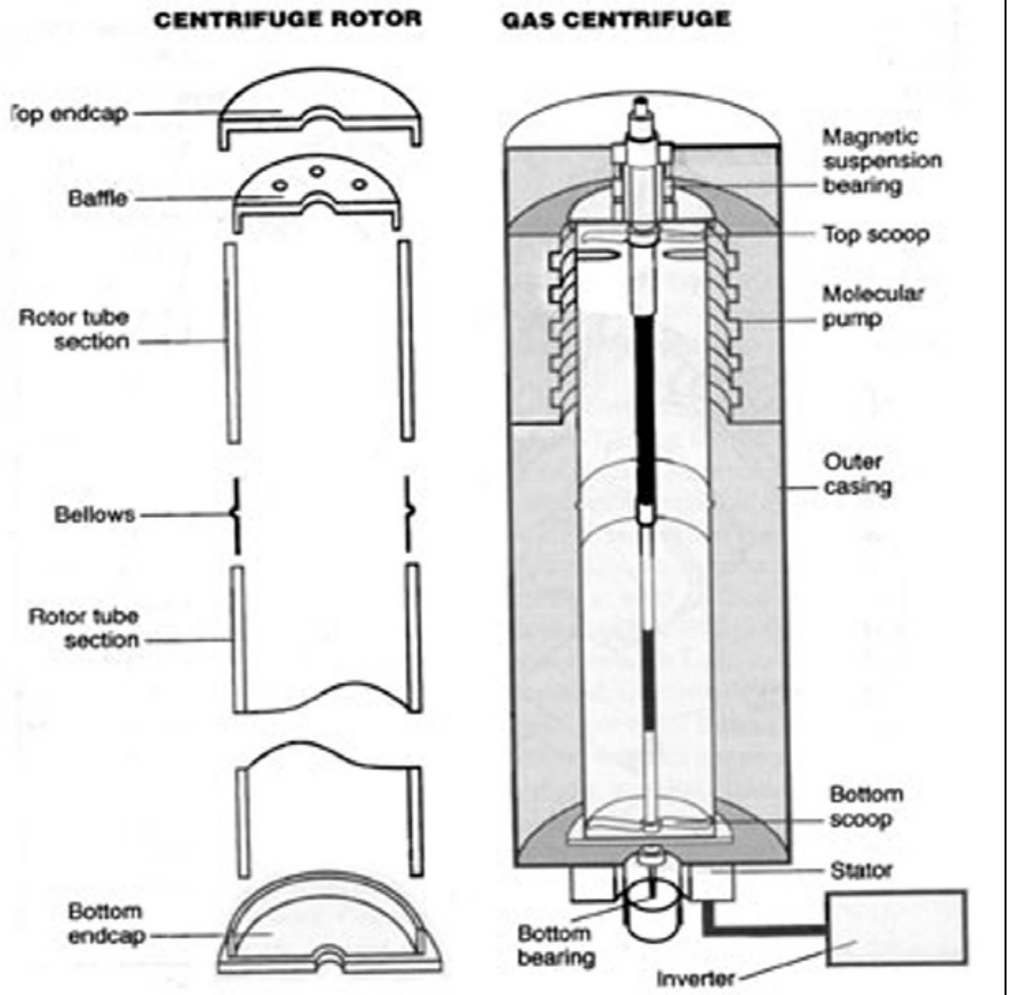
- Isotopes were discovered in early 1900's.
- Centrifuge separation of isotopes first suggested by Lindemann and Aston (1919)
- Chapman, Mulliken, Harkens and others tried unsuccessful experiments.
- First successful experiments at UVA in 1934 by Prof. Jesse Beams with isotopes of Chlorine.
- Attempts to use centrifuges in Manhattan project were unsuccessful.

Isotopes of Uranium

- Natural isotopes of Uranium are ^{235}U and ^{238}U
- Fissile isotope is ^{235}U (0.711% in nature)
- *Enrichment* refers to alteration of the isotopic composition (For example, 3 - 4% ^{235}U for power reactors)
- Uranium in gaseous state with Flourine, UF_6.

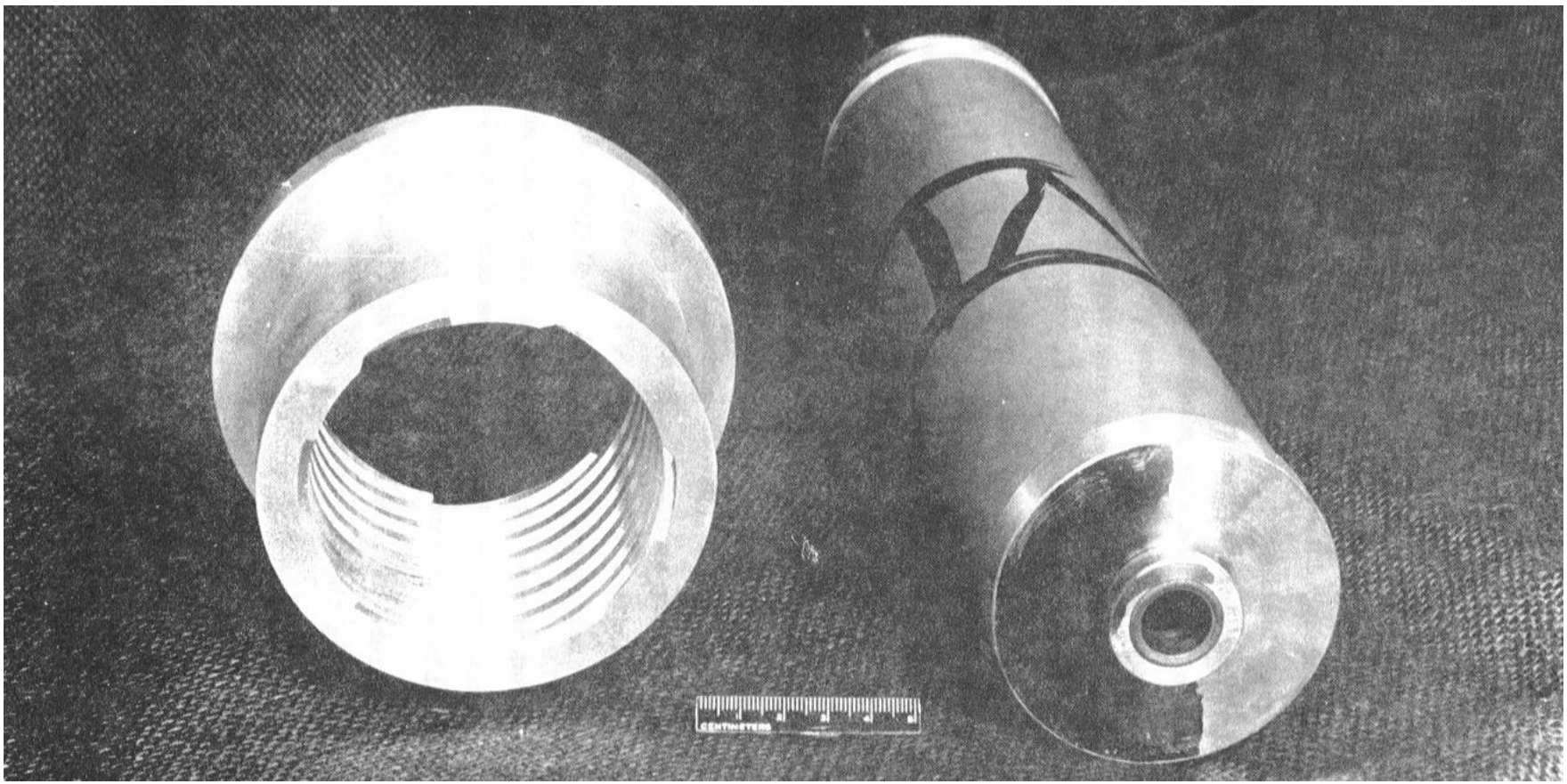


Source: David Albright Drawing: Jandos Rothstein

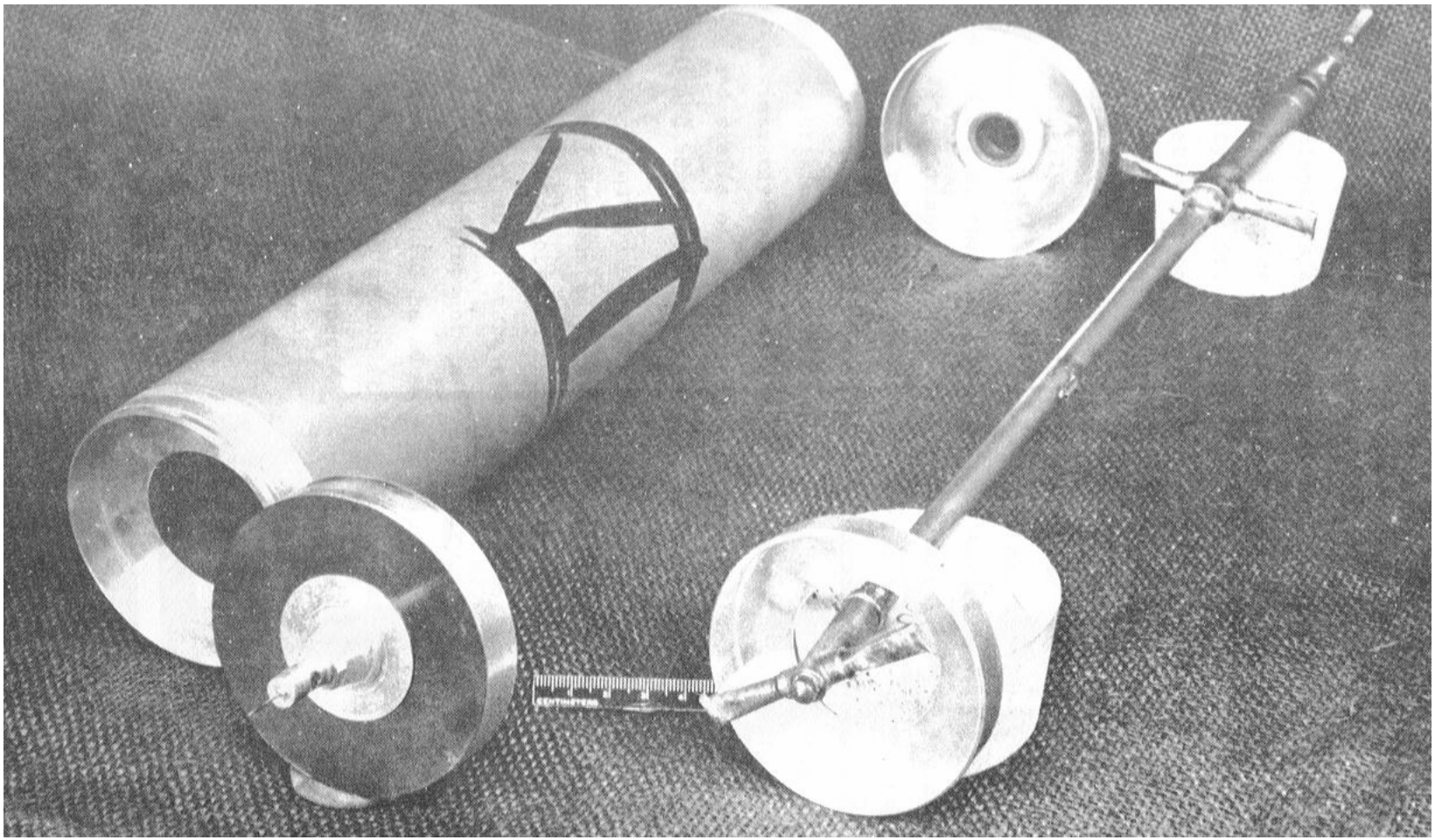


Source: Albright, D. and Hibbs, M., 'Iraq's shop-till-you-drop nuclear program', *Bulletin of the Atomic Scientists*, vol. 48, no. 3 (Apr. 1992), pp. 32 and 33.

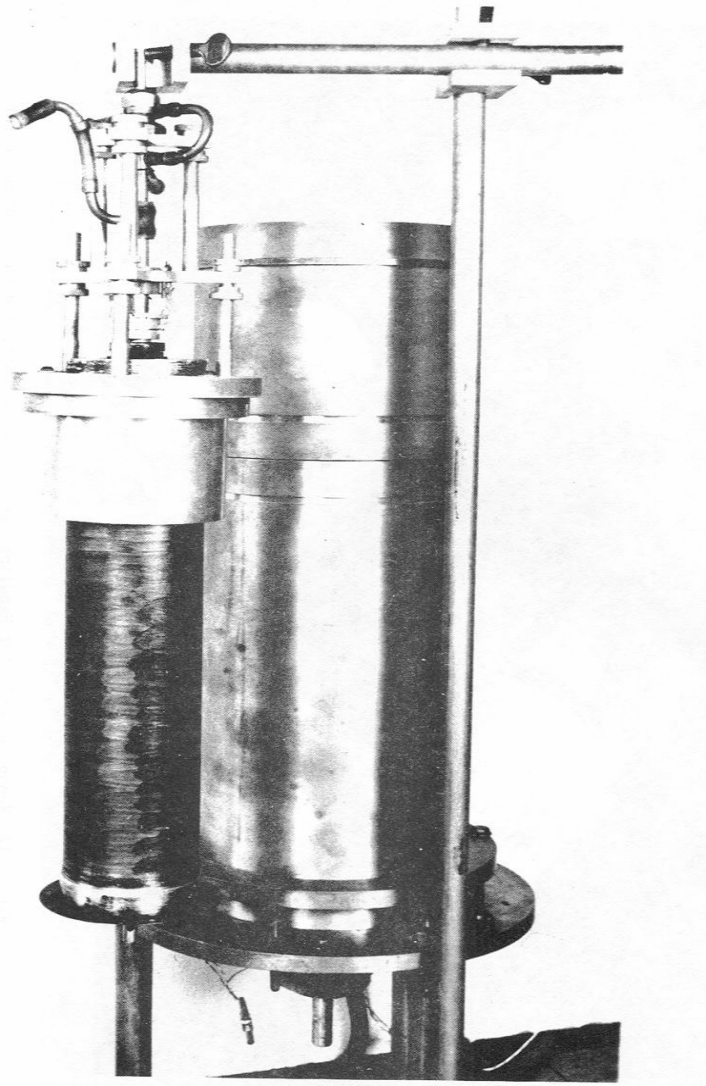
Molecular Pump & Rotor



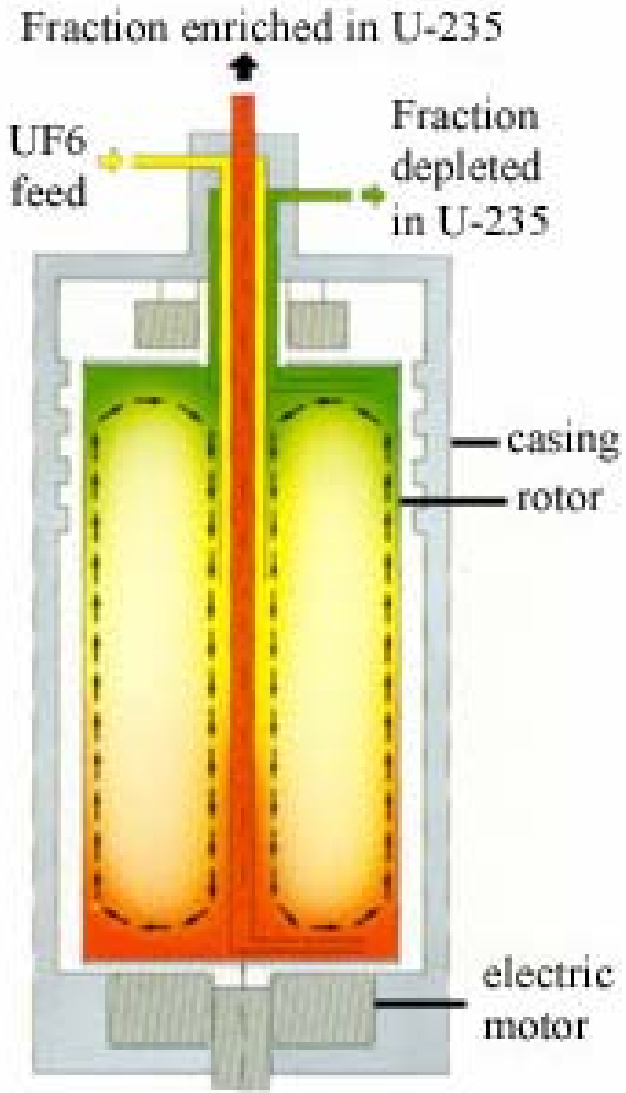
Scoop Assembly



Rotor With Pump & Scoops



Countercurrent Centrifuge



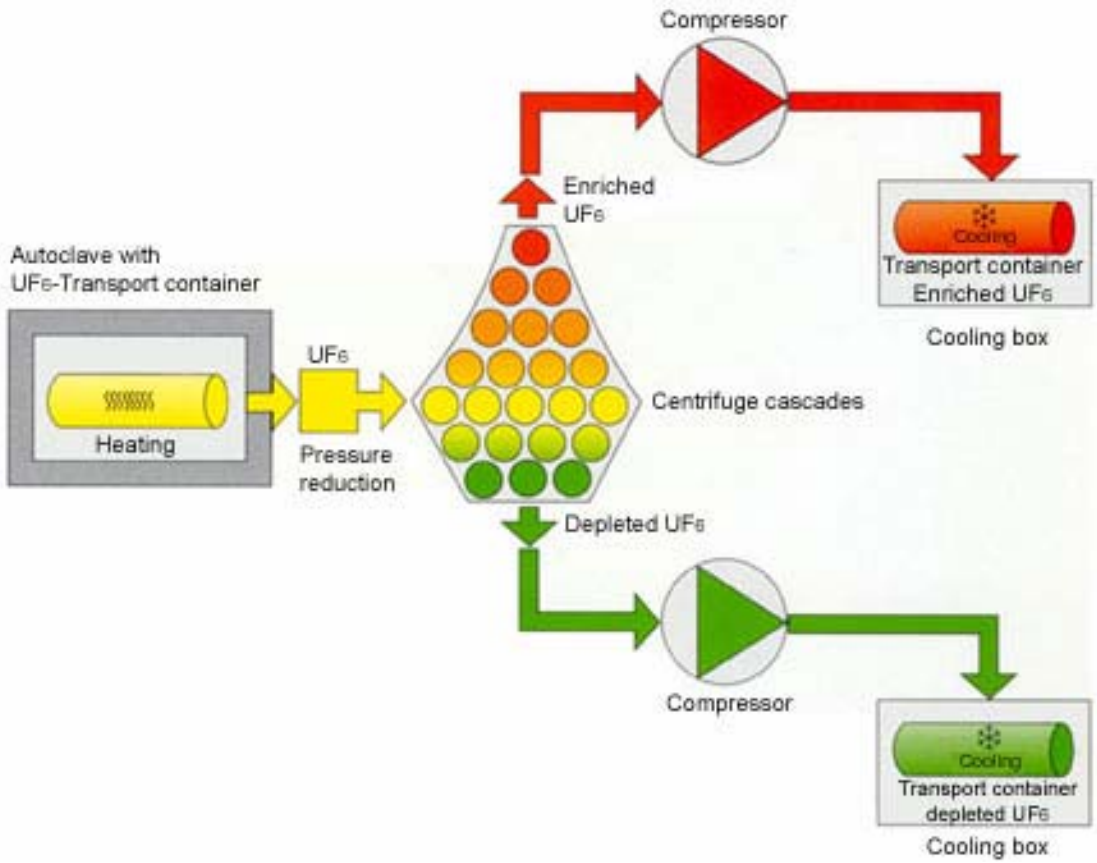
Countercurrent Gas Centrifuge

- UF_6 gas enters the interior of the centrifuge from a pipe at the center of the centrifuge rotor.
- Gas is removed with more ^{235}U at one end of the centrifuge rotor and more ^{238}U at the opposite end of the centrifuge rotor.
- Gas is removed inside the centrifuge by stationary pipes called “scoops.”

Cascades

- Centrifuges do not generally produce desired enrichment in one machine.
- Machines are connected in series to attain the desired enrichment and in parallel to attain the desired product flow rate.
- This arrangement is called a *Cascade*.
- The amount of enrichment performed is called Separative Work and is measured in Separative Work Units (SWU).
- SWU usually has units kgU/year.

Cascade Schematic



Kurchotov Institute - Moscow

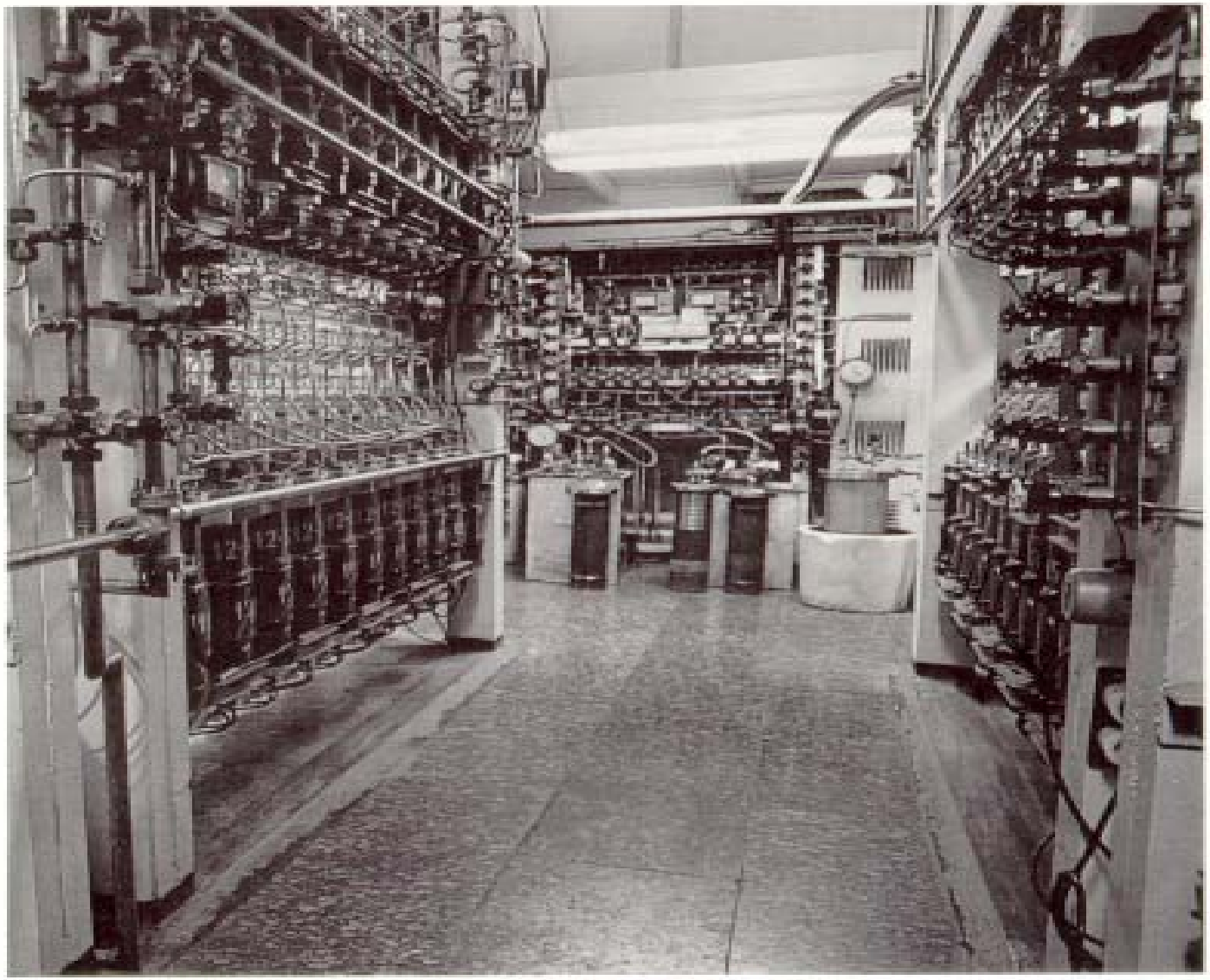


Fig. 2. The separation centrifuge facility for production of chromium-50.

Kurchotov Institute - Moscow

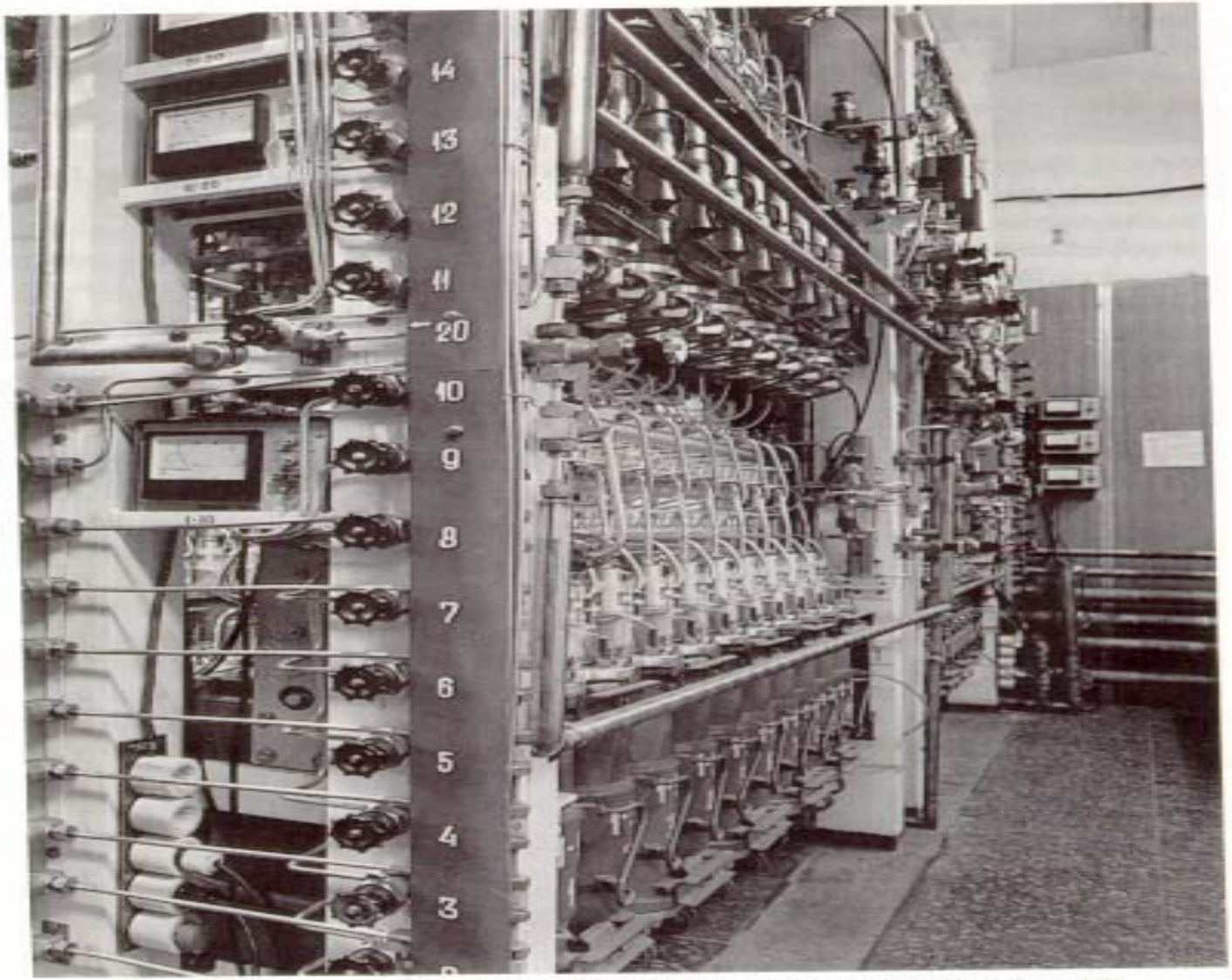
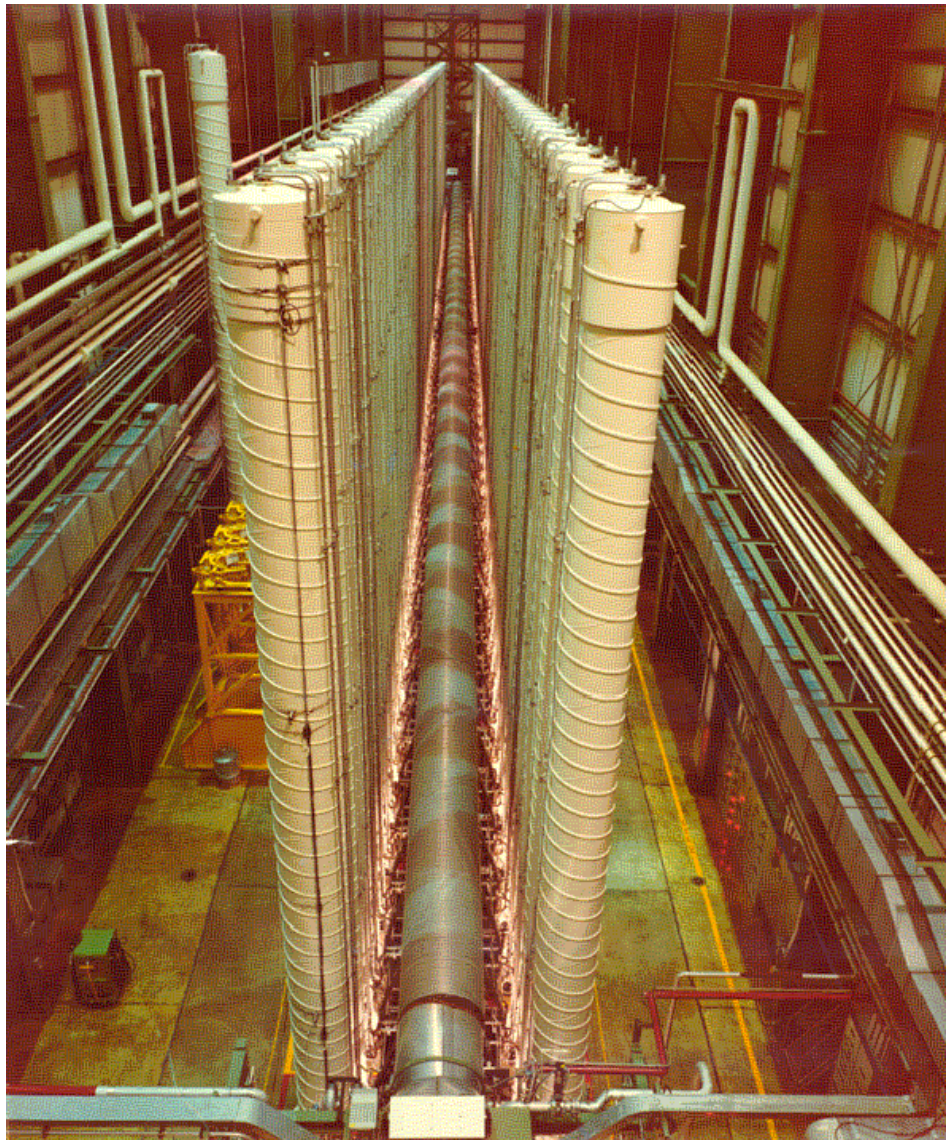


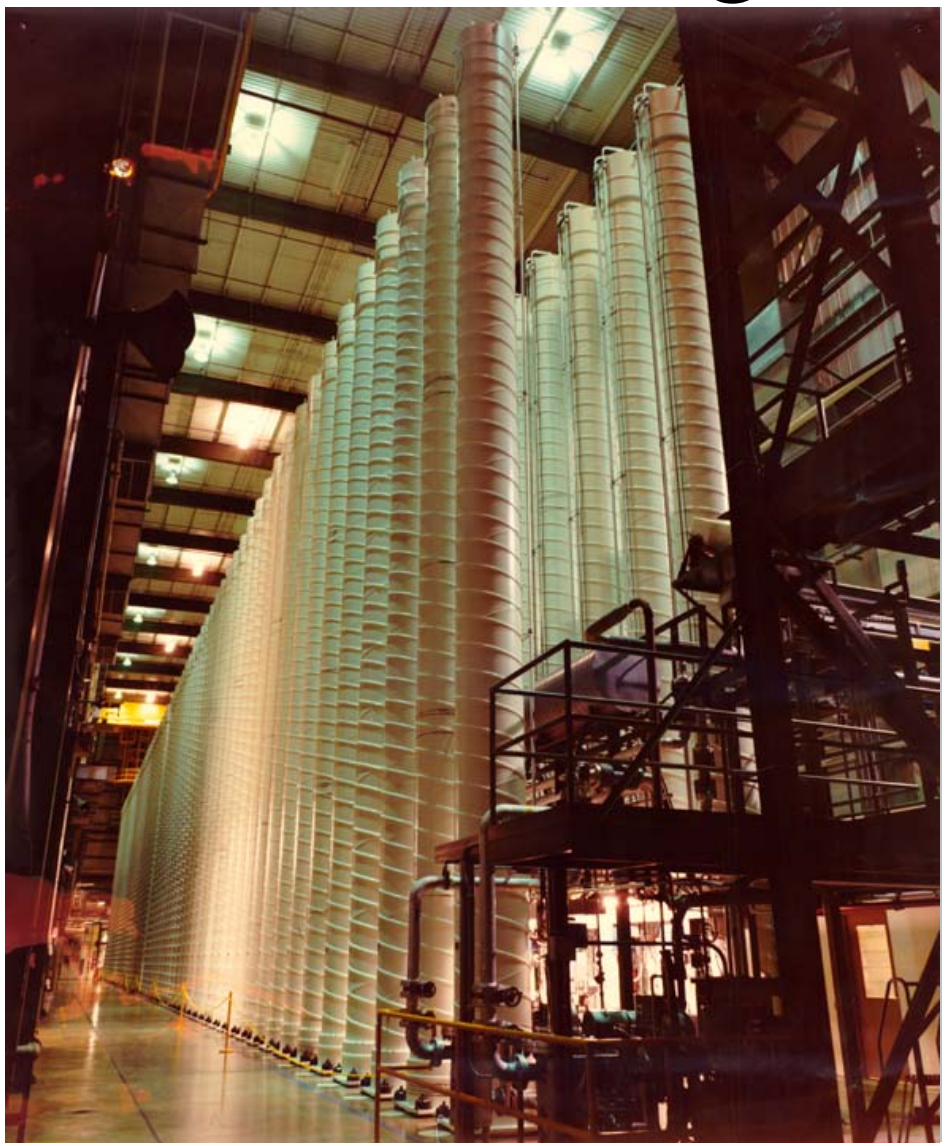
Fig. 3. The separation centrifuge facility for production of chromium-50.

Enrichment Plant at Almelo

U.S. Centrifuges



U.S. Centrifuges



Lifecycle Overview

- Creation of a gas centrifuge program requires commitment, resources, and time.
- A program must establish its objectives, strategies, and policies.
- A program will need to go through several stages to build an operational gas centrifuge facility, including the development of a prototype centrifuge and the creation of an industrial infrastructure aimed at researching, developing, testing, and building gas centrifuges.

Program Objectives

- Many decisions need to be made before a gas centrifuge program is started.
- Decisions are required about the type of centrifuge, the annual goal for enriched uranium production, the methods of acquiring necessary technology, equipment and materials.

Strategies

- The program must decide whether to buy a complete gas centrifuge plant or create the industrial infrastructure to make centrifuges.
- The creation of an indigenous industrial gas centrifuge infrastructure depends on domestic or overseas acquisition.
- If sensitive raw materials, equipment, and parts are acquired overseas, the program must decide about the quantities to acquire and when to acquire them.

Policies

- The program may decide to focus on small, short-time scale technical targets. The aim would be to rapidly reach conclusions that can facilitate decision-making on major goals and identify technical shortcomings or a lack of understanding.
- Alternatively, the program may be able to define large, long-time scale targets.

Policies (cont.)

- The program must decide how to recruit and train a competent staff.
- It must establish methods to acquire centrifuge expertise and experience. For example, will foreign experts be sought for technical assistance and participation in experimental work?
- If items are procured overseas, the program must establish the methods to acquire these items, including procurement organizations and networks, transport routes, and payment methods.

Policies (cont.)

- Relationships must be developed between the gas centrifuge program and other national entities that are part of foreign procurement or that are needed in the design, manufacture, construction, or modification of components, buildings, and utilities need for the program.

Steps to an Operating Centrifuge Plant

- Prototype centrifuge development
- Creation of research and development facilities
- Building centrifuge manufacturing facilities
- Using supporting infrastructure
- Making uranium hexafluoride (UF_6)
- Building an experimental centrifuge cascade
- Building production-scale cascades
- Maintaining and improving centrifuges

Prototype Centrifuge

- Design development
- Procurement
- Parts manufacture
- Facility construction
- Mechanical testing
- Process testing with UF_6

Research and Development Facilities

- Construction of workshops for centrifuge research and development work in parallel to the development of the prototype centrifuge.
- Design requirements for prototype centrifuge and cascade development work

Centrifuge Manufacturing

- Design of plant and workshops
- Construction activities, including clean rooms
- Procurement of technology, equipment, and materials
- Commissioning of plant and fixing production technology

Supporting Infrastructure

- Other organizations and industrial facilities and activities that support the gas centrifuge program
- Political decision-making bodies and organizations that oversee or control the gas centrifuge program

Uranium Hexafluoride (UF_6) Production

- Development of technology and designs
- Laboratory-scale units
- Preparation of UF_6 for separation tests in prototypes (kilogram quantities)
- Procurement of necessary materials and equipment
- Construction of facilities for UF_6 production
- Commissioning

Experimental Cascade

- Studies for centrifuge cascades
- Procurement of necessary materials and equipment
- Design and construction of cascade hall or building
- Erection of piping and centrifuges
- Commissioning

Production-Scale Cascades

- Studies for cascades with hundreds of centrifuges
- Selecting a site
- Procuring necessary materials and equipment
- Manufacturing items
- Designing and constructing cascade building
- Erecting piping and centrifuges
- Commissioning

Maintaining and Improving Centrifuges

- Trouble-shooting and improving centrifuge performance and designs
- Replacing broken or out-dated centrifuges
- Improving and updating manufacturing capabilities and sites
- Procuring additional items