The History of the Gas Centrifuge and Its Role in Nuclear Proliferation

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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.
Early Days at UVA

• Work on centrifuges during Manhattan project had a number of failures.
• Project was terminated.
• Concern over potential competition from German centrifuges led AEC to restart work at UVA in 1955 under guidance of A.R. Kulthau.
Meanwhile in Europe

• German research was being led by Konrad Beyerle in Göttingen and Wilhelm Groth at University of Bonn

• Research in the Netherlands was being directed by Jacob Kistemaker.
USSR

- At the end of WWII, Soviets took many POWs from Germany.
- They started effort to develop nuclear weapons.
- Organization at Sinop:
  - Von Ardenne – Electromagnetic Separation
  - Thiessen – Gaseous Diffusion
  - Steenbeck Group – Included Centrifuge

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USSR (cont’d)

• Competition between gaseous diffusion and gas centrifuge.
• Reputed problems with GD enriching to weapons grade level.
• Centrifuge considered for “topping off.”
• Competition for long rotor vs. short rotor.
• Steenbeck group transferred from Sinop to Kirov plant in Leningrad (~1951).
USSR (cont’d 2)

• Steenbeck managed to get concessions from the Soviets for the Germans to be released when they were successful.

• Steenbeck’s group won centrifuge competition and was transferred to Leningrad in September 1953 to begin quarantine period.
Dr. Gernot Zippe

• He was a flight instructor for Germany during WW II.
• Became POW in Russia after the War.
• He was member of the Steenbeck group who worked on gas centrifuges.
• He refused to work on the long rotors, which ultimately failed.
Dr. Gernot Zippe: 1917 - 2008
Dr. Oswald Francis “Mike” Schuette was US Naval Intelligence officer.

He interviewed Russian POWs, including Zippe.

US AEC was interested in Zippe.

Under a fake passport, Zippe was brought to Washington, D.C. and interviewed by Kulthau and other intelligence agents.

Zippe was then escorted to UVA by Schuette for discussions with Kulthau and others.
Zippe to UVA

- Zippe returned to UVA in 1958 under contract to AEC to reproduce work he had done in Russia.
- Project’s manager was Kulthau.
- Zippe was in a separate building from the Ordinance Research Lab, where classified work was underway.
- Separation tests with UF$_6$ began in Sept. 1959 and continued until end of project in May 1960.
After 1960

• Zippe went to Germany and worked for DEGUSSA, a predecessor company of what eventually became URENCO – a consortium of Britain, Germany and Netherlands.
Dr. A. Q. Khan

- Native Pakistani who worked for Urenco in the Netherlands.
- Took drawings to Pakistan circa 1974
- Developed gas centrifuge program in Pakistan and headed A. Q. Khan Research Institute.
Abdul Qadeer Khan
Spread of Centrifuges

• After first Gulf War in 1991, IAEA inspectors discovered centrifuges in Iraq.
• In 2002, Aluminum tubes headed for Iraq were alleged to be for centrifuges.
• This was proven to be false, but the long secret subject was now being discussed in the media.
• In October 2002, DPRK stated they were building a centrifuge plant.
• It was known A. Q. Khan visited DPRK.
• By January 2003, DPRK denied this.
Spread – II

• In Feb. 2003, IAEA inspector ElBaradei visited enrichment plant at Natanz.
• During 2nd Gulf War in 2003, Mahdi Obeidi turned over centrifuge parts buried in his back yard.
• In 2004, Libya gave up their centrifuges.
• Khan network of centrifuge and weapon design was involved in all of these.
Genealogy of the Gas Centrifuge

(slide provided by Alexander Glaser, PS&GS, Princeton)

Orig. R&D (pre-commercial, "Zippe-connection")
Tech. transfer (confirmed or planned)
Indep. Dev. or unconfirmed foreign assistance
Status or achievement unclear
Gas Centrifuges & Cascades
Separative Work

- Enrichment of uranium is measured by separative work units (SWU) in kgU.
- Separative capacity is SWU per unit time.
- To fuel a typical power reactor requires separative capacity ~125,000 SWU/yr.
- If a single centrifuge has $\Delta U = 10$ SWU/yr, the cascade requires 12,500 centrifuges.
SEPARATIVE WORK EXAMPLE

PRODUCT - 1kg
OF 3\% {^{235}}U URANIUM

NORMAL 0.711\%
{^{235}}U FEED
5.479 kg OF URANIUM

ENRICHMENT STEP

4.306 SWU

SEPARATIVE WORK UNITS (SWU)
MEASURE THE ISOTOPIC
SEPARATION EFFORT INVOLVED
IN THE ENRICHMENT STEP

TAILS - 4.479 kg OF 0.2\% {^{235}}U

Fig. 9: Subcritical, short Centrifuges in Russia
Centrifuge Hall / Almelo
U.S. Centrifuges
Dual Use

• Any uranium enrichment process can be used to make material for fuel in a nuclear power reactor or for a bomb.
• The line between civilian and military use is very thin.
• Are there ways to thicken this line?
Thickening the Line

- Transparency and inspections.
- Safeguards.
- Materials accountability and control.
- Defining a trigger event.
- Clearly stating the response to the trigger.
- Clandestine facilities are another issue.
Questions?

Comments?