SF_6 Utilization at the Holifield Radioactive Ion Beam Facility

HRIBF

Presented to

Fugitive Emissions Working Group

B. Alan Tatum

November 16, 2010

U.S. DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

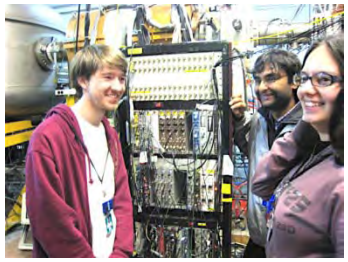
Outline

- HRIBF overview
- Tandem accelerator SF_6 use
- Opportunities for Improvement

HRIBF

- Produces high-quality post-accelerated beams of unstable nuclei
  - Radioactive Ion Beams (RIBs)
- A national user facility for RIB science funded by DOE/Nuclear Physics
  - Users group has 570 members
  - Research programs in two primary areas
    - Nuclear structure & reactions
    - Nuclear astrophysics
  - Operates on a 5 day 24 hour schedule
    - 4000 to 4500 total research hours per year

- Only facility of its type in the U.S.
- Has capabilities that are unique worldwide
  - Beams of n-rich fission fragments at energies above the Coulomb barrier
- Helping to develop ISOL RIB science in the U.S. & worldwide
  - Pioneering techniques, developing technology
  - ISOL team has made many world-leading developments

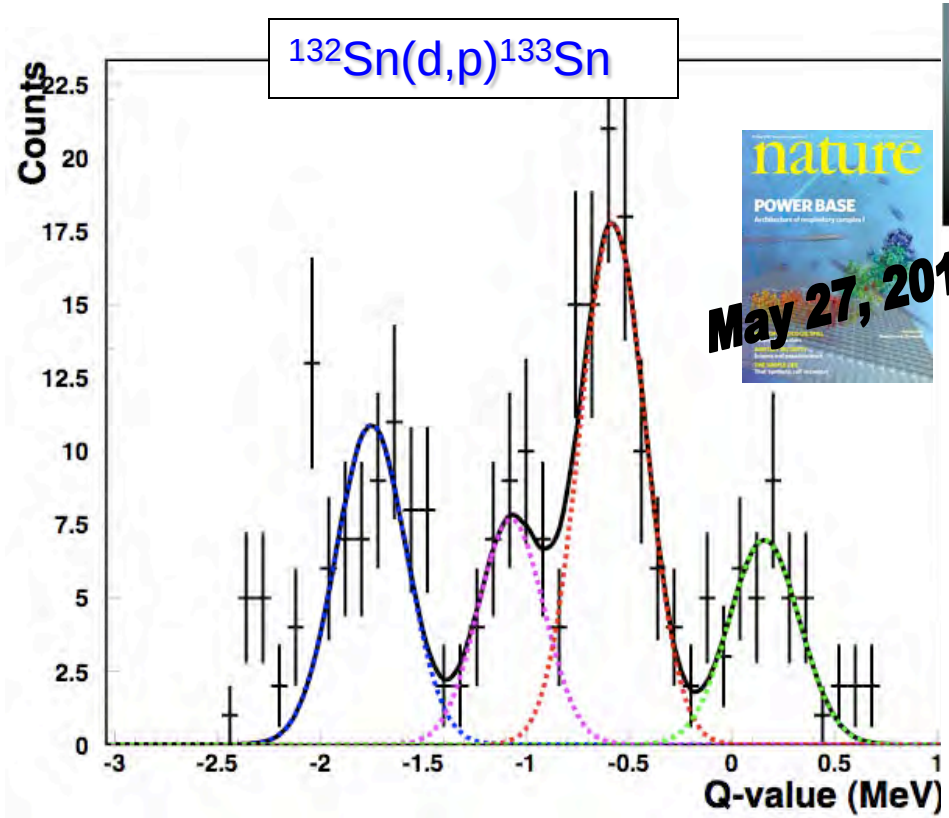


- Provide world-class research tools
- Helping to establish, and maintain an international user base for FRIB era
- Apply core capabilities in nuclear science to problems of relevance to society

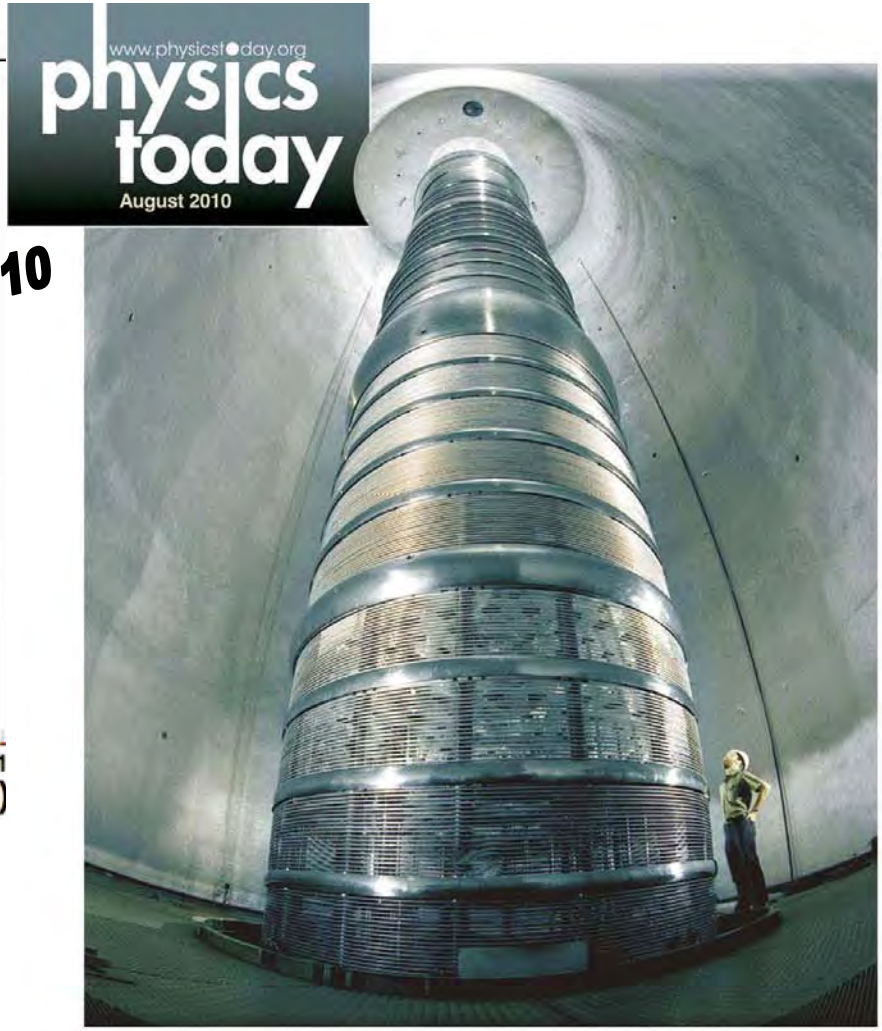
Recent Scientific Accomplishments

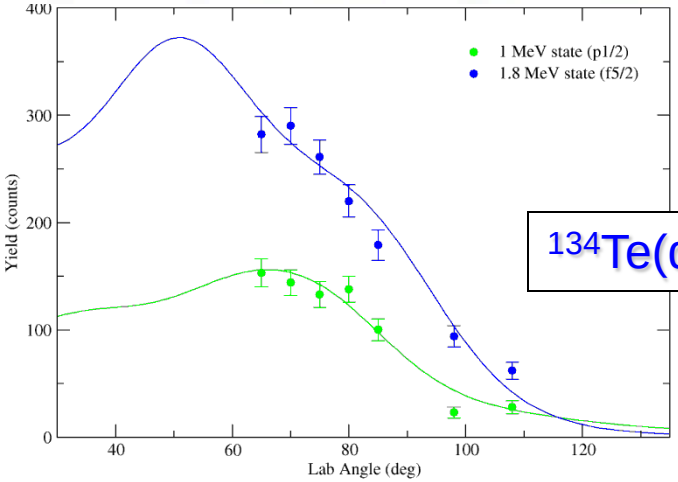
Pioneering nuclear astrophysics studies

Rapid neutron capture process (d,p) studies



May 27, 2010

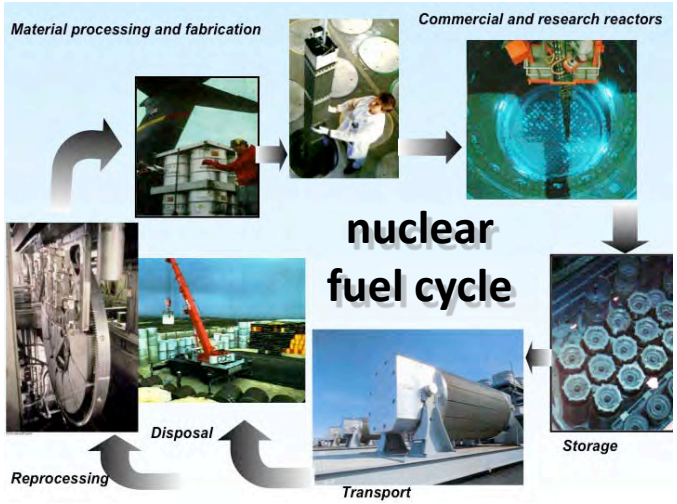




$^{134}Te(d,p)^{135}Te$

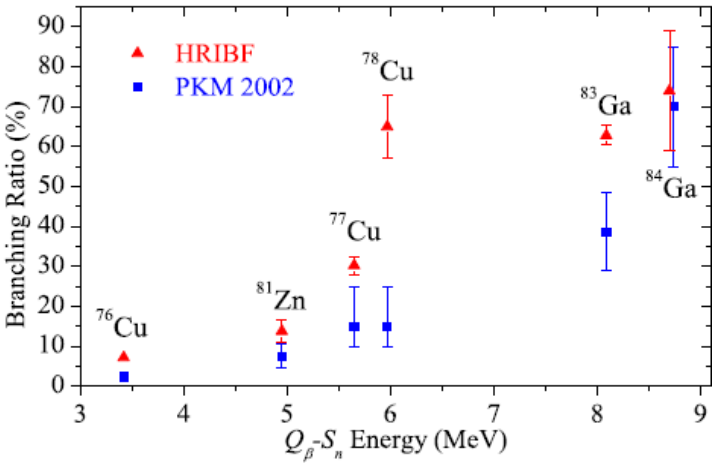
Decay Studies at HRIBF (Societal Applications)

How knowledge gained and core capabilities in nuclear science can serve society and national priorities



Schematic demonstration of the applicability of the calculations performed within the Standardized Computer Analyses for Licensing Evaluation (SCALE)

J.A. Winger et al., Phys. Rev. Lett., 102, 142502 (2009)



The data used by SCALE are often outdated and inaccurate. For instance, serious discrepancies have been found between beta-delayed neutron branching ratios from HRIBF and the currently used best values (PKM 2002).

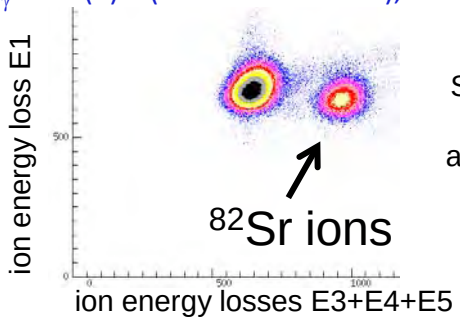
The beta-delayed neutron emission from fission products created in nuclear reactors contributes to the total number of neutrons inducing fission in nuclear fuels. By studying the decay of pure isotopic samples of uranium fission products, we found the intensities of beta-delayed neutrons much higher than previously reported. The HRIBF measurements important for the nuclear fuel cycle will include decay heat released by radioactive nuclei occurring in nuclear fuels – the project will continue in collaboration with reactor scientists from ORNL.

HOT NEWS!!

Ongoing experiment: Verification of ^{82}Sr→^{82}Rb →^{82}Kr decay chain for medical diagnostics

There are ~ 400 patients diagnosed daily in the US by using ^{82}Sr tracer. To estimate the ^{82}Sr production required as well as evaluate the dose received by the patient during medical diagnostics, the decay properties of the ^{82}Sr activity have to be well known. There is a discrepancy in the published data on the intensity of the 776-keV γ-ray used to define the activity of ^{82}Sr, I_γ=13.4(5)% (measured ~ 1970), and I_γ=15.08(16)% (1987).

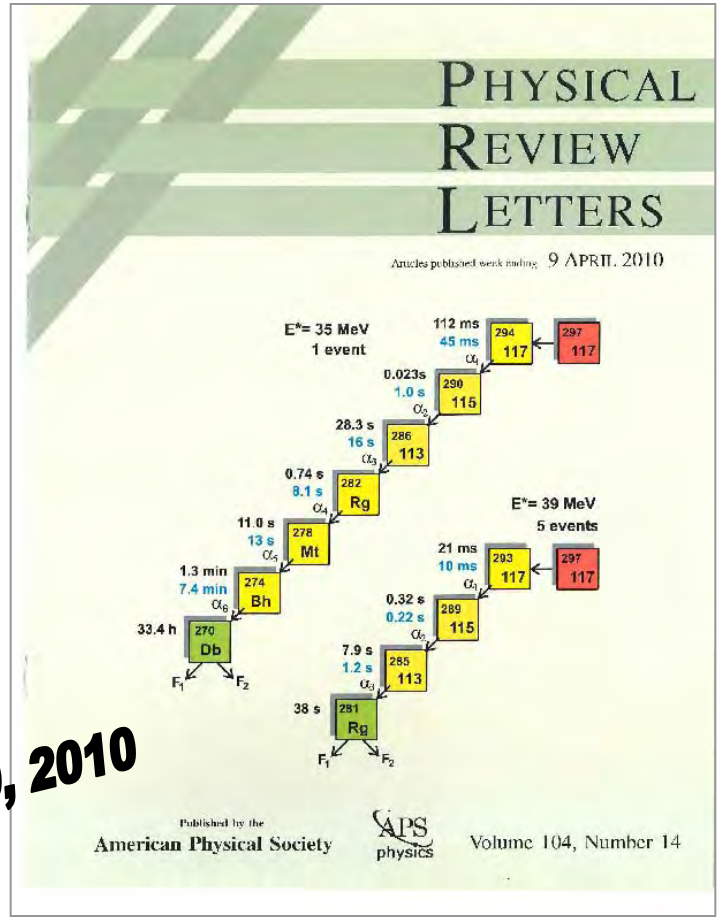
The HRIBF is currently performing a measurement of the absolute intensity of the 776 keV γ-ray. The post-acceleration of ^{82}Sr radioactive beam allows us to identify and count the implanted ions using energy loss signals and subsequent offline measurement with Ge γ-detector.



Spectrum taken with 212 MeV ^{82}Sr ions at HRIBF (July 2010)

Recent Science

- More societal applications
  - ^{7}Be-based prosthetic wear studies
  - Accelerator Mass Spectrometry centered around the 25MV tandem
- HRIBF staff (Krzysztof Rykaczewski) collaborated in the discovery of Element 117 (Roberto, session NP01)



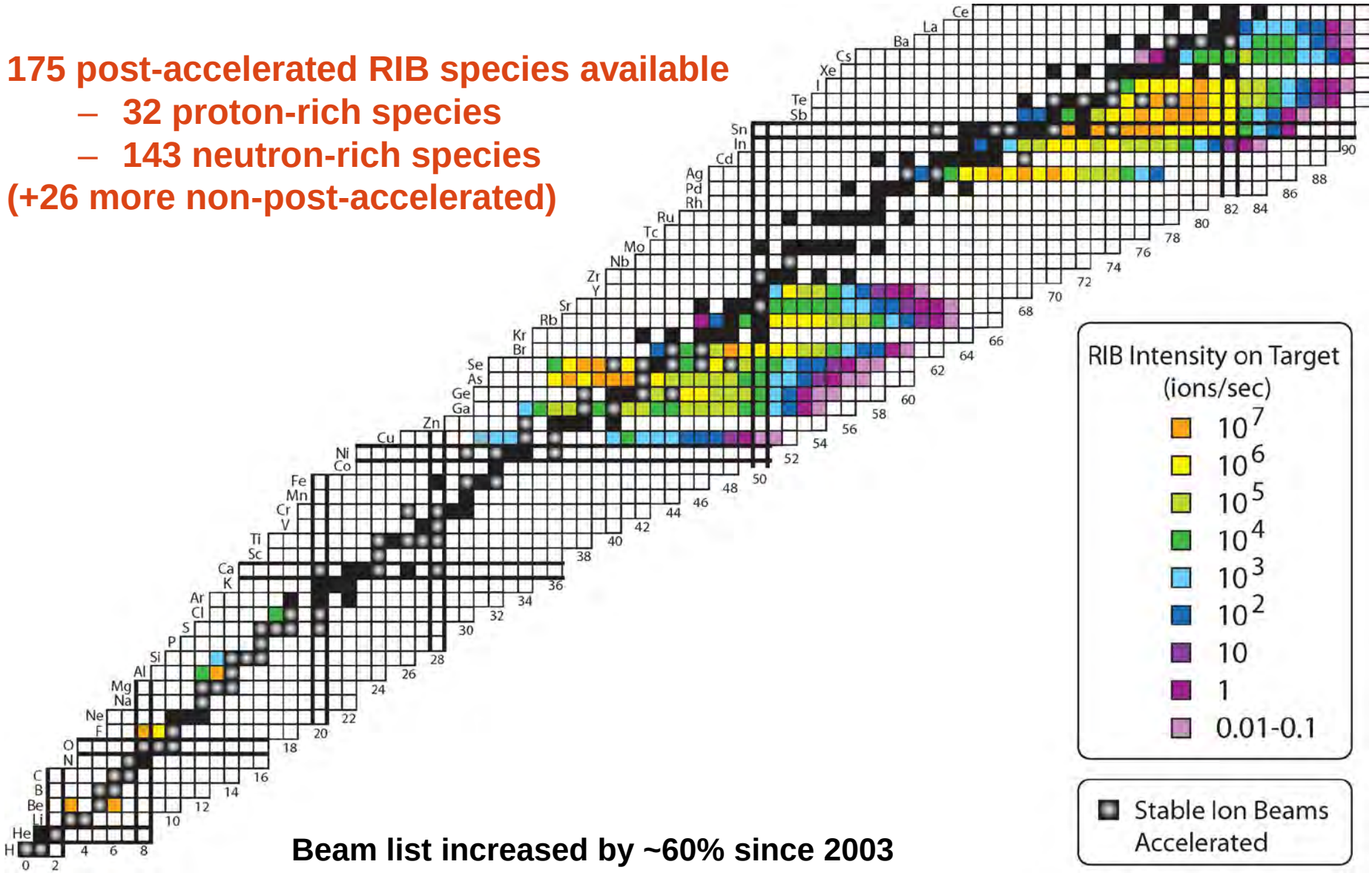
April 9, 2010

HRIBF Beams

175 post-accelerated RIB species available

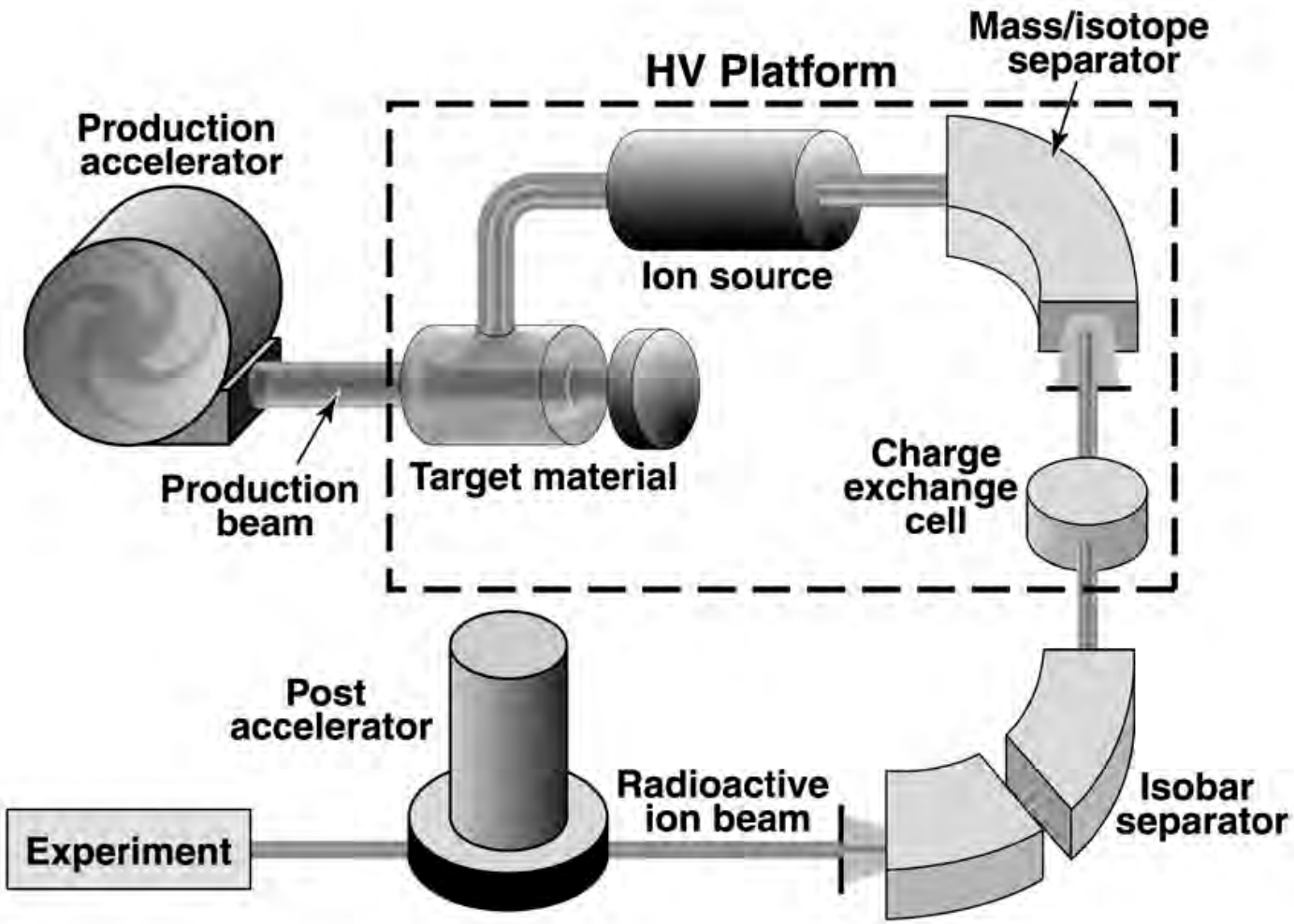
- **32 proton-rich species**
- **143 neutron-rich species**

(+26 more non-post-accelerated)



Beam list increased by ~60% since 2003

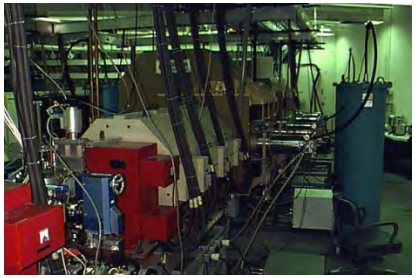
Isotope Separator On-Line (ISOL) RIB Production Process



HRIBF Systems

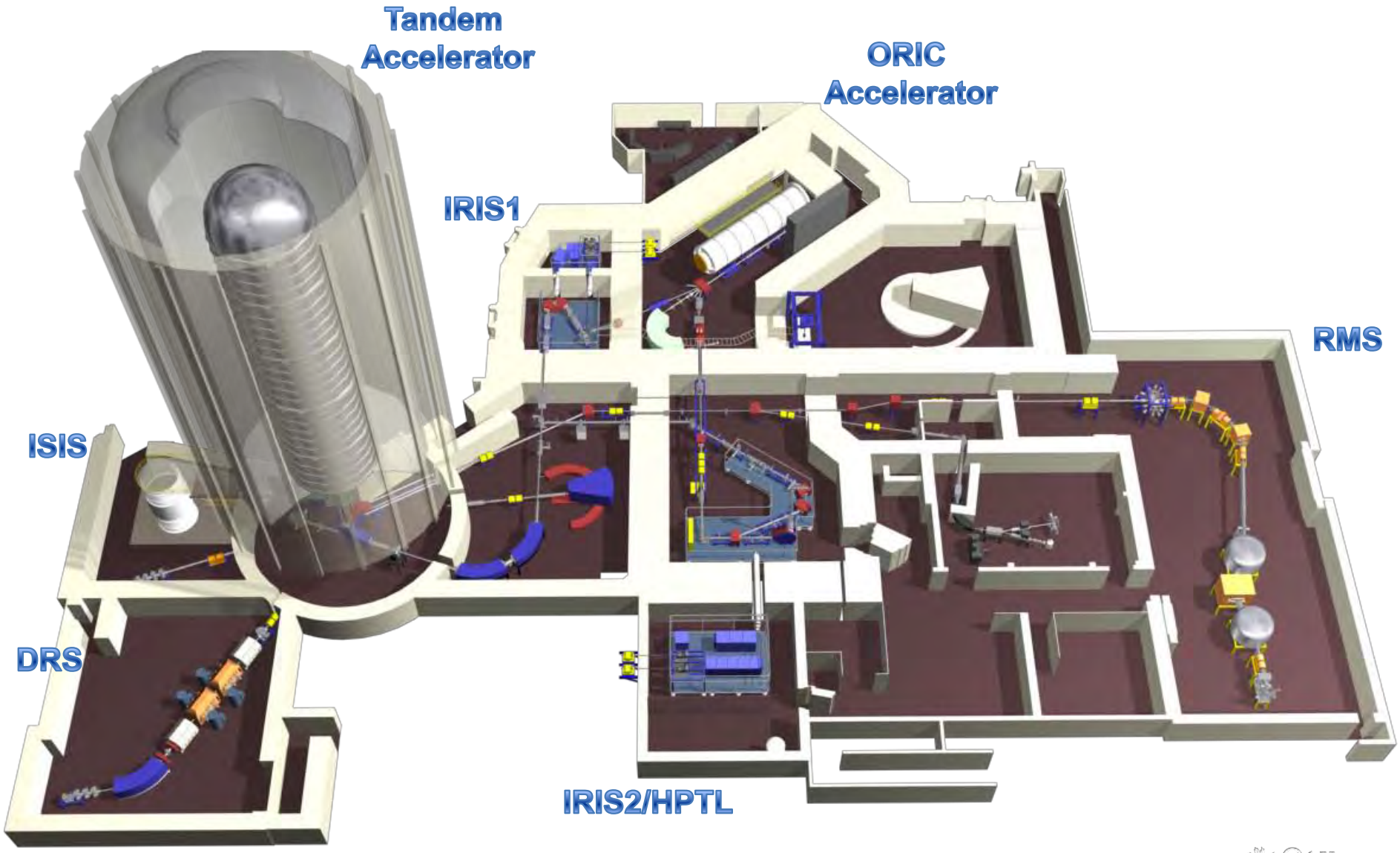
- RIB Production:
  - Oak Ridge Isochronous Cyclotron (ORIC)
  - IRIS1: RIB production station
  - IRIS2: RIB production station (new in 2010)
  - 25 MV tandem electrostatic accelerator

- ISOL Development:
  - 2 off-line Ion Source Test Facilities (ISTF1,2)
  - 1 low-power On-Line Test Facility (OLTF)
  - 1 high-power On-Line Test Facility (HPTL)

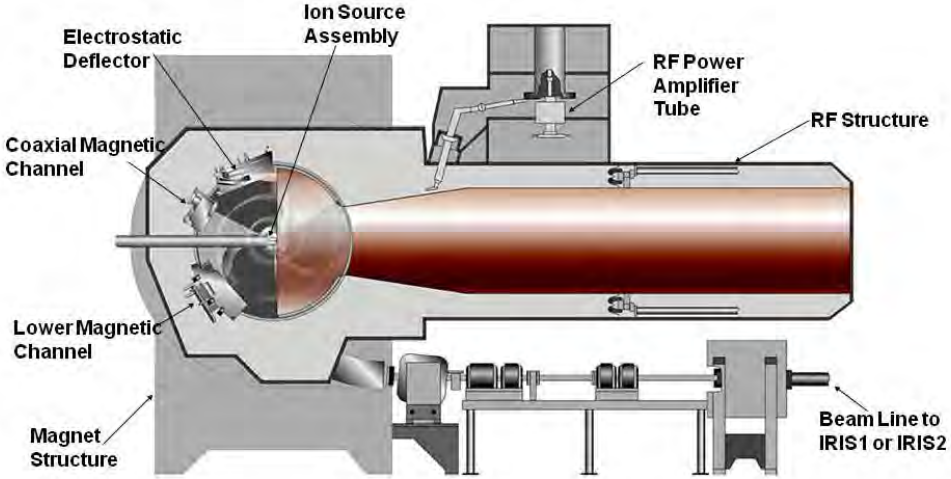


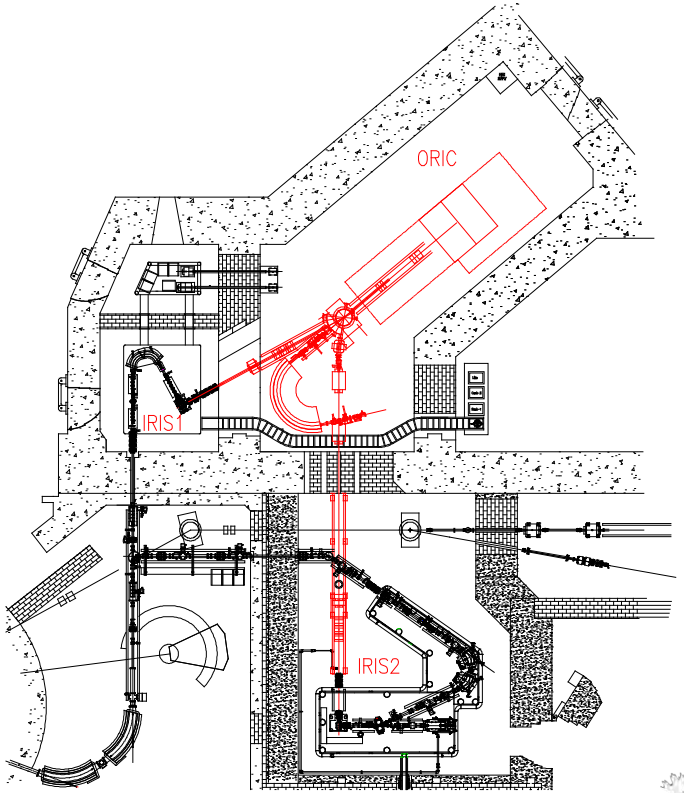
- Experimental End Stations
  - Recoil Mass Spectrometer (RMS)
  - Daresbury Recoil Separator (DRS)
  - Enge Spectrograph
  - Low Energy Radioactive Ion Beam Spectroscopy Station (LeRIBSS)
  - Several general purpose end stations

HRIBF Layout



ORIC Beams

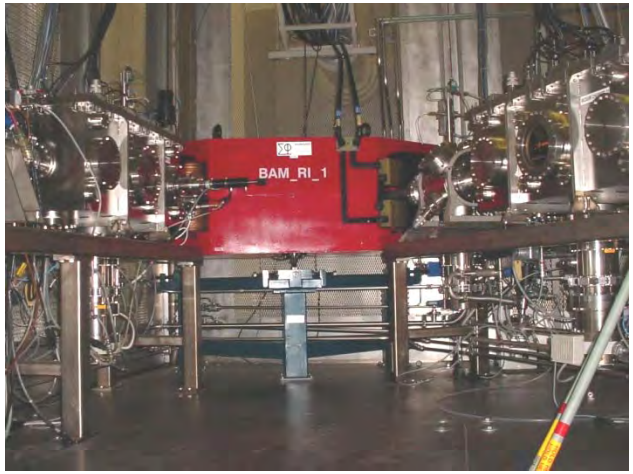


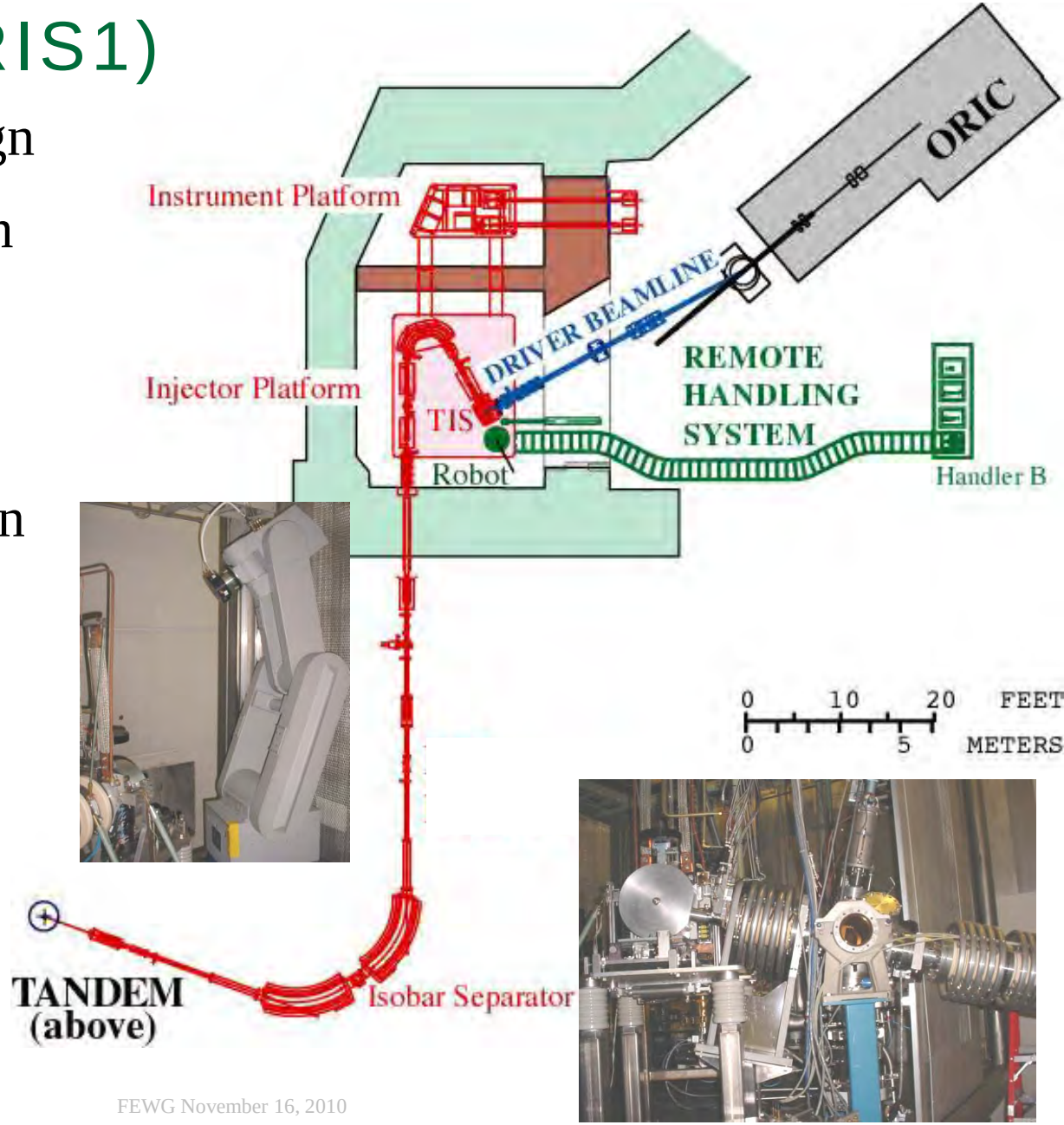


	Maximum Beam Energy (MeV)	Maximum Intensity on Target (uA)
Proton	54	20
Deuteron	49	15
Alpha	85	5

Injector for Radioactive Ion Species (IRIS1)

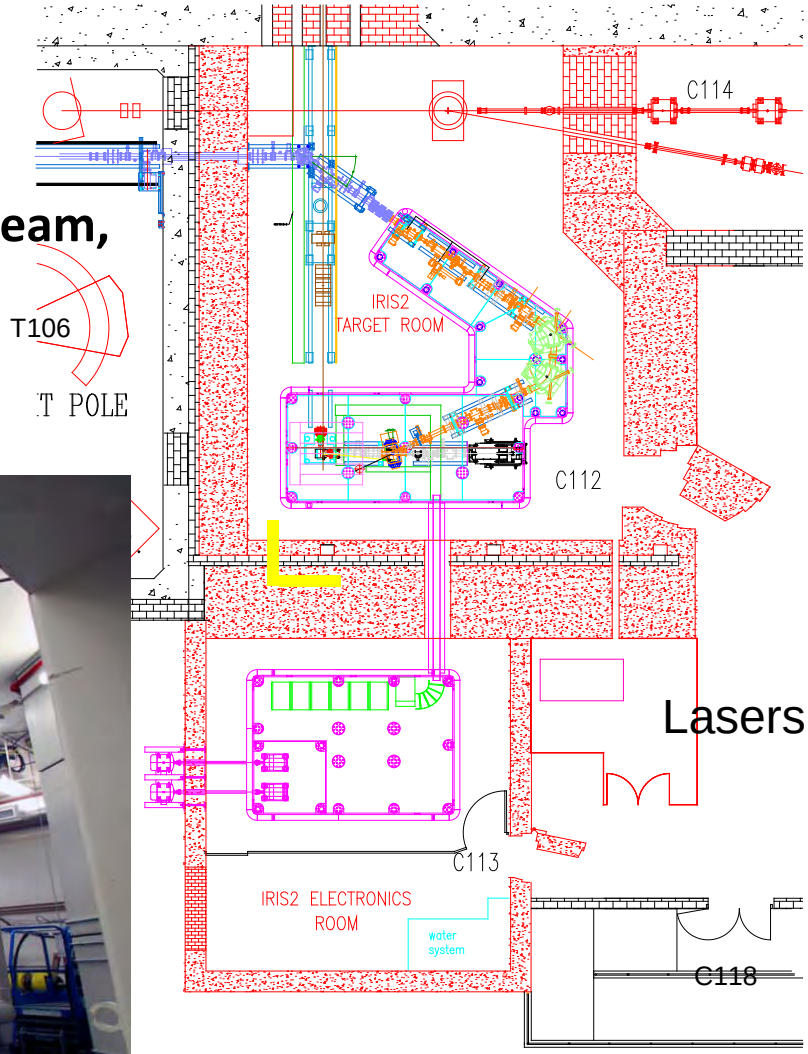
- nominal ±200 kV design
- 2-stage mass separation
  - M/ΔM ~ 1000
  - M/ΔM ~ 20000
- robotic handling of activated targets and ion sources





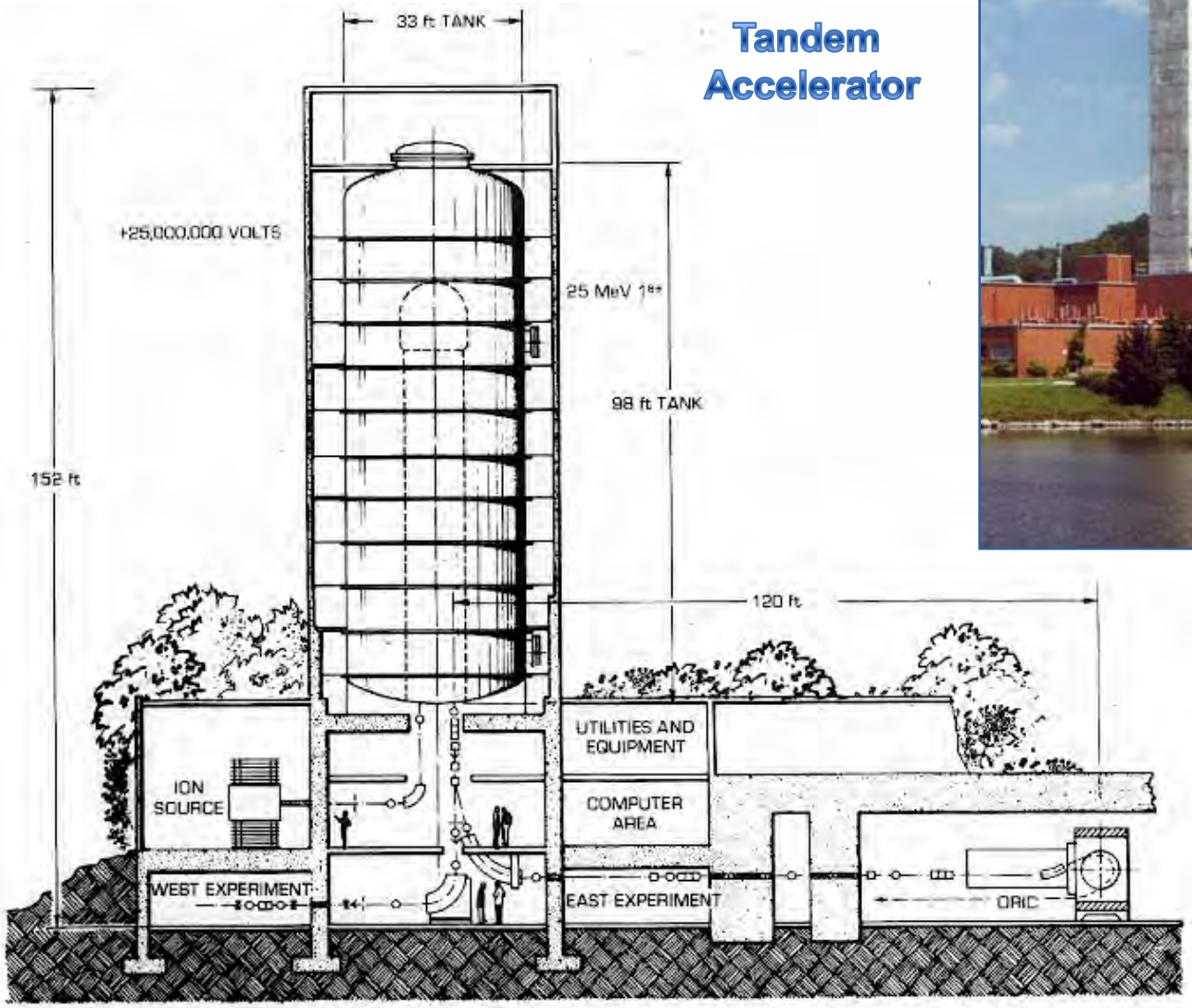
IRIS2/HPTL

- **Combined $9.5M investment**
- **Can use thin & liquid targets, raster ORIC beam, purify RIBs with lasers**
- **Room for expansion**



+/-200 kV Production Platform

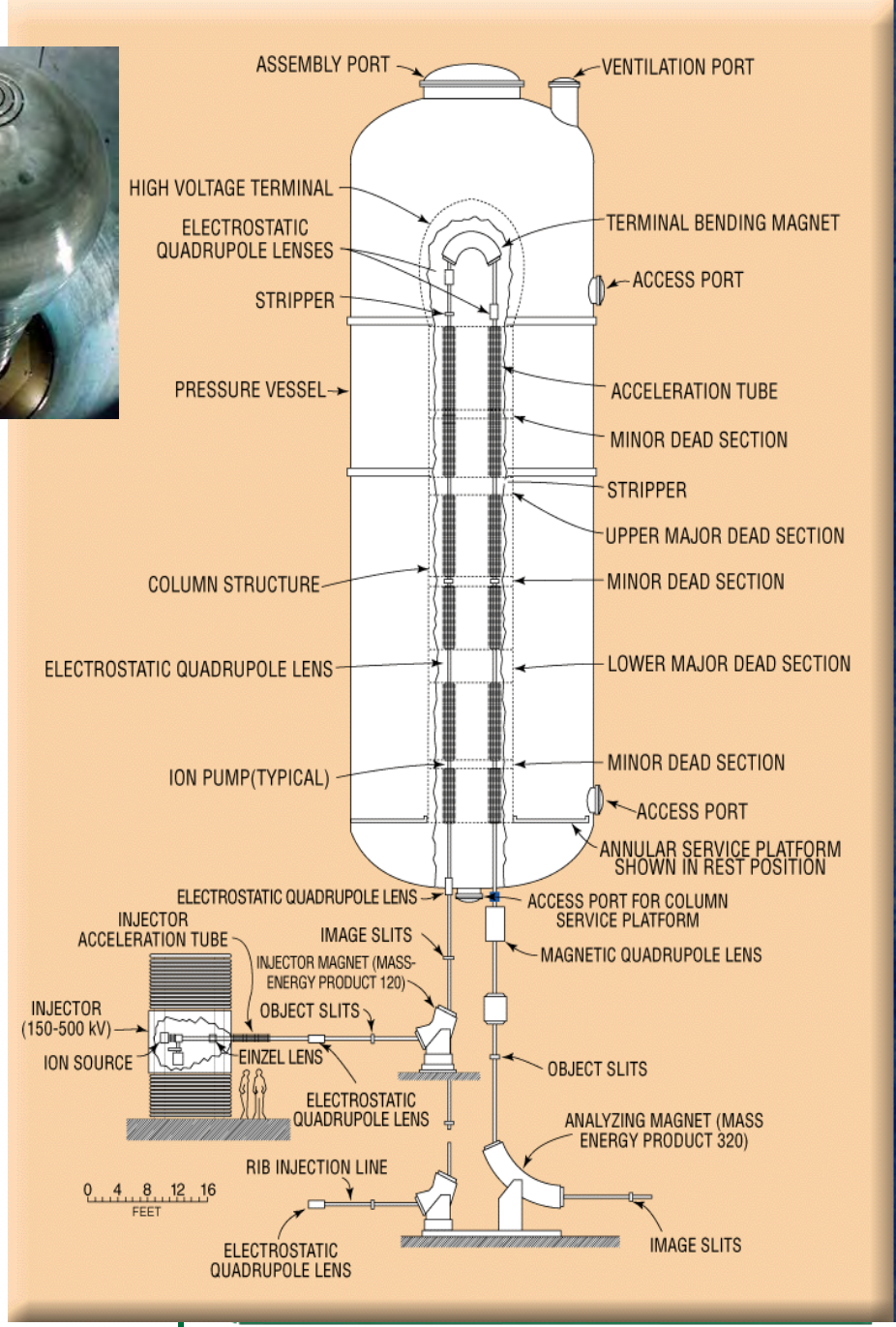
Tower Section



Tandem Accelerator

25-URC Tandem Accelerator

- Manufactured by National Electrostatics
- Unit Reverse Conservative (27 units for 25 MV, with folded configuration)
- SF_6 insulation
- Optic elements, strippers, and diagnostics in 2 major dead sections and the terminal

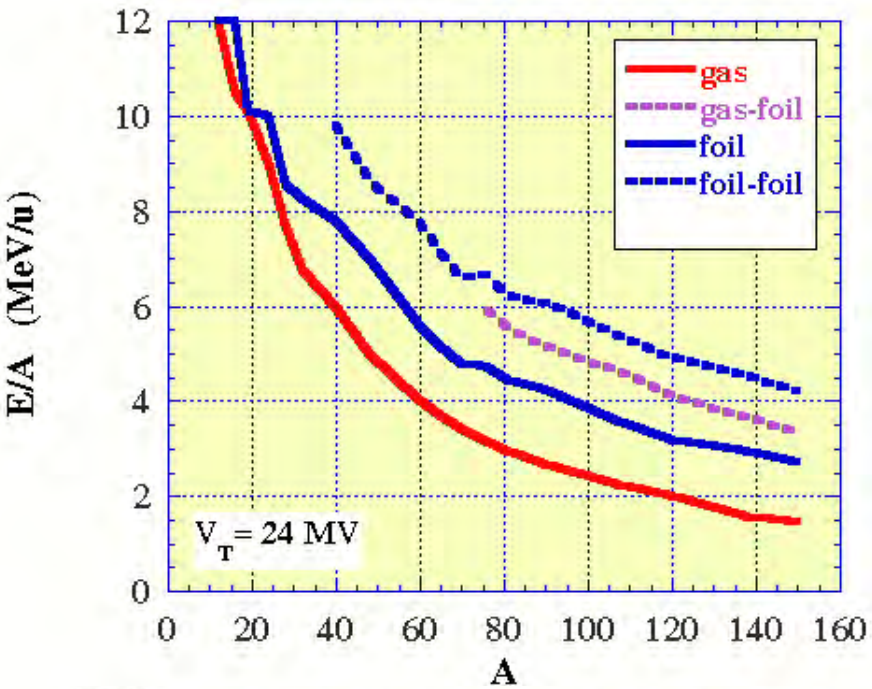


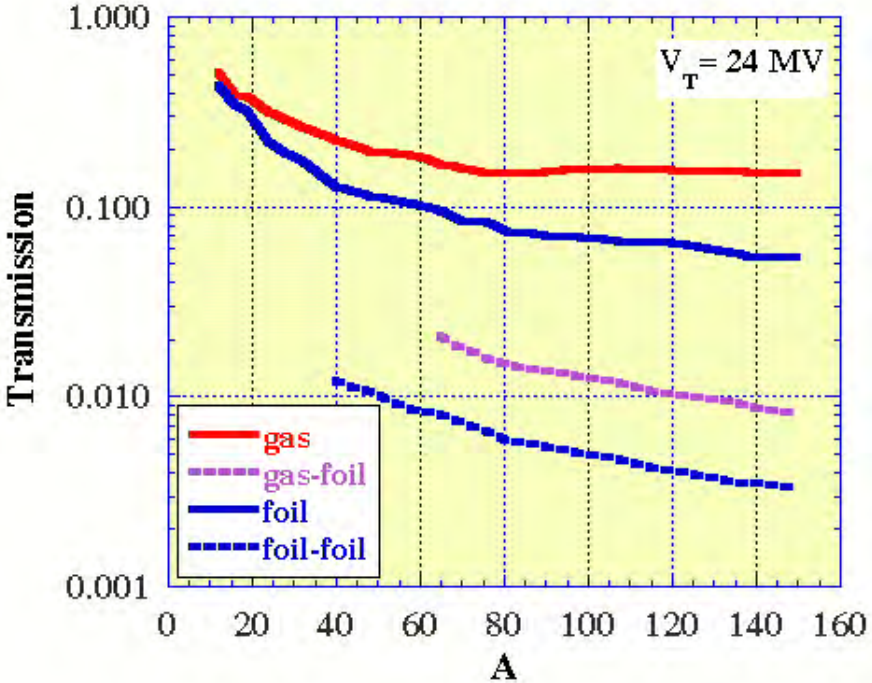
World-record Voltage

- During the voltage test of the tandem accelerator in May 1979, a record voltage of 32 MV was attained without accelerating tubes installed. The voltage is still the highest sustained man-made potential difference.
- The tandem accelerator has operated at 25.5 MV (i.e., with accelerating tubes installed), the highest voltage ever achieved for any electrostatic accelerator.

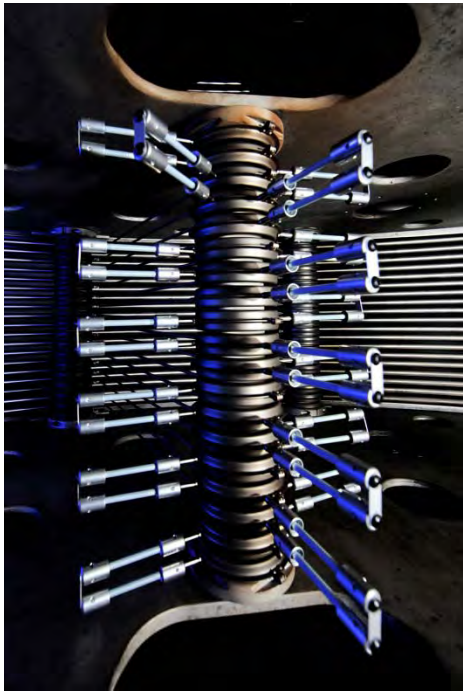
Tandem Advantageous Characteristics

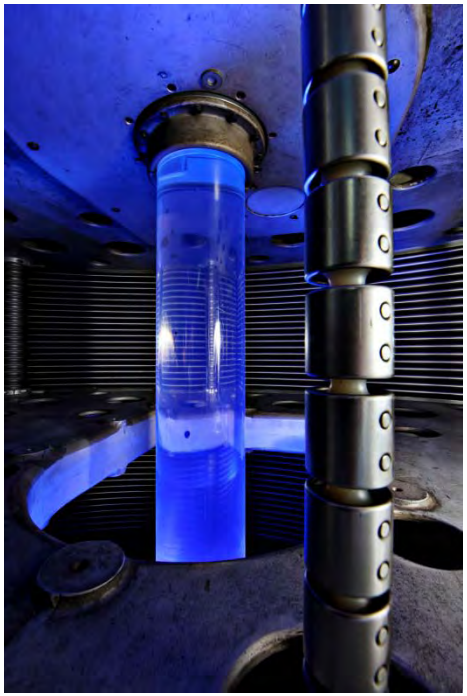
- Beam can be accelerated with simplicity, reliability, economy
- Wide range of operating voltage
  - 1MV - 26 MV
- Large Acceptance
  - Well suited to RIB source emittance
  - Weak dependence on injection E
  - Trans. eff. 15%-50% for gas stripping
- Excellent beam quality
  - Good Energy Resolution ($E/\Delta E > 10^4$)
  - Low emittance
    - 0.3-0.5π mm mrad (gas),
    - 1.0π mm mrad (foil)
- Easy energy variation
- Second stripper provides energy extension

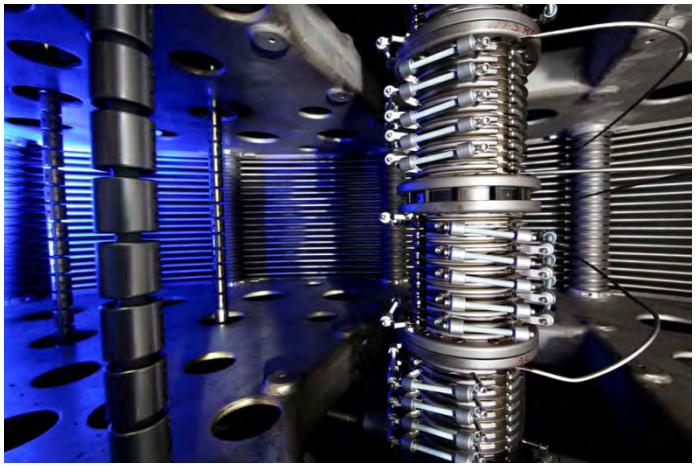




March 13, 2010: Producers and film crew from the “National Geographic Naked Science" series filmed a segment of a series on the origin of the elements at HRIBF.

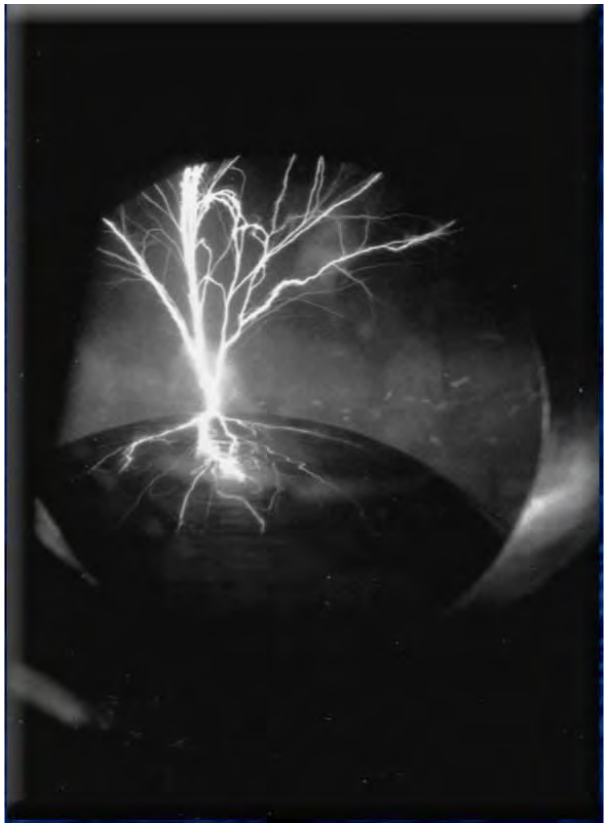






SF_6 Use at HRIBF

- Sulfur hexafluoride (SF_6) insulating gas is required for operation of the tandem accelerator to prevent electrical discharge from the high-voltage terminal and accelerating column to the pressure vessel.
- SF_6 has been used in accelerators, switch gear, and high-voltage power supplies for many years. Pure SF_6 is one of the most stable gases known and is completely non-toxic.
- There have been several studies over the years to identify viable SF_6 alternatives. There are gases that have better dielectric strengths than SF_6, but they have other bad qualities. They are also greenhouse gases, toxic, and/or they generate breakdown products (such as solid carbon). No single gas has been found that is superior to SF_6 in all respects. Some mixtures have been explored such as SF_6/Nitrogen and SF_6/carbon dioxide.
- If an alternative were identified, the cost to convert would likely be in the $10M range. The risk to facility operations would be fairly high since no one has operated a tandem accelerator at 25 MV with another gas.

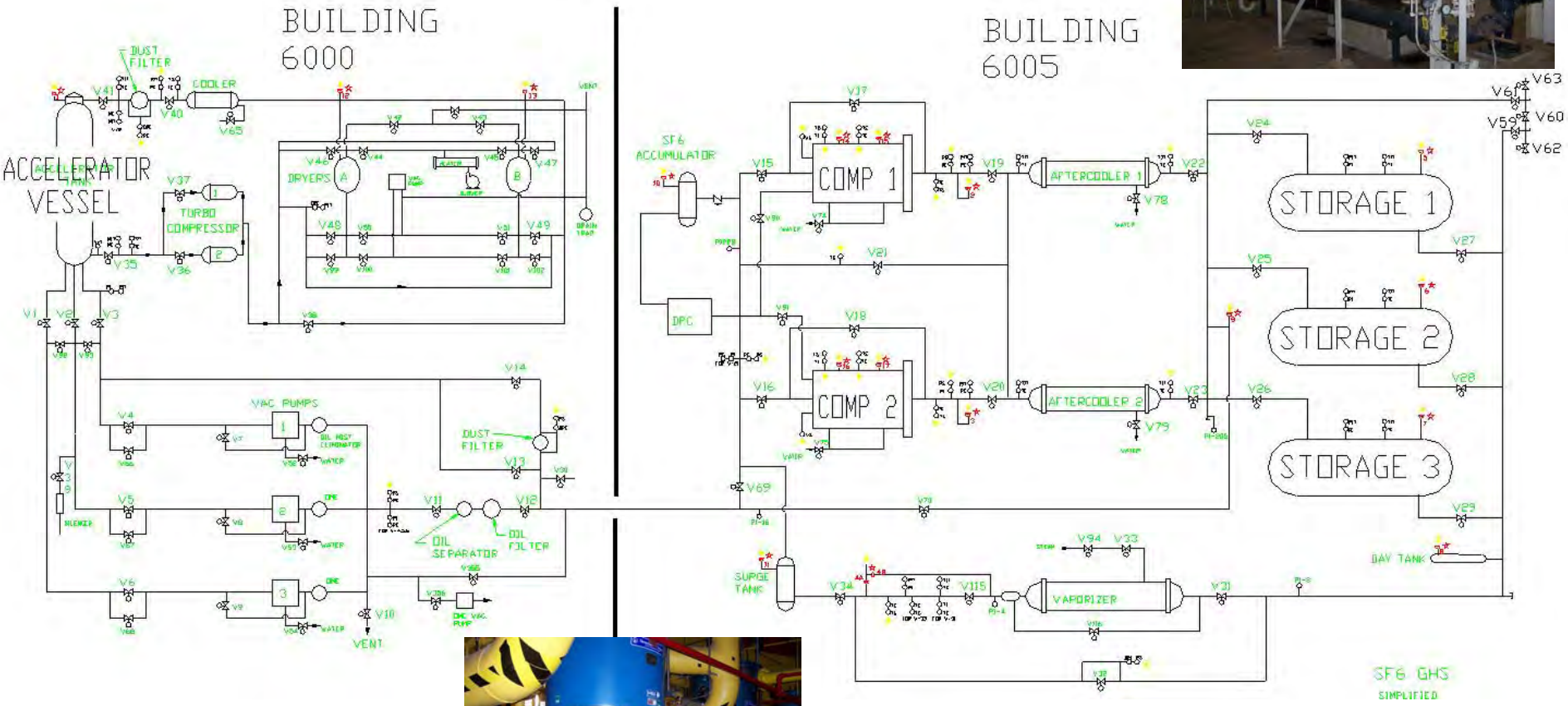


Energy of a 25MV spark is ~200 kiloJoules

Tandem SF_6 Gas Handling System

- Re-circulating during accelerator operation
- Liquid storage in adjacent building during maintenance
- Typically, 12-hour transfer from the accelerator to storage
- Typically, 15 hours to get tank back to pressure
- Certified Gas System Operators

SF_6 Gas Handling System Simplified Schematic



HRIBF SF_6 Inventory

- The SF_6 inventory at HRIBF is determined by a weighing system located in the gas storage building. Present inventory is 225,000 lbs.
- In order to determine the current gas inventory at the facility, all of the gas must be in storage, distributed between three storage tanks.
- The weight of each of the three storage tanks, and thus their contents, is recorded immediately after a gas transfer to storage and again immediately before transfer back into the tandem pressure vessel.
- Weights are affected by temperature variations.
  - The storage tank building is not temperature controlled,
  - The process of transferring gas to storage causes the storage tanks to be quite warm after the transfer.
- Weights are measured to the nearest 20 pounds. Thus there is some uncertainty in the measurements, but the current weighing system is more reliable and accurate than the original system which was replaced around 2002.

Losses

- Analysis of the gas inventory data over the past five years indicates that the average annual loss is around 2500 lbs.
- Losses associated with recirculation in the tandem pressure vessel during normal accelerator operation appear to be around 2 lbs per day, attributed to a collection of small leaks.
- Gas transfers from the tandem pressure vessel to storage results in a loss of approximately 75 lbs of gas per transfer.
- There are essentially no routine losses associated with transfers from storage to the pressure vessel.
- The number of transfers to storage varies from year to year based on operating time, planned maintenance outages and unplanned equipment maintenance needs, but typically ranges from 5-10 per year. This equates to 375 to 750 lbs of SF_6 losses from the transfers per year.
- Inventory data also indicates that there are some losses while the gas is in storage, typically around 60 days per year. Presently, these losses appear to be around 15 lbs per day maximum, or 900 lbs per year.

Opportunities for Improvement

- Better diagnostics, such as an infrared camera to detect leaks, would provide a long-term-use tool to ensure that leaks are identified and can be prioritized for repair.
  - An immediate benefit would be to use this device to locate leaks in the storage system which would, hopefully, be straightforward to repair. Such a diagnosis is presently difficult to perform because of the size of the tanks and inaccessibility of potential leak points.
  - The camera would also be utilized to assess losses during gas transfers, particularly around the two compressors and other areas which cannot be easily accessed while equipment is operating.
- Compressors presently in use are approximately thirty years old and are believed to have leaky seals. Thus rebuild, or replacement of these aging compressors with new units, could also lead to a reduction in SF_6 losses.

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