Laboratory-Scale UF_6 Test Loops

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Uranyl Nitrate Calibration Loop

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Uranium Process Testbeds

- **ORNL has two types of (laboratory-scale) test beds which can simulate phases of the Uranium fuel cycle**
  - **UF_6 Test Loops (two – in operation)**
  - **Uranyl Nitrate Calibration Loop Equipment (UNCLE) – to be in operation late FY08**
- **These test beds could prove useful for testing instrumentation designed to detect radioactive emissions from uranium in a process setting**
- **Systems are available on a part-time collaborative basis for DOE and similar researchers**

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UF_6 Test Loops: Background

- The original test loop was built for DOE/EM Molten Salt Reactor Experiment remediation program in the mid 1990s, and supported that project exclusively for several years
- Over the last few years, other programs have required lab-scale simulation of uranium enrichment or processing conditions involving UF_6
- It's advantageous to test newly developed instruments in a controlled setting prior to testing in the field, but...
- There are major internal regulatory hurdles to setting up a UF_6 experimental system for single-program use
- A common solution is for the developer to have us carry out tests in our loops using their instruments or materials

These UF_6 test facilities provide what has become

a fairly unique capability within the DOE complex

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Typical Applications

- Instrument testing – intrusive or non-intrusive instruments placed in or near simulated plant components
  - Uranium enrichment measurement
  - Gas flow measurement
  - Mass spectrometer testing
- Chemical compatibility
  - Materials (metals; elastomers; porous membranes)
  - Hardware components
- Other applications
  - Chemistry of impurities in UF_6 environment
  - U-daughter fate
  - Sample preparation
- Test Loops typically function in a collaborative 'user' mode
  - Outside users bringing instruments, samples, or hardware
  - ORNL carrying out the actual testing

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UF_6 Test Loops: General Characteristics

- Temperature
  - Main loop: usually ambient temperature
    - Heat tracing allows ~100ºC operation on Loop #1
  - Test apparatus and materials can be at significantly higher temperatures
- Pressures: Vacuum (~1 mbar) to atmospheric (1 bar)
- Flow: Metal bellows pump circulates gas up to 1 std-L/min at 0.1 bar
- Gases: System is designed for UF_6, F_2, HF, and ClF_3
  - Also used: $COCl_2$, SF_6, Xe, Ar
- UF_6: Partial pressure is limited by its vapor pressure
  - Present configuration: accurately measurable from 5 to 100 mbar
  - If flow system is heated, pressures to ~800 mbar are possible
- U Assays: depleted (0.3%), natural (0.711%), HEU (91.8%), or blends
- 'Pipe simulators' filled with UF_6 gas are favorite 'targets' for instrument tests
  - 8, 4, 2, 1, and ½ inch Sch. 40 Aluminum pipe sections

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Test Loop #1 in Operation

- **Enrichment Monitoring System**

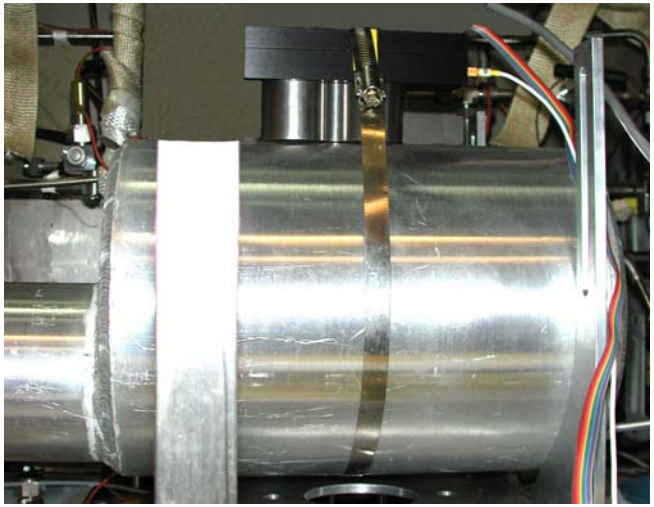
  A non-intrusive gamma detector (in black container) interrogates the UF_6-filled 8-in aluminum pipe simulator

UF_6 Test Loop #2

- **In FY06-7, the second UF_6 loop was constructed**
- **Increases loop availability**
  - **More than one experiment at a time**
  - **Operation of one loop when maintenance needed on the other**

UF6 Test Loop Experiment Example:
Self-contained CdZnTe Data Acquisition System for Unattended Monitoring of Gaseous UF_6 Processes

- **WFO collaboration with LANL (Gardner & Murray)**
- **Device tracked varying U-235 density in simulated 4-in and 8-in aluminum process pipes**
- **Dual collimated detectors compensate for wall deposits**
- **Successfully detected all process transitions and anomalies in a "blind test"**



CdZnTe detector mounted on 8-in pipe simulator in UF_6 test loop

G. Gardner, W. S. Murray, L. D. Trowbridge, D. W. Simmons, "A Miniature Self-contained CdZnTe Gamma Spectrometer for Use in Unattended Nuclear Material Monitoring," 2005 IEEE Nuclear Science Symposium Conference Record, p. 545 (23 Oct 05)

Uranyl Nitrate Calibration Loop Equipment (UNCLE)

- UNCLE was developed to address the need to calibrate neutron detectors on a full-scale uranyl nitrate loop prior to deployment as part of a safeguards monitoring system at conversion plants
- UNCLE provides a test facility for various instrumentation with applications in natural uranium conversion plants (NUCPs)
- UNCLE is designed to simulate the conditions of the purified aqueous uranyl nitrate solution exiting the strip column after solvent extraction purification for an NUCP operating at 100 MTU/year
  - System is also capable of operating with various contaminants
- UNCLE is designed to accommodate a variety of instruments, i.e. flowmeters, density probes, neutron detectors, etc.
- Construction of UNCLE is expected to be completed during FY08

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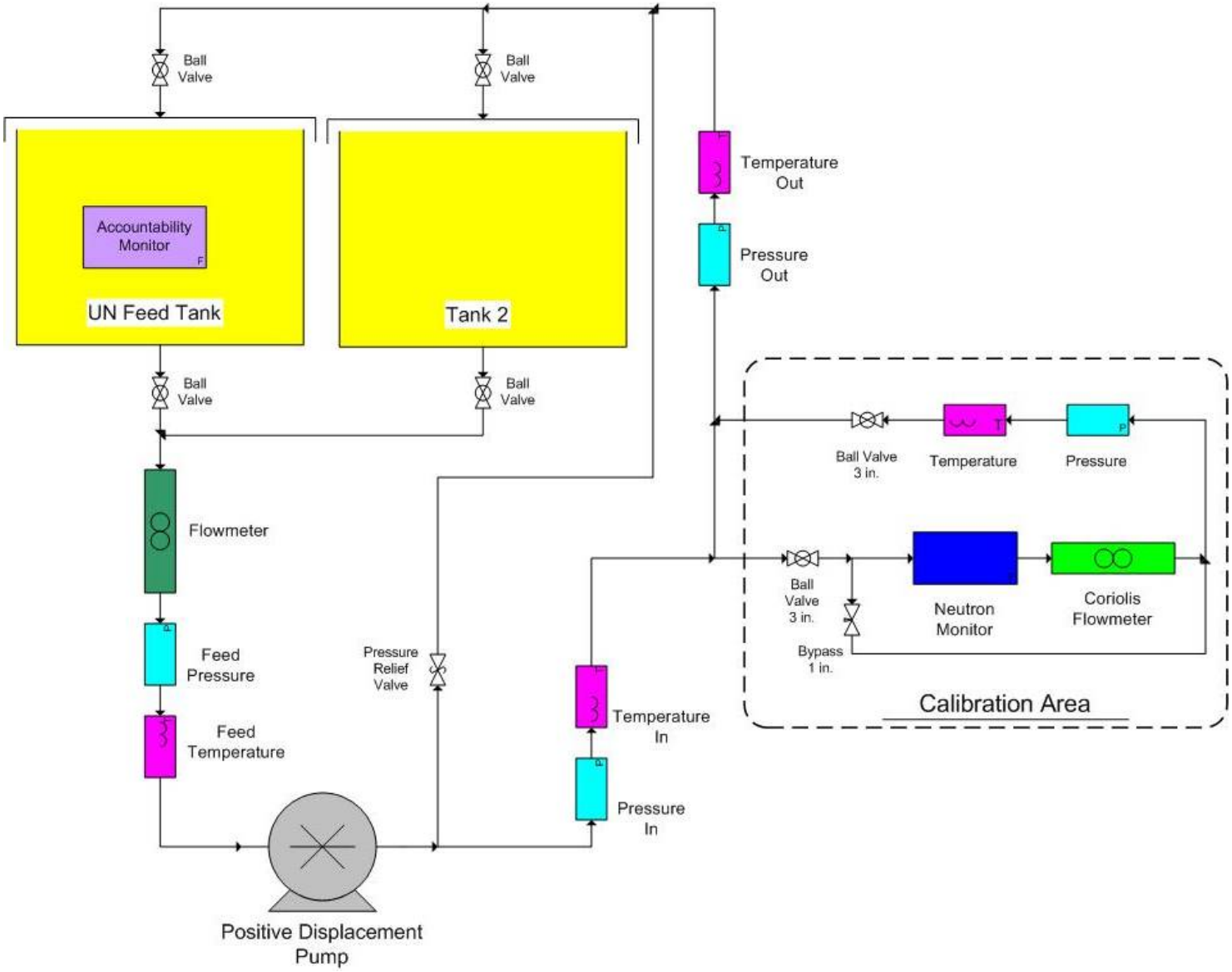
Design Flow Sheet for UNCLE



Capabilities of UNCLE

- **Measurement of flow rate, density, neutron counts, etc.**
- **Multiple flow rates**
- **Multiple solution concentrations**
- **U assays: Designed to accommodate depleted or natural U**
- **Multiple fluids**
- **Multiple pipe sizes**
- **Complete bypass calibration area of the loop**
- **Bypass neutron monitor and flowmeter with fine control ("garden hose" diversion scenario)**
- **Continuous or intermittent bypassing of the instruments in the calibration area**

Summary

- These laboratory systems are capable of providing a flexible environment for testing instruments, materials, or hardware with UF_6 or $UO_2(NO_3)_2$ solutions and could provide useful and cost-effective support to other research programs
- Specifically, they could be used as test beds for testing in-process, non-intrusive, or stand-off detectors for U in simulated process environments
- Systems are available on a part-time collaborative basis for DOE and other sponsors

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