A “Proof of Concept” Demonstration of Radio Frequency-Based Technologies for UF₆ Cylinder Tracking at a Centrifuge Enrichment Plant

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Agenda

• Benefits for tracking UF$_6$ cylinders
• Cylinder Tracking System Goals
• Work Completed to Date
• A “Proof of Concept” Cylinder Tracking System Demonstration Project
• Current system components
• Future issues and concepts
• Conclusions
Safeguards Benefits

• **Timely Detection of Diversion for Declared Cylinders**
  – Increased inventory efficiency by rapid positive ID of cylinders for IIVs and PIVs
  – Enhanced material flow verification and item tracking
  – Remote monitoring and timely access to information at IAEA HQ
  – Easily detect changes in cylinder attributes (such as tare weight)

• **Detect Production of LEU from Undeclared Feed**
  – Detect presence of untagged cylinders and undeclared activities in F&W areas when combined with other process monitoring and safeguards systems

• **Detect Undeclared Production of HEU**
  – Detect presence of undeclared cylinders in combination with other C/S systems for cascade areas

• **Additional Benefits**
  – Improve data accuracies (human error typical up to 10%)
  – Provide capability to track cylinders between sites
  – Track cylinders throughout their life cycle
  – **Potential to reduce frequency of on-site inspections**
Other Benefits of Cylinder Tracking

- Improve the effectiveness and efficiency of inventories
- Potential for developing dynamic site models that integrate data from other sensors and systems
- Provide enhanced time/date/location information for improved verification and analysis
- Eliminate the cost and complexity of wire-based systems
- Radio Frequency (RF) devices can be built to monitor other attributes such as tamper, motion, radiation, etc.
Cylinder Tracking System Goals

- Overarching goal: Increase IAEA inspection efficiency and effectiveness,
  reduce costs, if possible, and provide possibility for remote, secure access to IAEA authenticated data

- Provide the capability to track the movement of all cylinders within an enrichment facility
  including feed cylinders, parent product (or intermediate) cylinders, customer cylinders, sampling containers, and tails cylinders

- Develop a unique, robust, and tamper-resistant RF device
  that can be attached to each cylinder either before it enters the enrichment facility or at the point of entry

- Ensure RF devices and attachment can survive and do not interfere with operational requirements

- Ensure data integrity and system reliability
Work Completed To-date

- Developed preliminary functional and operational system requirements for a CTS
- Completed a preliminary RF tag vendor survey and procured tags for testing and evaluation
- Developed a conceptual system design
- Completed preliminary environmental and performance testing
- Identified operating site for “Proof of Concept” field testing
- Engaged other U.S. National Laboratories and developed a comprehensive path forward
- Put together system for “Proof-of Concept” testing and will soon begin to install at site
COTS Component Testing: Preliminary Conclusions

Only 2 of the 13 RF tags tested survived the single cycle of environmental testing with acceptable physical and performance characteristics

- However, most tags could be read even after extensive physical deformation
- Only the tags protected with a thick ceramic or ceramic-like coating were unaffected by the heating test

Not all the tags complied with industry-established RF formats

The size (i.e., surface area) of the antenna used by the reader system significantly affects the distance at which the tags can be read at maximum gain

- Standoff height between the RF tag and the metal cylinder proved to be critical to minimizing metal interference
- There was generally good consistency in the read data for the tags
Current Work: Testing at an Operating Facility

- None of the tags met all of the CTS performance requirements, so *improved RF tag designs will be needed*
- Some vendors expressed a willingness to develop custom tags
- A prototype passive RF Gen2 tag has been developed for further testing
- Custom high-temperature enclosure
- Read range at 90º on metal is approximately 7+ feet
- Passed preliminary environmental testing of -40º C and +140º C
Real-Time UF₆ Cylinder Tracking System (CTS)

- Receiving Feed Cylinder Entering Plant - Cylinder Receipt
- Cylinder Moved
- Feed Storage Area
- Cylinder Moved
- UF₆ Cylinder Tracking System
  CTS is integrated into facility via RF receivers located at critical process points such as storage and processing areas, including Feed and Withdrawal areas, to give a real-time accounting of cylinder movements, process operations, and measurements. CTS will alarm if feed or withdrawal is attempted from an unauthorized cylinder.
- Cylinder Moved
- Autoclave Feed Area
- Cylinder Moved
- Feed Cylinder Flow Diagram
- Cylinder Moved
- Feed Staging Area
- Cylinder Moved
- Empty Feed Cylinder Leaving Plant - Return to Supplier
- Cylinder Sampling
Proof of Concept Demonstration
System Components for CTS Proof of Concept Demonstration

Autoclave antenna mounting

RF Reader that supports up to 4 antennas

Scale antenna mounting

Thermally protected RF Tag
Current User Interface

- Modern data management features
- Built for growth
- Not technology specific
- Supports data authentication
- Rules-based event processing
Testing at Operating Facility

- Conduct the “proof of concept” test at an operating U.S. facility
  - Demonstrate survival in a real-world operating environment of an enrichment facility
  - Evaluate operational performance and durability of RF tags and system components
  - Test hardware and software performance
  - Identify user issues/needs
  - Test rules-based approaches
  - Identify safety concerns (e.g., autoclave drain plugging)
  - Develop a more comprehensive set of system requirements
  - Define next phase testing

- Lessons learned will be applied to full CTS design and integration
Issues To Be Addressed For Future RF-Based CTS

- **Cultural issues** - Cultural resistance to using wireless technologies exist largely because of questions regarding security and reliability

- **Security and vulnerability issues** - Vulnerabilities include spoofing, counterfeiting, transfer, and cloning. Sophisticated encryption techniques can mitigate these concerns. Must look at CTS as a part of a “defense in depth” approach in conjunction with other systems

- **RF interferences** - RF signals may interfere with existing systems and equipment
Issues To Be addressed For Future Efforts

- **Frequency limitations** - The frequencies allowed for use at a facility or in a country must be known and factored into a system using RF.

- **Tags versus seals** - Criteria for when to use RF-based tags versus RF-based seals are needed. These criteria should include a design-based threat analysis and a cost-versus-performance evaluation.

- **Reliability** - Reliability of RF technologies must be compared with current approaches and existing systems. Tags must be durable enough to survive the environmental and operational environments at a facility.

- **IAEA authentication** - The system must be certified in a manner that assures the IAEA that the system is operational and the data is trustworthy.
Future Concepts: Integration of the RF and Radiation Portals at Key Measurement Points

- Direction
- Occupancy
- Gamma/neutron levels
- Item ID
- TID status
- Camera
The RF-Base TID (Enabling Technology)

- Single-use plastic strap passive RFID E-seal with reusable electronics
- Records data when it is armed: last time read, tamper-event information
- Real-time clock: temperature sensor
- EPC Global Generation 2, Class 1+ tag
- Operating frequency range: 860-960 MHz
- Read range: 21 feet
- Operating temp: -40°F to 158°F
- Humidity: 95% non-condensing at 158°F
Future Concepts: Link with GPS

**GPS-Based UF₆ Cylinder Tracking**

- When a UF₆ cylinder is loaded onto the transport vehicle, the RF system on the vehicle communicates with the RF-reader to verify that the correct cylinder has been loaded.
- The tagged cylinder RF-identity number is stored in RF-GPS system on the vehicle.
- The GPS system communicates with the satellite during transit and provides authentication of the identity of the tagged UF₆ cylinder to a central database.
Conclusions

- Developing a CTS is highly relevant when considering increasing emphasis on nuclear power and enrichment services.
- Limited IAEA budget growth - technology can be a part of the solution.
- Operators and IAEA will need to cooperate to help solve the problem.
- Operators must be open to new technologies such as RF devices and consider dual benefits.
- Such technologies should be incorporated early in the design of new facilities for most efficiency.
Final Remarks

- There are several pros and cons associated with RF-based technology and it is important that operational, security, and performance requirements are well known and evaluated before a technology is selected.

- Many operational issues can be overcome but real world site specific performance tests are a must.

- Rules-based systems can be set up to enhance “near real time” detection and trigger other devices or systems to respond.

- Good system design and evaluation methodologies must be utilized, along with stringent (in the field) operational and performance evaluations.